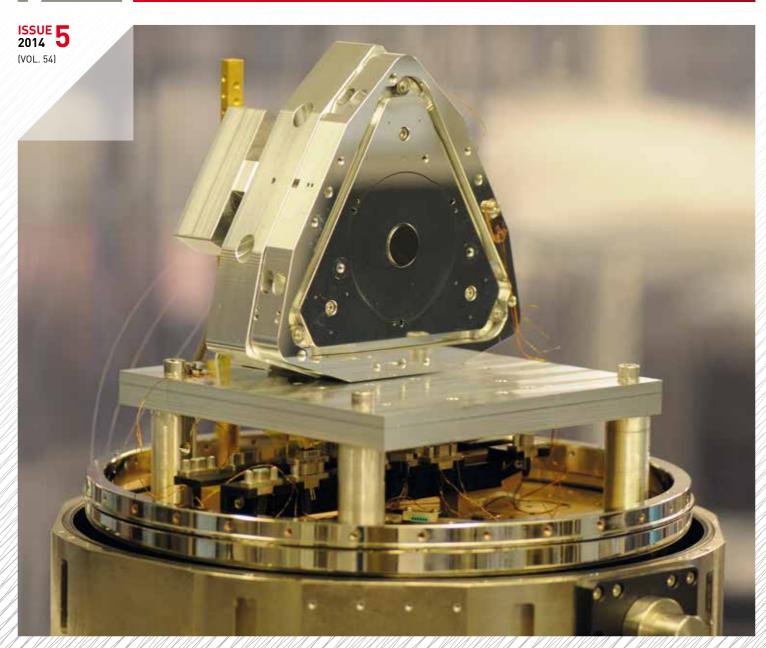
## MIKRONIEK



- DSPE **60 YEARS COLD CHOPPING** OF BABY STAR LIGHT
- SILICON FLEXURE-BASED MECHANISMS "REVOLUTION VS. EVOLUTION"











HIGH TECH SYSTEMS - AUTOMOTIVE SYSTEMS - FACTORY AUTOMATION - MEDICAL TECHNOLOGY - MARITIME APPLICATIONS



#### **PUBLICATION INFORMATION**

#### **Objective**

Professional journal on precision engineering and the official organ of DSPE, the Dutch Society for Precision Engineering. Mikroniek provides current information about scientific, technical and business developments in the fields of precision engineering, mechatronics and optics.

The journal is read by researchers and professionals in charge of the development and realisation of advanced precision machinery.



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The main cover photo (METIS cryogenic Chopper) is courtesy of Janssen Precision Engineering.

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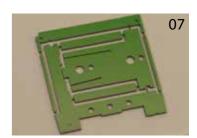
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#### **EDITORIAL**

## **60 YEARS OF DSPE -**INTO THE FUTURE AS A GUILD SOCIETY

Looking from the past to where we are today provides insights into the trends of tomorrow.

Over the past few years, precision engineering has become even more important to the economy of the Netherlands. Precision engineering has also become a symbiosis of all kinds of organisations working together. This has seen a certain guild-like approach develop, with market players coming together and sharing their knowledge and passion. This guild-like society is something that DSPE has been successfully exploring. During a strategic session led by the organisational expert Ivo Mannaerts, the DSPE board concluded that this guild-like society should be our destiny and that DSPE should continue to play a role in shaping the industry's future by making good use of the society's various platforms.

DSPE publication Mikroniek is very well regarded in the industry as the journal for precision engineering. What's more, the society's website www.dspe.nl is widely used to find information on precision engineering subjects. The most recent DSPE Conference in September was attended by 160 people, and we have special interest groups in the fields of optics & optomechatronics, robotics and thermomechanics.

However, the most important role DSPE can play in shaping the industry's destiny concerns young precision engineers. As a guild society, DSPE has to cherish young professionals and ensure that the passion, knowledge and craftsmanship of experienced professionals is shared with the young.

Needless to say, this ongoing development towards a more guild-like society enjoys the wide support of our membership base, which includes individuals, large, medium and small companies, institutes and universities. It always gives me a warm feeling when I see the range of different people from across our membership base working passionately together in an enthusiastic environment.

Precision engineering is fun!

Hans Krikhaar DSPE President

> 13 November 2014 **DSPE 60 Years Event** see page 56

In 1954 ...

Elvis arrived on the music scene, the first nuclear submarine was launched, Jeen van den Berg won the Dutch skating race the Elfstedentocht, **Texas Instruments** produced the first transistor radio, the first Walt Disney TV series hit on our screens, Albert Schweitzer won the Nobel Peace Prize. Chevrolet introduced the V8 engine and DSPE history started.

#### **DSPE**

## **ANNO 2014**

Since its predecessor was founded in 1954 (see the historical overview elsewhere in this issue), the Dutch Society for Precision Engineering (DSPE) has evolved into an independent professional branch organisation for all precision engineers in the Netherlands, and – in recent years – for colleagues abroad as well. DSPE continues to be a unique community of precision engineers that fosters professional relationships, knowledge sharing and passion in the precision engineering industry. In the (Dutch) spirit of free and creative thinking, DSPE brings together professionals from a wide range of disciplines and professional educational levels, promoting multidisciplinary collaboration and international partnership.

n the high-tech systems industry, which is a major economic sector in the Netherlands and accounts for some €2 billion in annual R&D investment, the technological and economic performance of companies is heavily influenced by the expertise and skills of precision engineers. Precision engineering is a major asset of the high-tech systems industry, as the design of high-tech systems using precision engineering principles largely determines the performance, productivity and cost of these systems and products.

#### Mission

DSPE's mission is to promote the position of the Dutch high-tech and precision engineering industry in the international arena, along with the innovation required to maintain that position. To that end, DSPE facilitates knowledge sharing, professional networking and peer recognition. The Netherlands is home to approximately 400 companies active in precision engineering – over 100 of the key players are DSPE members.

#### Contribution

DSPE contributes to the industry in a number of different ways; the society:

- encourages knowledge sharing through collaboration and fostering personal relationships;
- facilitates partnerships between education, industry and science;
- connects Dutch precision engineers with international networks;

- builds relationships with adjacent industries;
- recognises opportunities for innovation;
- promotes education by way of summer school initiatives and certification of courses;
- shares knowledge through its magazine Mikroniek and website www.dspe.nl, by organising events and creating special interest groups.

#### **Technology areas**

DSPE is active in:

- · Precision mechanics
- Physics
- Mechatronics
- Optics & optomechatronics
- Materials engineering
- Tribology

- Dynamics
- Systems engineering
- · Control engineering
- Thermodynamics
- · Manufacturing technology

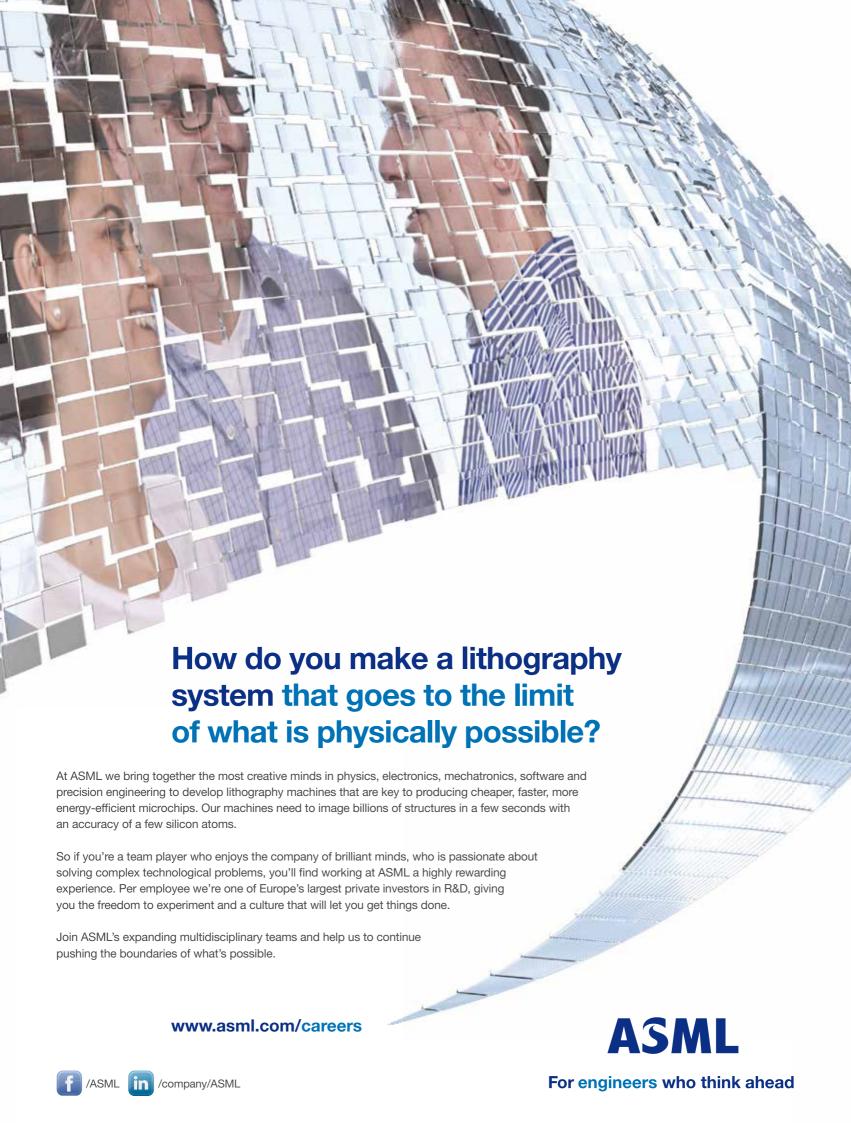
DSPE also explores:

- · Additive manufacturing
- Photonics
- Medical precision devices
- Robotics
- Microsystem technology

#### Keeping eyes open

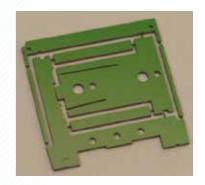
DSPE will continue its mission, keeping eyes open for technological and collaborative opportunities.





## THE EVOLUTION OF SILICON MICROMACHINING

Miniature, complex and integrated systems can be created using silicon micromachining. This article presents two assembled monocrystalline silicon centimeter-scale mechanisms, machined with Deep Reactive Ion Etching (DRIE). The first demonstrator is a delta robot (x,y,z-manipulator) and the second a tip-tilt piston mirror mechanism. Both were designed using design rules derived from prior research. The innovation of this work lies in splitting kinematic structures into flexure-based monolithic silicon substructures and in the isostatic alignment concepts used to assemble these planar substructures into 3D demonstrators.



JOHAN KRUIS, MIRSAD SARAJLIC, FRANÇOIS BARROT, DARA BAYAT, SIMON HENEIN, LAURENT GIRIENS, MATHIAS GUMY AND SERGE DROZ

#### Introduction

The evolution of silicon micromachining has allowed the creation of miniature, complex and integrated systems, also known as MEMS. Over the past decade, silicon micromachining has been introduced into larger-scale precision engineering applications. There are some key advantages to using silicon, such as the absence of fatigue, machining accuracy, the option to integrate actuators and sensors into the articulated structures themselves, and batch production on wafers.

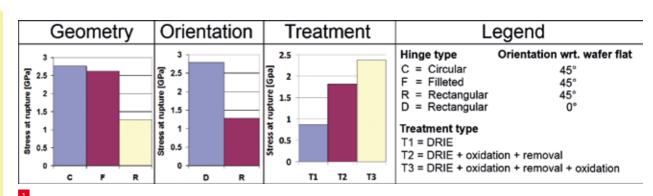
The main challenge we overcame was the assembly of a brittle material. This assembly challenge has been addressed in various publications [1]-[12], but always on

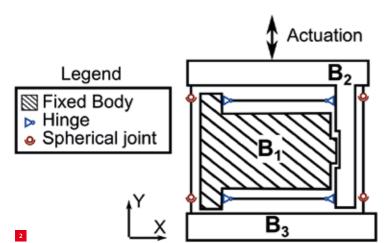
a microscale. In our past publications [3], [4], we highlighted the possibilities of using silicon as a material for centimeter robotic and optomechanical systems.

This article first provides a recap of the design rules taken from prior work. These design rules are then applied to two demonstrators, which are presented after. The first is an x,y,z-manipulator (delta robot) and the second a tip-tilt piston mirror. The innovation of these demonstrators lies in the combination of DRIE (Deep Reactive Ion Etching), puzzle-like assembly and splitting complex kinematical systems into flexure slabs, which are assembled into three-dimensional demonstrators.

#### **AUTHORS' NOTE**

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#### **Design rules for silicon**

In our previous work [3], we examined the effects of crystalline orientation, geometry and surface on the ultimate strength of monocrystalline silicon flexures. Our main motivation was to have a set of applied design rules for silicon flexure systems, as opposed to the general values given in literature [13].

The results of this work are:

- Filleted hinges and circular hinges enhanced the ultimate material strength by a factor of 2 compared to rectangular hinges.
- Orienting flexures parallel to the wafer flat instead of positioning them in a perpendicular manner enhanced the ultimate strength by a factor of 2.
- The oxidation and reoxidation surface treatment (T3) enhanced the ultimate material strength by a factor of 3 compared to DRIE.

This is illustrated in Figure 1.

- 1 Ultimate strength of monocrystalline silicon against hinge geometry, hinge orientation and surface treatment. Average standard deviation is 320 MPa; average stress uncertainty is estimated to range from 80 MPa for the thickest hinges to 230 MPa for the thinnest hinges. (Image adapted from [3])
- 2 Kinematic structure of a single delta robot slab. Each slab is monolithic and consists of three bodies interlinked by a set of flexures.
- 3 A schematic illustrating the vacuum system used to assemble the sugar cube delta robot.

#### A delta robot the size of a sugar cube

Using a set of design rules based on experiments, we were able to design fully assembled 3D flexure-based structures in silicon. We first highlighted the potential of these structures in silicon with the manufacturing and assembly of an x,y,z-manipulator, a delta robot the size of a sugar cube, also known as the sugar cube delta robot.

#### Kinematics and fabrication

The delta robot was constructed out of three slabs, each containing an identical kinematic structure (see Figure 2).

The kinematic structure was realised using twelve filleted rectangular hinges, four of which allow an out-of-plane motion (3D compliant structure). Three of these kinematic structures were assembled into a delta robot. For fabrication, the hinges were positioned parallel to the wafer flat and the oxidation and reoxidation treatment was used. The sugar cube delta robot was assembled using a vacuum base and assembly jig to keep the parts in place, while a glue or solder was applied to fix the components (see Figure 3).

#### **CSEM**

Centre Suisse d'Electronique et de Microtechnique (CSEM) is a privately owned applied research and development centre specialising in micro- and nanotechnology, systems engineering, photovoltaics, microelectronics and communications technologies. It offers its customers and industry partners custom-made, innovative solutions based on its knowledge of the market and its technological expertise derived from applied research. CSEM creates a dynamic link between research and high-tech industries, such as medtech, industrial controls, watchmaking, aerospace, cleantech and environmental monitoring. CSEM also collaborates with other innovation centres to provide solutions for cutting-edge products and applications.

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#### Results

The assembled sugar cube delta robot is able to perform translations of  $\pm$  0.6 mm and has a cubic volume with edges of 20 mm. The actuation is realised with three commercial ultrasonic piezo actuators. Position sensing is done using a shadow imaging encoder principle utilising CSEM's icycam, a contactless absolute nanometric 3D precision sensor. A single slab and the final assembly are shown in Figure 4.

The rigidity of the assembled sugar cube delta robot was measured and compared to the theoretical and FEA (finite-element analysis) values. Table 1 shows a relatively good match between the values.

**Table 1** Stiffness measurements of the delta robot.

Nominal values (N/m)		Relative values (%)		
Analytical	64.83	Analytical/FEA	95	
FEA	68.26	Meas. /Analytical	95	
Measurements	61.79	Meas. /FEA	90	

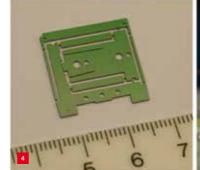
#### The tip-tilt piston mirror mechanism

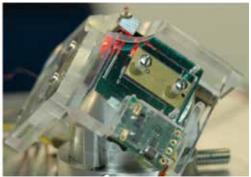
The methodology of silicon assembly was further implemented on a tip-tilt piston mirror mechanism (TTPmm). The following section outlines the fabrication, kinematic decomposition and assembly.

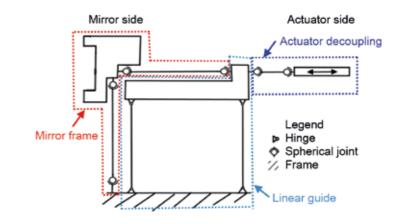
#### **Kinematics**

As with the sugar cube delta robot, the kinematic structure of a tip-tilt piston mirror mechanism was subdivided into a set of slabs, in this case four. The mechanism resides in three identical monolithic silicon slabs (hereafter referred to as 'the flexure slabs'). These mechanism slabs are coupled to the fourth brick, a silicon part with a gold-deposited mirror. The flexure slabs have multiple functionalities, namely decoupling the actuators while allowing for less demanding tolerances between the flexure slab, frame and actuator, and providing a translation of the integrated mirror frame.

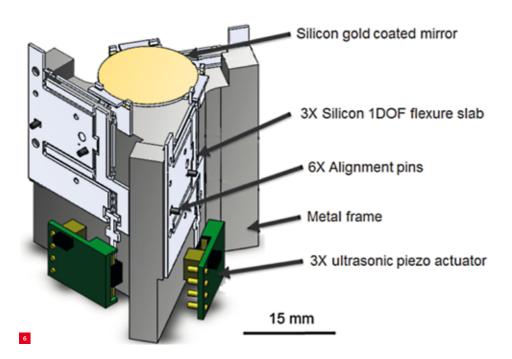
The kinematic structure of a single flexure slab is displayed in Figure 5. Each flexure slab contains a mirror frame, which holds the mirror in an axial position with respect to a linear guide and a tangential blocking the rotation along the mirror's normal axis and in-plane translations of the mirror. The linear guide is connected to an actuator decoupling, allowing for overconstraints resulting from







- 4 Photos of a slab of the sugar cube delta robot (left) and the final assembly (right).
- 5 Kinematics of a flexure slab. (Image taken from
- 6 Tip-tilt piston mirror mechanism. (Image taken from [4])





#### DESIGN AND ASSEMBLY OF SILICON FLEXURE-BASED MECHANISMS

imperfections in either actuator, geometry or assembly to have no significant effect on the functionality. The implemented design of the TTPmm is capable of  $\pm 4^{\circ}$ (tip and tilt) rotations in the mirror plane; the (piston) translation range of the mirror plane is  $\pm$  0.6 mm.

#### Assembly

For the assembly, each of the three flexure slabs constrains the mirror in two degrees of freedom (DoFs): one axial and one tangential DoF. With this method for alignment, we achieved an isostatic positioning of the mirror. The flexure slabs are fixed to a metal frame. The entire assembly fits in a 40 x 40 x 42 mm<sup>3</sup> rectangular volume (see Figure 6). The actuators are, in turn, coupled to the silicon rods to provide the actuation. The flexure slabs are fixed by either gluing or soldering. To allow for soldering, the interfaces of the flexure slabs and the mirror have a gold coating.

#### **Actuation** and sensing

The TTPmm allows for various actuation and sensing possibilities. In this case the actuation was realised using the same ultrasonic piezo actuators as used with the sugar cube

delta robot. Sensing functions are not directly implemented in the current design. The first approach is to use an optical measurement system based on the mirror itself to characterise its displacements. An FEA of the system's lowest eigenfrequency was also performed. This analysis revealed the lowest parasitic mode as 580 Hz, which is the out-of-plane mode of the linear guide of the flexure slabs.

#### Conclusion and outlook

The two assembled and functioning demonstrators reveal the possibilities and opportunities of silicon flexure-based mechanisms. Taking into account design rules and splitting complex system kinematics into a set of silicon slabs, macro-scale robotics and optomechatronic systems can be recreated on a centimeter scale. Our future work will outline in more detail the integration of sensors and actuators and also present a wider discussion of puzzle-like assembly features, which show the full strength of these systems. These systems provide a worthy and often overlooked equivalent to the many millimeter-to-centimeter-scale precision engineering applications in fields such as medtech, watchmaking and aerospace.

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## HIGH LEVEL OF ACCURACY, **ZERO DEFECTS AND LOW COST IN UDEN**

Present industry requirements for high-quality ceramic components are characterised by a high level of accuracy, processes that ensure zero defects and a low-cost production set-up. To meet these requirements, Philips Ceramics Uden uses ceramic manufacturing technologies that have been developed at Philips Lighting over the past few decades. This technology is now available to other companies.

ARNO BRUS

hilips Ceramics Uden has sixty years of experience in providing Philips with ceramic technical solutions. Over twenty million highquality ceramic components are manufactured each year at the production site of Philips Ceramics Uden (Figure 1). Depending on the product design, either extrusion or injection moulding is used. These products showcase the state-of-the-art technology that is available nowadays for manufacturing high-end ceramic products. These products are used in lighting, sensor and other applications where product requirements are very high (Figure 2).

Ceramic components are renowned for their unique combination of characteristics. The combination of being able to withstand high temperatures, while also offering

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arno.brus@philips.com www.lighting.philips.com chemical inertness means these components can be used for very specific purposes. By using the proper manufacturing technologies, Philips Ceramics Uden can produce ceramic components with an accuracy in the order of microns. Some technologies available at Philips Uden are highlighted below.

#### In-house feedstock compounding

There are numerous advantages to having in-house compounding equipment and technology. The compounding process that has been developed over the last few years by the Philips Uden development team ensures a perfect homogenisation between ceramic raw materials and binders (Figure 3). The process boundaries of the extrusion and injection moulding technology can be stretched by adapting the raw materials recipe. Specific customer requirements that would not have been possible using



Production facilities at Philips Ceramics Uden. (a) Mechanised production lines for ceramic injection moulding. (b) Industrial furnaces operated under hydrogen condition ensure controlled sintering conditions.







standard compounds can be realised by adjusting feedstock composition, e.g. binder optimisation to enable the injection moulding of thin-walled products (Figure 4) or adding dopes to the feedstock compound to improve mechanical product characteristics.

#### Joining technology

Besides feedstock compounding, Philips Ceramics Uden has also developed various technologies for joining ceramic components. The choice of joining technique depends on the application. Figure 4 shows an example of two ceramic components connected with a gas-tight, monolithic join. This product also demonstrates a gas-tight, metal-toceramic connection.

#### Injection moulding and extrusion facility

For its main products, Philips Ceramics Uden runs automated lines at the plant 24/7 (Figure 1a). Injection moulding can be done using a single cavity mould or multiple-cavity moulding, if economically beneficial to the customer. For extrusion, a high-speed drying process is available. This ensures fast production, but also results in a high level of accuracy in the sintered product. Various industrial furnaces, operated under hydrogen condition, are available for creating and controlling the required sintering conditions (Figure 1b).

#### Mould and process design

Philips Ceramics Uden has a development and engineering team including material specialists and mould and process designers. They work very closely with selected mould suppliers. An accuracy in the order of microns can be achieved in the end product. To realise this, both the mould and process designers are involved from the very beginning of product development.

Making technical ceramics with product details in the order of microns requires a perfect control of the compounding, shaping and firing processes. When designing the mould cavity for injection moulding, different shrinkage factors are taken into account depending on the product orientation and the related feedstock flow. The shaping process is monitored and process control is applied to eliminate spread in density levels after shaping. The hydrogen furnace environment ensures a densification to full density, thereby eliminating pores and potential spread on product dimensions. Different furnace conditions can be applied when required.

#### **Available to others**

The technology that has been developed at Philips has recently been made available to other companies. This new commercial strategy has opened up options for companies looking for ceramic solutions. Philips Ceramics Uden has a high-volume production capacity in extrusion and injection moulding. By using a high level of mechanisation, costs can be kept at an acceptable level.

- 2 Some examples of injection-moulded products (a) Array of lenses. (b) Specially designed surfaces with sharp edaes.
- 3 After the homogenisation of alumina, binder components and dopes. the mixture is formed to pellets.
- 4 Injection-moulded ceramic component. Wall thicknesses of less than 0.2 mm are moulded. The product consists of two joined ceramic components with a co-sintered metallic feed-through.





## DSPE - THE FORMATIVE YEARS

DSPE is 60 years 'old' and still alive and kicking (read on page 5 what DSPE stands for in 2014). A dive in the archives tells us that the same was the case in the formative years. From the founding of its predecessor in 1954, the Dutch Association for Precision Mechanics (N.V.F.T.), it has been very much alive in the variegated world of instrument makers, precision engineers and glass technologists. And it's also been kicking, because with a great deal of personal effort and various differences of opinion and character, work has been undertaken on a wide range of initiatives which, in 2014, live on in DSPE and Mikroniek.

he true origins of DSPE date even further back, namely to 1901, when in Leiden Professor
Heike Kamerlingh Onnes formalised having unpaid 'students' by establishing the 'Society for the Advancement of Instrument Maker
Training', thereby actually creating the Leiden Instrument Makers' School (LiS), which to this day is a very well-respected professional education institute. DSPE thus also appears to have Nobel Prize roots, because in 1913
Kamerlingh Onnes won the Nobel Prize for Science for the liquefaction of helium (Figure 1).

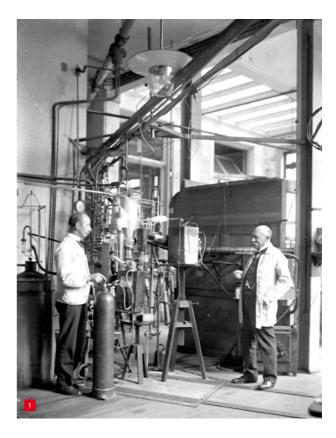
**Former students** 

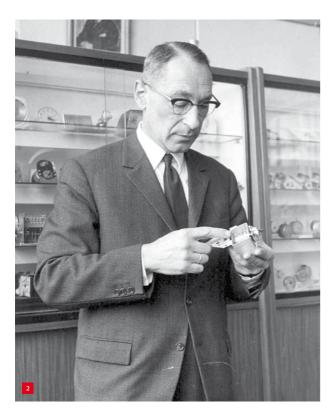
Over the years the LiS has produced a large number of instrument makers and in 1947 a number of them established the Association of Alumni of the Leiden Instrument Makers' School (V.O.L.I.). The aim of the association was to safeguard the level of education at the LiS. Seven years later, on 9 November 1954, the Dutch Association for Precision Mechanics (N.V.F.T., *Ned. Ver. voor Fijnmechanische Techniek*) was founded, with its secretariat in Utrecht.

#### **Precision mechanics**

The initiator behind N.V.F.T. was ir. A. Davidson, who had set up the Precision Mechanics Design Group (FMOG) at Philips (Figure 2). He believed that in industry a new discipline was emerging, in addition to the established discipline of metal working. Together with others, he defined this discipline by writing the Handbook of

1 Professor Heike Kamerling Onnes (right) together with research instrument maker Gerrit Jan Flim next to the helium liquefier used in the discovery of superconductivity. (Photo taken around 1919, source: Museum Boerhave) Precision Mechanics. In-house publications have been important from the start. V.O.L.I. launched a Newsletter in 1952 and renamed it two years later as Instrument Building (*Instrumentenbouw*). N.V.F.T. was given space in the Polytechnic Magazine (*Polytechnisch Tijdschrift*).





- 2 Ir A Davidson in front of a showcase of his Precision Mechanics Design Group at Philips. (Photo from 1968)
- 3 The first Mikroniek.

#### **Symposia**

In addition to annual meetings, in the early years activities included evening discussion meetings in the region, on-site meetings, attendance at 'The Instrument' exhibition, etc. Locations included the Kamerlingh Onnes laboratory at the University of Leiden, the Physics Lab at the University of Utrecht, Medical Physics at the Free University of Amsterdam, the Physics Lab at the University of Amsterdam, the Physics Lab at the RVO (National Defence Research Council, part of TNO) in Waalsdorp. A LiS Symposium was organised five times between 1958 and 1966. The first was characterised as the long-anticipated meeting of the 'School' with the 'Rest of the Netherlands'. In addition to technical lectures, the symposia also paid attention to themes such as 'Person and task of the instrument maker/design engineer'.

#### **Partnership**

For the 'Leiden' V.O.L.I. it proved difficult to exert influence on the policy of the LiS, which was managed from the Kamerlingh Onnes lab during those years. The idea arose to take the association to a national level and to seek a partnership with N.V.F.T. In 1961 this resulted in a change of name to N.V.E.I. - Dutch Association for Experimental Instrument Building (Ned. Ver. voor Experimentele Instrumentenbouw), and a joint N.V.E.I - N.V.F.T. publication entitled Fine Mechanics (Fijntechniek).



#### Two publications

However, the partnership quickly went wrong, mainly due to personalities, which was the reason why a year later N.V.E.I. resumed its own Instrument Building, resulting in two publications appearing side by side for a period of five years. However, keeping two publications going and generating sufficient income from advertising demanded a great deal of effort from volunteers. This was the reason why, ultimately, it was decided to resurrect the partnership after the personal 'coldness' had been cleared. Both associations remained independent but in 1967 they started jointly publishing a magazine entitled Mikron, which appeared six times a year.

#### Mikroniek

The Swiss firm Mikron soon objected to the use of the name, so Mikroniek quickly emerged as an alternative name: chronicle (kroniek) of the micron (Figure 3). At the same time, in order to generate extra income, N.V.F.T. launched its own monthly publication - the Finemechanical Journal (Fijntechnisch Journaal) - which contained extracts from world literature relating to precision mechanics, laboratories, instrumentation and related technologies. In an editorial meeting of Mikroniek, Davidson had it recorded that he objected to the untranslated inclusion of English articles.

#### **Current theme**

The partnership between N.V.E.I. (as representative of the laboratory sector) and N.V.F.T. (from the industry sector) was gradually growing closer. For example, the N.V.E.I. secretariat moved in with the N.V.F.T. in Utrecht where, however, it still did its own bookkeeping. On 29 May 1968 the first joint activity was organised: the Precision Mechanics Day in Utrecht, with the (even in 2014 still

highly topical) theme of 'One-off production and efficiency'.

#### Mikrocentrum

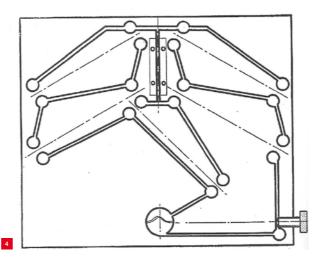
At the end of 1968 an exhibition was opened in Utrecht entitled "Mikrocentrum – treasure house of precision mechanical technology". This was organised by A. Kauling (who had been appointed as the secretary of the N.V.F.T. two years earlier) and his wife. One and a half years later the Mikrocentrum and the N.V.F.T. secretariat moved into the renowned Hoog Catharijne (office and shopping centre) in Utrecht. A. Davidson died in 1969 and was succeeded as Chairman of the N.V.F.T. by D. de Jong, Professor of Precision Mechanics at Delft University of Technology, specialising in gears.



Administratively, the associations then entered a period of calmer waters for a number of years, undertaking a wide range of activities, until 1976 when the Mikrocentrum relocated to Eindhoven together with the N.V.F.T. secretariat. On 10 December 1972, the gradually more intensive partnership between N.V.E.I. and N.V.F.T. was clinched with the establishment of the Mikron association. N.V.E.I. was discontinued and N.V.F.T. continued in a new style for the benefit of businesses, which could not become members of Mikron. The new association had three departments: Precision Mechanical Products (Fijnmechanische Produkten), Experimental Instrument Building (*Experimentele Instrumentenbouw*) and Glass Technology (*Glastechniek*), but the last-mentioned department had difficulties in becoming established.

#### **Recurring** issues

In Mikroniek the departments were clearly identifiable. Over the years the magazine had no shortage of copy but a shortage of copywriters. The editorial staff sought to strengthen this by searching amongst retired Philips employees. In 2014 it still remains difficult for the editor of Mikroniek to find authors willing to contribute; after all, most contributors are researchers and company staff who write their articles for free. There are also freelance staff with a Philips past. Discussions about the target group, the reference reader, also appear to be an ongoing issue. For example, at that time it was noted that Mikroniek should mainly focus on intermediate-level engineers. In 1977 the sister publication, Fine-mechanical Journal, started providing information via a database. However, this attempt turned out to be (as yet) aimed too high and the 11th volume was also the last. The content of Mikroniek remained good (Figure 4), but it continued to be difficult to operate from a financial point of view, which was the reason for a change of watch on the publisher front.



#### **Open to business**

On 2 March 1988 Mikron and N.V.F.T.-new style merged to form NVFT (written without the full stops). This meant that the association was once again open to business members. On 1 January 1995 the NVFT was renamed NVPT (Dutch Society for Precision Technology). Later, the society's secretariat moved in with the employers' association FME-CWM, having offices in Zoetermeer; in 2007 once again the secretariat was transferred, to the Mikrocentrum (history repeats itself) in Eindhoven, the centre of the Dutch high-tech industry. As of 2013, DSPE's secretarial address is on the High Tech Campus Eindhoven.

#### International reach

The promotion of this high-tech industry, with its competencies in fine mechanics, instrument making and precision engineering, was already pending at an early stage, as became evident from a (non-honoured) proposal in 1984 to add 'Holland Precision Land' to the name 'NVFT'. With the international (promotion) ambitions in mind, the NVPT was translated into English and since 2008 the association has officially been known as the Dutch Society for Precision Engineering (DSPE). The circle is now completed because the reach was already international at the beginning of the last century, as evident from Kamerlingh Onnes' Nobel Prize, which was in part thanks to the performance of his instrument makers.

4 Example of Mikroniek content in the early 1990s: a flexure hinge, by ir. P. Rosielle.

#### SOURCES

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- www.mikrocentrum.nl

#### **CPE** COURSE CALENDAR

COURSE (content partner)	CPE points	Provider	Starting date (location, if not Eindhoven)
BASIC			
Mechatronic System Design - part 1 (MA)	5	HTI	8 December 2014
Mechatronic System Design - part 2 (MA)	5	HTI	15 December 2014
Construction Principles	3	MC	18 November 2014 28 October 2014 (Utrecht)
System Architecting (Sioux)	5	HTI	10 November 2014
Design Principles Basic (SSvA)	5	HTI	to be planned
Motion Control Tuning (MA)	6	НТІ	19 November 2014
DEEPENING			
Metrology and Calibration of Mechatronic Systems (MA)	3	HTI	1 December 2014
Actuation and Power Electronics (MA)	3	HTI	16 March 2015
Thermal Effects in Mechatronic Systems (MA)	3	HTI	5 November 2014
Summer school Opto-Mechatronics (DSPE/MA)	5	HTI	to be planned
Dynamics and Modelling (MA)	3	HTI	28 October 2014
Summer School Manufacturability	5	LiS	17 August 2015
SPECIFIC	_		
Applied Optics (T2Prof)	6.5	HTI	28 October 2014
Applied Optics	6.5	MC	5 March 2015
Machine Vision for Mechatronic Systems (MA)	2	HTI	19 March 2015
Electronics for Non-Electronic Engineers (T2Prof)	10	HTI	13 January 2015
Modern Optics for Optical Designers (T2Prof)	10	HTI	23 January 2015
Tribology	4	MC	21 April 2015 28 October 2014 (Utrecht)
Introduction in Ultra High and Ultra Clean Vacuum (SSvA)	4	HTI	27 October 2014
Experimental Techniques in Mechatronics (MA)	3	HTI	1 April 2015
Design for Ultra High and Ultra Clean Vacuum (SSvA)	3	HTI	to be planned
Advanced Motion Control (MA)	5	HTI	to be planned
Iterative Learning Control (MA)	2	HTI	3 November 2014
Advanced Mechatronic System Design (MA)	6	HTI	3 July 2015
Finite Element Method	5	ENG	30 October 2014

#### **DSPE Certification Program**

Precision engineers with a Bachelor's or Master's degree and with 2-10 years of work experience can earn certification points by following selected courses. Once participants have earned a total of 45 points (one point per course day) within a period of five years, they will be certified. The CPE certificate (Certified Precision Engineer) is an industrial standard for professional recognition and acknowledgement of precision engineering-related knowledge and skills. The certificate holder's details will be entered into the international Register of Certified Precision Engineers.

WWW.DSPE.NL/EDUCATION/LIST-OF-CERTIFIED-COURSES

#### Course providers

· Engenia (ENG)

WWW.ENGENIA.NL

• The High Tech Institute (HTI) WWW.HIGHTECHINSTITUTE.NL

Mikrocentrum (MC)

WWW.MIKROCENTRUM.NL

· LiS Academy (LiS) WWW.LISACADEMY.NL

#### **Content Partners**

· Dutch Society for Precision Engineering (DSPE)

#### WWW.DSPE.NL

· Mechatronics Academy (MA)

WWW.MECHATRONICS-ACADEMY.NL

Settels Savenije van Amelsvoort (SSvA)

WWW.STTLS.NL

Sioux

WWW.SIOUX.EU

• Technical Training for Professionals (T2Prof)



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## **COLD CHOPPING OF BABY STAR LIGHT**

To answer a question like "Are we alone in the universe?", the European Southern Observatory (ESO) is building the European Extremely Large Telescope (E-ELT). One of the detector instruments inside this telescope is called METIS and it comprises a key component known as the Chopper. This device switches the beam between a target and a reference sky. Post-processing subtracts these images to eliminate the background signal. Janssen Precision Engineering is responsible for the mechatronic development and realisation of a demonstrator.

#### MAARTEN DEKKER

1 A picture taken by the Paranal Observatory in northern Chile using infrared telescopy. This is Thor's Helmet, a nebula that is 15,000 light years away and over 30 liaht vears across. Nebulas are interstellar clouds of dust and gas from which stars are born. (Credit: FSO/R Railleul)

re we alone in the universe? Are our physical laws universal? What role do black holes play in the universe? Why are the theory of relativity and gravity not consistent? Why is the universe expanding? To try to answer these questions, telescopes observe and study the extrasolar universe and early objects from space, as well as such things as supermassive black holes. The telescopes gather significant information, which often comes from spectacular pictures (see Figure 1).

#### E-ELT

The European Southern Observatory (ESO) is building the European Extremely Large Telescope (E-ELT) in northern Chile (see Figure 2). The telescope basically works as follows: a large concave mirror collects and focusses the light (radiation) to the detector instruments which construct images and other information. The E-ELT is larger than any current telescopes and will gather more light to make pictures even more detailed than the Hubble space telescope; it should even be possible to observe the atmospheres of exoplanets. First light is planned for December 2020 and the E-ELT should be fully operational in 2022 [1].

The E-ELT is a telescope equipped with optic and nearinfrared instruments, implying that it can 'see' infrared light, but why? All celestial objects with a temperature above absolute zero emit electromagnetic radiation, such as visible light. As the universe expands, the radiation from

distant and early galaxies shifts to larger wavelengths, from blue to red and ultimately to infrared.

The E-ELT is able to detect this radiation with its detection instruments. What's more, although hypothetical dark matter doesn't emit radiation, the E-ELT is intended to provide information about it and possibly even about dark energy. This information could provide an answer for the inconsistency between the theory of relativity and gravity, and evidence of the supposed energy responsible for the expansion of the universe.

#### **AUTHOR'S NOTE**

Maarten Dekker is a mechanical systems engineer at Janssen Precision Engineering (JPE) ir Maastricht, the Netherlands. He would like to acknowledge the contributions to this article made by Sander Paalvast, Maurice Teuwen and Huub Janssen (CEO) of JPE.

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#### DEVELOPMENT AND REALISATION OF THE METIS CRYOGENIC CHOPPER DEMONSTRATOR



#### **Cryogenic Chopper**

The Mid-infrared E-ELT Imager and Spectrograph (METIS) is one of the detector instruments in the E-ELT. This infrared instrument will be cooled to cryogenic temperatures (40-80 K) in order to be sensitive to infrared radiation. A key component of the METIS is the Chopper. This device is used to characterise the fluctuating infrared background signal in post-processing. To be able to do this, a mirror changes its tip-tilt angle at set intervals so that the optical beam can switch between the target and a nearby reference sky, known as chopping [2].

The objects of interest are typically four orders fainter than the 'background'. To observe them, a first image is made. A second image is then made just outside the region of interest which incorporates identical background radiation. Both images are then subtracted from each other in order to cancel out the background (see Figure 3). Janssen Precision

- **2** The inside of the E-ELT. The seamented mirror has a diameter of almost 40 m and an effective surface of almost 1.000 m<sup>2</sup>
- **3** To observe faint objects, a first image is made. A second image is then made just outside the region of interest which incorporates identical background radiation. Subtracting the second image from the first, only the objects of interest remain for further study.

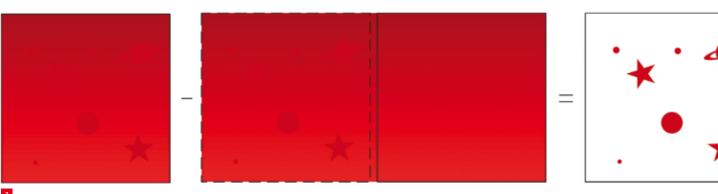
Engineering (JPE) is responsible for the development and construction of a demonstrator for the Chopper device.

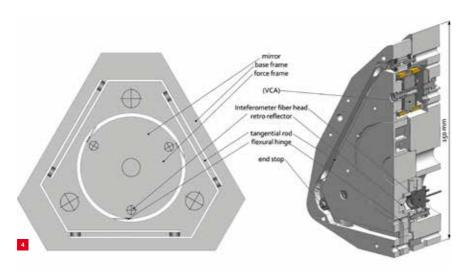
To have redundancy, the chopping movement has to be performed up to 10 Hz to be able to establish an average over several images within the time constant of atmospheric variations. The observation time and stability are crucial to achieve the best contrast. As such, a reconfiguration time of 5 ms including settling time is used to provide a duty cycle of 95% at 5 Hz. However, this stability and the reconfiguration time have pushed the mechatronic design of the Chopper to the limits. For example, the internal resonances of the device must be above 1 kHz to avoid mirror deformations directly after settling.

#### Mechatronic system

A mirror 64 mm in diameter has been made of aluminium because of its reflectiveness (when polished) and to minimise thermal expansion differences with respect to the rest of the METIS components. Therefore, the mirror and the entire Chopper are part of a monolith. In addition to the advantage of thermal expansion equality, the system does not comprise any backlash/play or hysteresis as a result of this monolithic structure. The mechanical path of the mirror to the fixed world (the METIS frame) is depicted in figure 4.

The mirror is fixed to the force frame via three point-hinges to ensure that the forces excited onto the force frame by the actuators do not cause any deformation on the mirror while its position remains kinematically constrained in six degrees of freedom (DoFs). The force frame may deform as a result of these forces, which will result in a displacement error of the mirror. This error is compensated through closed-loop control. The hinges are basically flexures, i.e. notched leaf springs. Thus, there is a thermal centre, and through the impact of light, the mirror is allowed to expand differently from the force frame. The pole of these hinges remains at the centre of mass of the mirror, because when





reconfiguring, the movement is above 30 Hz, i.e. on the mass line of the system. The force frame and mirror are both lightweight, simply because of  $f = 1/2\pi \sqrt{(c/m)}$  (see Figure 5).

The force frame is fixed to the base frame by way of three tangential rods [3]. Three tangential rods fix three DoFs of the force frame (and thus, the mirror), namely x, y and rz. As such, z, rx and ry are free and are imposed by three vertical actuators acting to the force frame. The mirror has to perform tip (rx) and tilt, so the z is a bonus. What's more, by using three tangential rods a 'parasitic' rz motion is present that is dependent on any movement in rx, ry and/or z. This prompts the question of why not use a concept that does not comprise this z actuation and parasitic rz motion? Well, the chosen concept is symmetrical and has a thermal centre in the middle of the mirror, while the parasitic rz movement is not an issue since the surface of the mirror is very flat and smooth. Furthermore, the symmetric layout provides homogeneity in forces and heat flux.

Each tangential rod is principally a rectangular beam which has one dimensional flexural hinge at each end. Thus, fundamentally, each flexural hinge cannot withstand torsion on the long axis of the rod. However, because the displacements are so small, the torsion does not pose a problem for the flexure. This, in turn, benefits the manufacturability. The flexural hinge can be easily machined into the monolith. Hinge surface roughness (for lifetime) and hinge dimensions (for stiffness) can be very stringent, while manufacturing using milling remains very cost-efficient.

The system should have a lifetime of 100 million cycles, derived from 50 observation nights a year for a minimum of ten years. While the internal resonances of the system

- 4 Concept and CAD model of the Chopper. The mirror is fixed by way of three flexural hinges to a force frame that is fixed to the METIS frame by three tangential rods. The force frame is actuated with three vertical actuators while mirror position is measured by three vertical position sensors.
- 5 Light-weighted rear of the mirror and force frame The three retroreflectors are also visible

must be above 1 kHz, the parasitic stresses (through torsion effects on the flexures) must not affect the lifetime requirement. The design of the hinges is optimised analytically (h/D [3]) and using a finite-element analysis for this lifetime and the torsional stresses.

#### **Custom actuators and sensors**

The actuators are custom voice-coil actuators (VCAs), developed by JPE because commercially available VCAs do not meet the stringent cryogenic and vacuum requirements. To prevent forces from going into the base frame, the VCAs are mounted to the bottom frame which is 6-DoF kinematically fixed to the base frame. The coils of the VCA are fixed to the bottom frame while the magnets move with the force frame. As such, a large thermal load to the mirror is prevented and the heat is directly transferred to the frame. Additionally, the lead wires do not move with the force frame, so they will not experience any fatigue stresses and no parasitic forces will be induced onto the system.

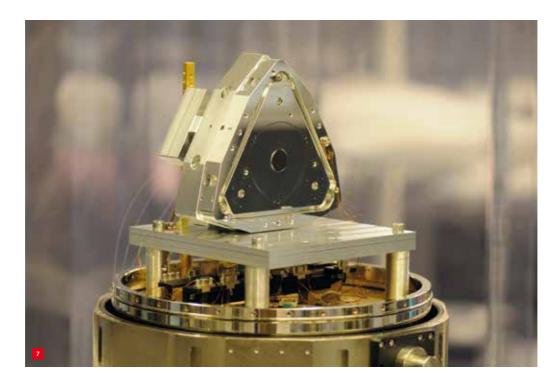
VCAs are inherently force actuators (continuous force tested at 9 N, force constant is 7.9 N/ $\sqrt{W}$  in cryo). To ensure position control, the actuators have to be in a closed loop with positioning sensors. As mentioned, absolute accuracy is not important, but reproducibility is. Therefore, monochromatic laser interferometers with a very high incremental accuracy are used. The active optical components are in the ambient environment, fibre-coupled to the sensor head which is located within



#### DEVELOPMENT AND REALISATION OF THE METIS CRYOGENIC CHOPPER DEMONSTRATOR



- 6 The coil as developed by Janssen Precision Engineering. In the background, the back iron (which will be placed on the coil) and the FeCo inserts.
- **7** The demounted test cryostat showing the Chopper. Here it is mounted on a test and calibrating set-up. The mirror surface and the top surface of the force frame are very flat and smooth to minimise polishing effort. In the centre, a reference mirror used to calibrate the Chopper.



the cryostat. Retroreflectors (see Figure 5) are used for the sensor mirrors to account for misalignments resulting from the achieved angles of the Chopper. Mechanical endstops are used for absolute reference and as a fail-safe for such things as earthquakes of up to 15 G accelerations at Chopper level.

In addition to lightweighting, the back iron (FeCo) of the VCAs is mounted to the coil holder. The magnetic field

now moves with the force frame, introducing magnetic (negative) stiffness and hysteresis. For stability issues, the negative stiffness is compensated using two inserts (FeCo) (see Figure 6) that are placed between the two coils. The hysteresis is compensated with an implemented selflearning control. This article does not address the control consisting of feed forward (tuned with the self-learning strategy) and feedback.

#### Lifetime test

After all the performance tests were carried out, an accelerated lifetime test in a cryostat (see Figure 7) was performed. This test comprised the revolving z-axis of a chop angle of 9 mrad, so tip and tilt alternated continuously. In reality, the Chopper will chop rather than perform this continuous motion, so this test is considered a worst-case scenario. As such, accelerated life was tested. The test was mainly intended to test the fatigue boundaries of the flexural hinges of the tangential rods because the fatigue depends on amplitude of motion, not on acceleration or other dynamical effects. At 80 Hz, the Chopper completed more than 100 million cycles and no changes in stiffness or change in transfer function were measured. Therefore, this test implies that the Chopper can meet the lifetime requirements.

#### **Performance**

To conclude, the most significant performance of the Chopper is summarised in Table 1. ■

Table 1 Performance of the Chopper.

Stability & repeatability	≤ 1.7 µrad	
Accuracy	≤ 85 µrad	
2D chop throw (req./goal)	≥ 8.5 / 13.6 mrad	
Chop frequency	0.1-10 Hz	
Reconfiguration time	≤ 5 ms	
Operation temperature	40-300 K	
Operation pressure	10 <sup>-10</sup> -1 bar	
Power (dissipation)	< 1 W @ 80 K	
Lifetime	> 100 million cycles	

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- [4] Precision Point, "2 Elastic hinges in series", www.jpe.nl/files/6113/9108/8212/2\_ Elastic\_hinges\_in\_series.pdf

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## SPOTLIGHT ON **MANUFACTURABILITY**

In order to make manufacturability compelling for young professional designers, the LiS Academy (part of the vocational training college LiS -Leidse instrumentmakers School) and its partners held the second edition of their summer school on manufacturability at the end of August. The summer school is an initiative of DSPE, Hittech and the LiS. Lectures, practical exercises, a workshop, assignments and excursions were organised over the course of one week in order to inspire the ten participants and allow them to familiarise themselves with the various aspects of manufacturability.

eld in Leiden and at various other locations in the Netherlands between 25-29 August, the summer school attracted participants from ASML, Bronkhorst High-Tech, Hittech Multin, PANalytical, TMC Manufacturing Support and Eindhoven University of Technology. It focussed on a variety of topics and subject matters:

- Manufacturing technologies such as turning, milling, cutting, aluminium casting, sheet metal working and die sinking.
- Critical reflection on subjects in relation to manufacturability, CAD/CAM work preparation and software simulations.
- Surface treatments with anodising.
- Measurement issues relating to surface roughness.
- State-of-the-art developments in micro-milling, 3D printing in metal and ceramics, and cutting very small and precise contours with micro-laser jet technology.

The participants (Figure 1) were enthusiastic and, based on the response of one of them, they wanted more: "CAM software was completely new to me, so this was incredibly educational. There was not quite enough computer time to try it out for yourself. I really would've loved to have had more time for that."

#### **AUTHOR'S NOTE**

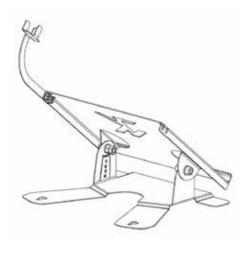
Erik Knol is the owner of Qeam consultancy and, as the initiator of LiS Academy, he was jointly responsible for organising the summer school.

www.geam.nl

#### Sheet metal working assignment

Besides the lectures and excursions relating to sheet metal working and construction with sheet metal, there was a design assignment that had to demonstrate clearly what the manufacturing challenges are regarding sheet metal construction. The assignment was to design a tablet holder made of sheet metal (Figure 2). During the course, the participants' designs were actually manufactured by sheet metal working company Suplacon in Emmeloord. They were then critically evaluated by experts working at Suplacon as well as by the participants themselves. Given the response of one of the participants, this assignment was a very educational approach to manufacturability using sheet metal constructions: "One high point was the combination of the topic of designing in sheet metal, as taught by Piet van Rens of Settels Savenije van Amelsvoort, with the possibilities and limitations of actually working with sheet metal, as provided by Suplacon."







#### **Workshop with experts**

During one workshop, the participants were divided into small groups and paired up with experts in the field of design, material use and the manufacturing of high-tech precision parts. They discussed manufacturability based on case studies provided by the experts and the participants. A range of perspectives came up, such as (re)designing to manufacture more cost-effectively, alternative materials in terms of manufacturability, design tips and tricks, and insights on machining tools. The participants really appreciated this informative session with the experts: "This was incredibly useful!"

#### Conclusion

The second edition of the LiS Academy Summer School on manufacturability was a great success (for more pictures see Figure 3). The week-long course was made possible with thanks to Dutch Space, ECN, Hittech, KO-AR, Mitutoyo, Radboud University, Settels Savenije van Amelsvoort, Suplacon, Ter Hoek Vonkerosie, Tetraëder FMT and TNO, with the support of DSPE, Brainport Industries, DPT and FME. The participants really valued the course, giving it an average mark of 8.3 out of 10. As one participant said: "The course itself, most of the topics, the interaction between the speakers/experts and the participants, plus the overall atmosphere were very positive."

- 1 The participants came from ASML, Bronkhorst High-Tech, Hittech Multin, PANalytical, TMC Manufacturing Support and Eindhoven University of Technology.
- 2 Tablet holder in sheet metal.
  (a) A participant's design that was created by Suplacon.
  (b) Another participant's design.
- 3 Pictures of the 2014 summer school.
  (a) Conventional turning at the LiS in Leiden.
  (b) Aluminium casting at Hittech Gieterij Nunspeet.
  (c) Work preparation of a component that was to be die cast, part of the course day at Ter Hoek

Vonkerosie in Rijssen.

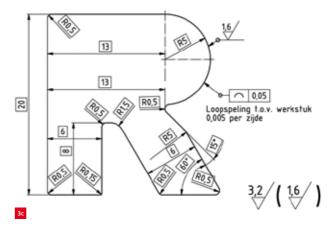




#### 2015

The dates for the next edition of the summer school have already been set: 17-21 August 2015. More information on the 2015 summer school and other LiS and LiS Academy activities will be available from the LiS stand at the 2014 Precision Fair, 12-13 November in Veldhoven, the Netherlands.

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## OPTICAL MEASUREMENT OF FOAM DEFORMATION

A Kinotex sensor, suitable for mechatronic applications, is a novel implementation of a flexible and potentially low-cost tactile pressure sensor. Its operation is based on the deformation of an optical cavity (such as ordinary foam rubber) and measurement of light from a controlled source scattered within the cavity. It is capable of measuring pressure locally across a surface area. As an optical device, the sensor can be made to operate in harsh environments by moving all electrical components into the body of a device and using an inert (silicone) foam surface.

**KEVIN PELZERS** 

he properties of the Kinotex sensor are useful in modern mechatronic applications in challenging environments, where more and more properties need to be measured during operation to achieve the required precision.

For example, measurement of forces and/or deformations is sometimes required in places where conventional principles are unusable due to electrical noise, thermal or chemical properties. In these kinds of applications a Kinotex sensor can provide an effective solution.

#### **Background**

The Kinotex technology was developed by Canpolar East Inc. and patented by the Canadian Space Agency in 1997 to detect collisions on the Canadarm2, a large robotic arm used to help construct and move material on the International Space Station (ISS). This arm is shown in Figure 1.

The technology was taken back to earth soon after and has moved through several companies and license holders seeking to make use of it. It can however still be considered new to the industry as it is not yet widely used and has been constrained to niche applications. Currently, an exclusive worldwide license is held by Kinotex Sensor GmbH for aviation applications, as well as exclusive European rights for industrial, medical and automotive applications.

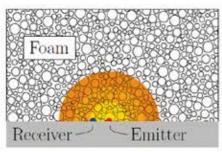
#### **AUTHOR'S NOTE**

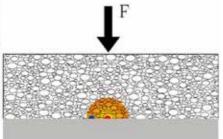
Kevin Pelzers wrote this article as a follow-up on his bachelor's (Mechatronics) graduation project at Alten Mechatronics in Eindhoven, the Netherlands. Having graduated cum-laude from Fontys University of Applied Sciences in Eindhoven, he is now studying Electrical Engineering at Eindhoven University of Technology.

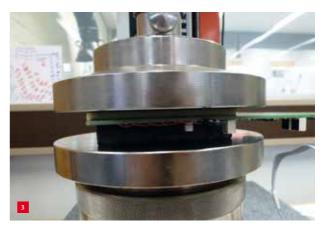
k.m.p.pelzers@student.tue. nl The origins of the technology show its potential robustness in adverse conditions, as it was required to operate in the high-radiation vacuum of space, coping with extreme temperature variations. This is something many other tactile sensors, such as force-sensitive resistors, piezoelectric foams or capacitive sensors, all using electrical signals, would have great difficulty with. Being an optical technology, Kinotex devices are non-conducting, non-corroding and immune to electromagnetic interference (EMI). Operating temperatures can range from –90 °C to over 240 °C depending on the choice of materials.

1 Austronaut Steve Robinson on Canadarm2, for which the Kinotex technology was developed.









2

In contrast, a low-cost Kinotex sensor can also be implemented, again depending on material selection. For example, this allows for large, high-resolution measurement surfaces to cover the body of large industrial or service robots, something that is now reserved mainly for small areas, low resolutions or research projects.

#### **Working principles**

The Kinotex sensor's working principles are based on the change in distribution of the light intensity in an isotropic scattering medium when it is deformed. This is implemented using a volume of elastomeric foam, a point light source and one or more light detectors, as shown in Figure 2.

The sensor functions by sending light into the optical cavity. This light can either be locally emitted by an LED, or transmitted through a waveguide, which is usually an optical fibre. This light is spread diffusely through multiple scattering in the foam, caused by its cell struts. At a short distance this causes any information about the original direction of the light to be lost and all the light is spread isotropically outwards [1]. A receiver measures the remaining light intensity at a fixed distance from the light source. Just as the light source, this receiver may be local or at a distance and coupled via an optical fibre.

When the foam is compressed by an outside force (Figure 3), its cell struts are moved closer together and the density of the foam increases. This causes the emitted light to be focussed in a smaller area near the source. This change in light distribution is measured by the receiver and is approximately linear with respect to compression distance. The pressure on the foam can be deduced if the stiffness of the foam is known. Through the use of multiple tactile sensor cells across a surface, the distribution of pressure is also known, which in turn provides information about the

- 2 Working principle: scattering distance decreases under compression.
- **3** A prototype sensor being examined under a bench press.

object's shape and position and can also be used to calculate the total load force on the measurement surface.

#### **Foam**

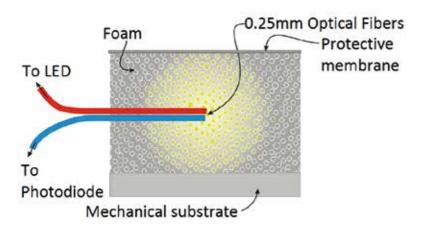
One of the main components is the foam used as a scattering medium. This foam is what determines many of the final sensor specifications, such as its measurement range, sensitivity and environmental resistance. A large variety of foam materials can be used, from low-cost polyurethane to robust and inert silicone foams, depending on the application requirements. Using silicone foams a temperature range from –90 °C to over 240 °C can be reached.

Some other possible foam choices include latex, polypropylene or styrene. In general these foams will be elastomeric for repeated usage, but for one-time use applications, such as automotive crush zone deformation [2], they need not be so. To increase the dynamic range of operation, it is possible to stack different types of foam on top of each other.

The foam used can be either open cell or closed cell, and can be either very flexible or stiff. So far, sensors can be configured to sense pressure as low as 0.1 kPa to over

#### Alten

Alten is a leading service provider in the field of technical consultancy and engineering. They started in France in 1988 and currently have 16.000 employees worldwide (300 in the Netherlands). The Alten Mechatronics business unit was formed in 2012 and specialises in mechatronics and robotics.



200 kPa depending on the material, however absolute pressure measurement accuracy is currently limited to around  $\pm$  5% due to visco-elastic properties of the foam materials used.

A Kinotex sensor can sense deformation as small as 0.025 mm or around 0.1% of the total foam thickness. which is far more accurate than pressure measurements since visco-elastic properties play no role. The response time is typically around 2 to 3 milliseconds and depends mainly on foam viscosity. In the future, more research into foam materials is expected to lead to better results in absolute pressure measurement as well as overall response.

#### **Mechanical construction**

There are essentially three implementations for a Kinotex sensor, as explained below: full space, half space and perpendicular half space [1] [3].

#### Full space

4

The basic sensor configuration is a full-space sensor as illustrated in Figure 4. In this case light is spread in every direction. Multimode, plastic, optical fibres are inserted between two layers of foam and are used to transmit and receive light. This is because they have a minimal footprint, with a typical diameter of 250  $\mu m$ , and are flexible enough to bend with the foam. A membrane can be placed on top of the foam to protect it from mechanical or environmental damage as well as prevent light from escaping or entering when thin foams are used.

An advantage of the full-space sensor is that it contains no stiff parts. Therefore, it can be implemented in a product whose structure is made from a soft, flexible material. Examples of this are modern polyurethane car seats, mattresses, clothing and soft robotics.

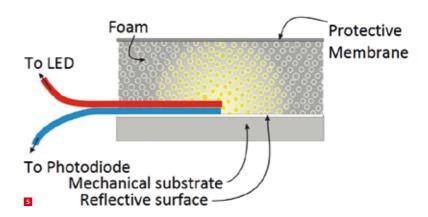
#### Half space

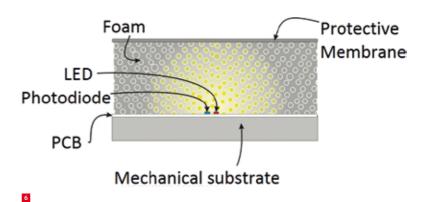
A half-space sensor uses only the top half of the foam and a reflective substrate on the bottom, reducing the required foam thickness and increasing the stiffness of the sensor. This implementation is shown in Figure 5. With this implementation foam thicknesses down to 1.6 mm have been achieved for a pressure-sensitive touchpad application.

This type of sensor can be useful in covering an existing robot frame or bumper. It also provides a higher signal gain, as the same amount of light is spread in a smaller volume, thanks to the reflective substrate.

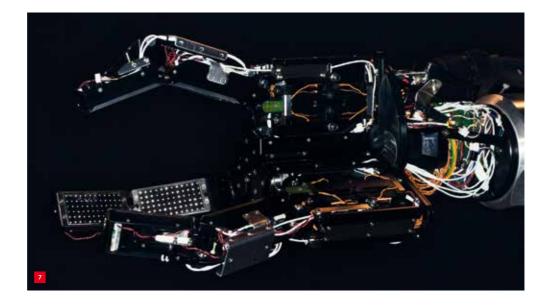
#### Perpendicular half space

Since light is spread isotropically within the foam and the original directionality of the light is lost, the orientation of emitter and receiver is unimportant. This leads to a perpendicular sensor implementation where light shines perpendicularly from the substrate, as shown in Figure 6. This makes it possible to directly place an LED and a photodiode on or just below the surface of the sensor, without the use of optical fibres. Conveniently, the PCB on which these are mounted can directly be used as a sensor substrate, though it should be sufficiently supported.





- **4** Full-space sensor implementation.
- **5** Half-space implementation.
- **6** Perpendicular half-space implementation.
- 7 Internal structure of the SeeGrip deep-sea manipulator (invented by DFKI Bremen), showing Kinotex sensor pads on the gripper's surface.



This implementation reduces the EMI immunity that is provided by an entirely optical sensing surface, but doesn't require optical fibres, which in turn reduces the required components and manufacturing steps.

#### **Electrical construction**

Electrically, a Kinotex sensor has two main components, namely light emitter and receiver, which are discussed below.

#### LEDs and photodiodes

The most straightforward implementation of this sensor uses a discrete LED and photodiode for each channel, or a device containing both an LED and a photodiode for each channel. LEDs and photodiodes are abundant and low-cost thanks to their use in optical communication systems. Typically, the LEDs would be switched in a matrix and the photodiodes individually amplified and multiplexed to the rest of the signal chain. For high safety integrity it is also possible to keep each diode output as a continuous analogue signal.

#### LED and camera

Another option to read out a large amount of sensor channels, is to use a single camera chip. A single, large LED can be used to illuminate a large amount of optical fibres, and the returning fibres can be interfaced to a regular CCD-or CMOS-camera chip, which is capable of reading many sensor channels in a small package. Thanks to their use in many consumer products, general-purpose image sensors are widely available, which makes them good options for cost-sensitive implementations. The small size of this implementation makes it a proper solution for high-resolution sensors in applications where little space is available, such as inside a robot end-effector.

#### **Application areas**

Modern mechatronic systems become increasingly fast and more complicated. At the same time, the environment is often becoming less static and robots are moving into our unpredictable human world and once static factories become more flexible to achieve shorter system integration times and provide a wider range of capabilities. To achieve this, these systems are equipped with more and more sensing capabilities to perceive the world around them and act accordingly for more flexible, accurate and robust operation. A common example is vision, complemented – since not everything can be seen – by touch. The Kinotex technology provides touch in its capability to sense surface pressure and deformation.

Being different comes with its own downsides and benefits. When used as a pressure sensor a Kinotex device with its  $\pm$  5% accuracy is not a precision instrument and it will never be as accurate nor as fast as a machined metal load cell. However, the small size of a sensor channel as well as its low cost makes it ideal for a tactile solution, where many sensors are required in close proximity across a large area. Using 250- $\mu$ m optical fibres, sensors can be placed within a few millimeters of each other to provide a high-resolution grid pressure measurement.

As a displacement sensor, it can detect deformations down to 0.025 mm. Combined with a high-resolution grid, this allows for quick measurements of material thickness and thickness deviation by pressing a large sensor pad against the entire material surface. For example, this has been used in the thickness inspection of carbon fibre sheets, allowing the automated identification of bumps or slopes in the material.

Table 1 Example applications.

Industrial	Automotive	Medical
Safety skin for service robots, allowing direct Human-Machine Interaction (HMI)	Seat Occupant Classification (SOC) sensors (FMVSS 208)	Actigraphy bed sensor
Collision detection for industrial robots or automated guided vehicles	Crush Zone Intrusion (CZI) sensors for impact sensing	Early detection of bedsores (decubitus prophylaxis)
Grip force measurement and control	Active car hood for pedestrian protection	Sensor mats for investigating 'restless legs syndrome'
Object shape, size or deformation measurement	HMI input touch sensor	

Because the active area of the Kinotex sensor is optical, any electrical components can be moved away into the body of a device, connected by an optical fibre. This makes the active sensor area immune to EMI and safe to use near flammable materials or conductive liquids. Immunity to corrosion can be achieved by using inert materials, such as silicone foam, in the active sensor area. Another benefit of silicone foam is the large temperature range. These properties can lead to benefits in 'dirty' operating areas found in industrial or automotive applications, or areas where absolutely no electrical signals or metals are tolerated, such as inside an MRI scanner or other medical devices.

For safety applications, the sensor is capable of delivering a continuous analogue signal. If combined with a redundancy of sensor channels this allows for a high safety-integration certification. Another benefit of the sensor is that foams can be cast in arbitrary shapes and sizes, leading to a large flexibility in their use. The number of sensor channels can

vary from one for a single point sensor up to thousands for floors, beds or similar.

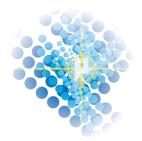
All of the above leads to possibilities in a large number of applications, some of which have already been mentioned earlier in this article. Another application is the SeeGrip manipulator [4] [5] (Figure 7), which uses an abundance of sensors, including Kinotex sensor pads to emulate a sense of touch in deep-sea environments with disturbed viewing conditions and with up to 600 bar of ambient pressure. More examples are shown in Table 1.

In conclusion, a Kinotex sensor itself does not provide the most accurate pressure or deformation measurements. However, its potential as a cost-effective tactile sensor, as well as its environmental immunity allows for applications that may have previously been unfeasible, adding more senses and allowing for faster, safer, more accurate and more flexible mechatronic devices.

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#### TAPPING INTO FACH OTHER'S EXPERTISE

## UCM – solutions for precision cleaning to highest cleanliness standards

UCM AG is a 100% subsidiary of the German Dürr Ecoclean Group, a global leader in industrial cleaning technology. With the integration of UCM, Dürr Ecoclean has become a full-solution provider for all sorts of industrial cleaning applications, from pre-cleaning via intermediate cleaning to fine and ultra-fine cleaning requirements.

he resulting combination of the UCM and Dürr Ecoclean product ranges and sales and service portfolios provides customers with a one-stop source for cleaning technology and associated services for every application, wherever they are located. UCM (Ultrasonic Cleaning Machines) stands for:

- more than 25 years of accumulated knowhow and experience in industrial precision surface cleaning;
- Swiss precision engineering and solutions to highest cleanliness standards;
- a considerable reference list of renowned client companies spanning all relevant application and industry types.

UCM is a manufacturer of multi-stage immersion-type ultrasonic cleaning lines. All equipment meets highest standards of substrate cleanliness. The sophisticated modular design allows these systems to be individually and cost-efficiently adapted to any application and requirement. Cleaning and drying operations are

> controlled and monitored by a PLC. An operatorfriendly process visualisation system facilitates tracking and logging of the entire workflow. A range of peripheral devices such as oil separators, filter units and water reconditioning systems ensures an eco-friendly, cost-efficient cleaning process. In most applications the systems operate fully automatically, relying on automated loading and unloading units and an automatic robot-based movement of parts along the line.



#### **Typical application areas**

- aircraft, automobile, watch and jewelry
- Medical industry, e.g. implants, surgical tools,
- Precision optics, e.g. lenses, mirrors, prisms,
- Coating industry, PVD-CVD processes, e.g. carbide tools, automotive parts, fixtures. ■





## ULTRASONICS PUSHING THE BOUNDARIES

In the area of micro moulding, OEMs now have a new and innovative technology to assess as they strive for a cost-effective, accurate, and efficient manufacturing. The new micro moulding process is based on the use of ultrasonics as the agent of polymer melting. With no need for a screw and barrel, the technology is extremely energy efficient and minimises waste. At the same time, as ultrasonics induces extremely low viscosity in melted materials, product designers can now explore entirely new innovative pathways.

**ENRIC SIRERA** 

ith the trend towards miniaturisation of plastic parts in many industry sectors, some suppliers have attempted to adapt injection moulding technology in order to better service the demands for small and precise parts. However, as is often the case, adaptations of macro technologies and processes to the moulding of precision and micro plastic parts is not always the best solution.

#### Ultrasonics versus traditional injection moulding

While in the world of precision and micro plastic part design and manufacture, with some of the aspects of the production process requiring special consideration when compared to the macro world, in essence all OEMs are looking for the most cost-effective and accurate technologies for their specific purposes.

The 'go to' technology for many plastic part manufacturers is injection moulding, a tried and tested technology with a pedigree going back decades. So ingrained in the psyche of the plastics industry is this manufacturing process that when technologies targeting the requirements of micro and precision plastic part manufacturers were needed, micro injection moulding machines were developed, scaling down the size of machines, but in essence using the same process.

Injection moulding machines, whether for macro or micro applications, work on the same principles. Plastic pellets are placed in a hopper, melted in a screw and barrel



surrounded by heating elements, and then injected into the mould under pressure. As such, they require a continual source of energy, and there is significant wastage of material that is melted and not required in production, and there is the age-old necessity to purge machines between cycles. In addition, as the injection pressures in traditional micro injection machines are typically quite high, expensive tooling is required.

Taking into account these basic inefficiencies in the injection moulding process – inefficiencies that are exacerbated when looking at the particular contingencies of the precision and micro moulder – Barcelona-based company Ultrasion spent a number of years researching and developing a brand new plastic moulding technology. Encapsulated in the Sonorus IG machine that is now being sold commercially worldwide (see Figure 1), Ultrasion designed a process based around the use of ultrasonics as the melting agent, which opens up enormous potential for manufacturers to save on energy, material, and tooling costs, while at the same time providing a technology that is extremely accurate and induces characteristics in the melted

#### **AUTHOR'S NOTE**

Enric Sirera is the Sales Director at Ultrasion, Barcelona, Spain.

esirera@ultrasion.com www.ultrasion.com polymer that allow product designers to overcome previously assumed limitations and truly innovate. It was decided to work on a technology and machine that catered for the precision and micro moulding sector that had a small footprint, used as little energy as possible, reduced material wastage, reduced tooling costs, and optimised the properties of melted plastics.

#### How the technology works

Most seasoned plastic manufacturing professionals looking at the new machine would immediately notice that there is no screw and barrel. In the Sonorus 1G, ultrasonic waves are used to melt plastic granules that are fed directly into the mould, are contacted by an ultrasonic horn, and are melted in milliseconds.

The basics of the ultrasonic moulding process is shown in Figure 2. Using a dosage system that delivers the correct quantity of standard pellets for every shot, the production cycle begins with the mould already closed and dosed with raw material at room temperature. The material is then contacted by an ultrasonic horn or 'sonotrode' which is lowered, and as well as melting the material forces the polymer to flow into the mould cavities. The sonotrode then returns to its original position, and the cycle begins again.

The ultrasound moulding technology is extremely precise, uses no heaters, and the process means that there is no material residence time, and no material degradation. In addition, as the energy needed in the process is only at the point when the ultrasonic horn contacts the raw material to induce melt, it uses upwards of 90% less energy than a traditional micro injection technology.

Material wastage, a problem in all sizes of injection moulding machines, is a massive issue in precision and micro moulding applications, where in some instances upwards of 99% of material processed will be scrapped. Where this material is expensive as is the case of some critical medical mouldings, this becomes an even bigger problem. In the Ultrasion process, only the material required is dosed, and so runner and sprue wastage is all but eliminated.

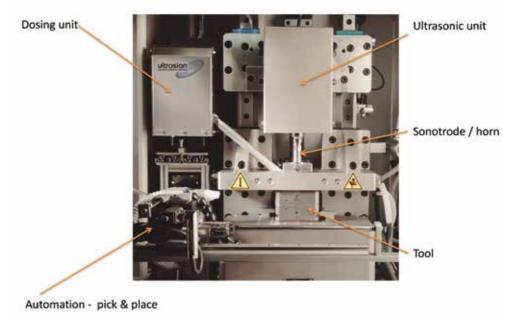
The nature of the ultrasonic moulding process is such that material melt characteristics are very different from those produced in injection moulding machines. The application of high-intensity mechanical vibration that transmits energy directly into the polymer molecular structure results in an extremely fast and efficient melting process 'inside out' rather than 'outside in', which is how melting occurs in injection moulding via the electric heater bands. In addition, the new sprue concept means that it behaves as an energy director, orientating the waves in the flow direction so that molten material and waves travel together towards the mould cavities, which induces extremely low viscosity (almost as low as water) in the melted plastic.

- 1 The new Sonorus 1G micro moulding machine.
- 2 Basics of the ultrasonic moulding process.
- 3 Examples manufactured using Ultrasion's micro moulding technology. (a) Part of an ear protection device. (b) An eye retina surgery tip.

#### **Application results**

The Ultrasion technology was commercialised towards the end of 2013, and is being sold worldwide into all industrial







sectors, including the medical, aerospace, electronic, and military sectors, where precision and accuracy are key.

The technology has been designed for ease of use, and requires no more than a short orientation and training session as the machine is installed. There are a few simple adaptations necessary to the tooling for the Sonorus 1G. There are no materials that cannot be processed using the ultrasonic moulding technology, with successful moulding projects using everything from standard polypropylene to high-density polyethylenes. The Sonorus 1G machine – which has been designed specifically for precision and micro applications – can accommodate shot weights from 0.05 g to 1.5 g.

In all materials, the reduced viscosity allows for the attainment of especially long parts or parts with extremely thin walls. The machine can easily mould 15 mm long parts with wall thicknesses of 0.075 mm, and achievable tolerances are in the region of 0.01 mm. For example, in a healthcare project for a medical device coloured polypropylene was used. This tissue management application required a difficult-to-manufacture tip. By using the Ultrasion technology, the OEM managed to produce a tip that was 43 mm long, weighing 0.22 g, with wall thicknesses of 0.075 mm, and with an outside diameter of 0.35 mm and an inside diameter of 0.2 mm.

In another application for the manufacture of a cap with a filter for an ear protection device made from raw polyamide 12~(PA12), the ultrasonic moulding process successfully manufactured a part weighing 0.02~g, with a 0.5~mm wall thickness, outside diameter of 4.4~mm and internal diameter of 2.9~mm. Crucial was that the part (see Figure

3a) – with a membrane overmoulding – was achieved in one operation. This proved impossible to achieve using a conventional micro injection moulding process, the alternative being to mould the part using one process, and then to glue the membrane in a secondary process. The manufacturer reported a 300% increase in productivity using the Ultrasion technology.

Finally, ultrasonic moulding was successfully used in the production of an eye retina surgery tip (see Figure 3b) made from raw polypropylene. The final part weighed 0.1 g, had an internal diameter of 0.6 mm with a 0.17 mm wall thickness, and a wall thickness at the tip of 0.1 mm. The tool for this application used two extremely small core pins sitting head to head, which would have broken using the high pressures of conventional micro injection moulding.

#### Limits?

While these achievements are in themselves impressive, the bottom line is that the limits are not (yet) known. In the case of the tip part mentioned above with 0.075 mm thickness along 15 mm with PP, when working on this project, Ultrasion generated flashes at the top of the tip due to a mould misalignment. The company has been unable to measure such flashes precisely, but they are definitely at least as thin as 0.003 mm along 3 mm. The customer was astonished as they felt that PP was not supposed to flash at such thicknesses, and this led to the development of parts that it had previously thought impossible to manufacture.

# FLEXURES FOR A CRYOGENIC COOLER IN A SATELLITE

Thales Cryogenics selected the photochemical etching process for an exacting manufacturing challenge, the production of flexures to be used for a cryogenic cooler in a satellite. The photochemical etching process can produce feature-rich, complex precision metal parts while retaining material integrity. The specifics of the process by which Precision Micro produced the flexures are used to illuminate the nature of photochemical etching and its suitability for a wide range of industrial applications.



**BONNY VAN GEEL** 

hen manufacturing parts for critical applications, it is vital that the process chosen is not only cost-effective and allows adherence to time-to-market objectives, but is also able to adhere to extremely tight tolerances and produces accurate parts in volume with minimal wastage.

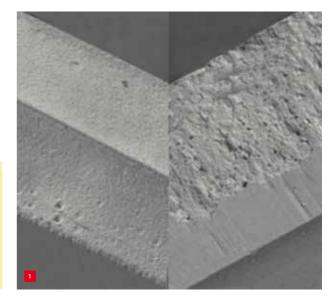
#### **Basics**

Despite the fact that photochemical etching has been a machining technology for over fifty years, it is still a relatively low-profile process, and its practical use in a variety of manufacturing scenarios with an ever broadening number of materials is one of industry's best kept secrets. To remain competitive and to stimulate innovation in the production of micro metal parts, it is vital that design engineers are made aware of the nature of this versatile technology, and the opportunities that it presents when compared with better-known and more traditional metal-working processes.

Commonly misrepresented as merely prototyping technology, photochemical etching is in fact a versatile and increasingly sophisticated metal machining solution, with an ability to mass manufacture complex and feature-rich metal parts and components. Using photo-resist and etchants to chemically machine selected areas accurately, the process is characterised by retention of material

properties, burr-free and stress-free parts with clean profiles, and no heat-affected zones.

Coupled with the fact that photochemical etching uses easily re-iterated and low-cost digital tooling, it provides a cost-effective, highly accurate, and speedy manufacturing alternative to traditional machining technologies such as metal stamping, pressing, CNC punching, and laser and water-jet cutting.



#### **AUTHOR'S NOTE**

Bonny Van Geel is the Technical Sales Manager for Benelux territories at Precision Micro, with headquarters in Birmingham, UK.

bonny.van.geel@ precisionmicro.com www.precisionmicro.com Traditional machining technologies can produce less-than-perfect effects in metal at the cut line (Figure 1), often deforming the material being worked, and leaving burrs, heat-affected zones, and recast layers. In addition, they struggle to meet the detail resolution required in the ever smaller, more complex, and more precise metal parts that many industry sectors require. There are instances – typically when an application requires multiple millions of parts and absolute precision is not a priority – when these traditional processes may be the most cost-effective. However, if manufacturers require runs up to a few million, and precision is key, then photochemical etching with its lower tooling costs is often by far the most economic and accurate process available.

Another factor to consider in process selection is the thickness of the material to be worked. Traditional processes tend to struggle when applied to the working of thin metals, stamping and punching being inappropriate in many instances, and laser and water cutting causing disproportionate and unacceptable degrees of heat distortion and material shredding, respectively. While photochemical etching can be used on a variety of metal thicknesses, it can also work on ultra-thin sheet metal, even as low as 10-micron foil.

It is in the manufacture of intensely complex and feature-rich precision parts that photochemical etching really finds its perfect application, as it is agnostic when it comes to shapes and unusual features in products to be manufactured. The nature of the process means that feature complexity is not an issue, and in many instances, photochemical etching is the only manufacturing process that can accommodate certain part geometries.

#### **Thales Cryogenics**

Founded as a separate company in 2000, Thales Cryogenics traces its roots back to the late-1940s when it was a department within high-tech equipment supplier Signaal USFA. Today, Thales Cryogenics is a leading developer and manufacturer of specialised cryogenic equipment, with offices and manufacturing facilities located in Eindhoven, Netherlands. Its expertise lies in offering — from design to manufacture — the most comprehensive range of cryogenic products for military, civil, or space applications. Its strengths include the translation of new concepts and techniques into custom-built working hardware, with special emphasis on prototype-building, series production, pre-production engineering, and the development of special-purpose tooling and test equipment.

#### **Precision Micro**

When looking for a reliable and cost-effective manufacturer for a particularly critical flexure component for a satellite



- Comparing finishing quality: etched edge on the left, stamped on the right.
- 2 The flexure component produced by photochemical etching.

cryogenic cooler, Thales Cryogenics selected Precision Micro. Active in the field for many decades, Precision Micro is constantly pushing the boundaries of what is possible in the process, making advances in etchant chemistry, and developing the process to embrace more and more metals, and enhance accuracy for its customers.

#### **Critical flexure component**

The critical nature of the flexure component (Figure 2) was key in choosing the photochemical etching process as the preferred manufacturing method. There is no more extreme environment than space, which demands that parts and components not only work as intended, but do so over prolonged periods of time. As a manufacturing process, photochemical etching has one key attribute when it comes to part integrity, and that is that during the production process it does not affect or degrade material properties.

The specific flexure used in the cryogenic cooler has been made since the 1990s. Initially, production of the flexures via machining and wiring was assessed, but these processes left small burrs on the parts and recast layers that would compromise performance. The photochemical etching process, as previously mentioned, induces no tension in the material being worked, and leaves no burrs.

While cost is an ever present concern when assessing alternative manufacturing technologies, in niche and highly

critical part manufacture like the flexures for the satellite application, its importance is matched by the location and use of a process that guarantees accuracy, repeatability, and conformance with extremely exacting tolerances and maintenance of material integrity.

Such considerations were of especial concern for Thales Cryogenics as the flexure component was essential to the reliability and system life-time of the company's LSF and LPT coolers, which Thales sells to a variety of customers that use them to cool high-sensitivity sensor systems. Examples of these applications include gamma-ray detectors, thermal night-vision detectors, and infrared spectroscopy detectors for use in satellites for observation of the earth. For all customers, long product life and high reliability are essential, as replacing the coolers in such instances is at best costly, and when a satellite is in space, at worst impossible.

As these linear coolers contain pistons moving back and forth at around 50 Hz, mounting them on a flexure spring with a radial stiffness and a low axial stiffness is essential for contact-free operation, which ensures that little or no wear

occurs during use. Thales Cryogenics found that flexures made using the photochemical etching process met these demanding requirements and retained their properties even after many years of continuous operation.

The purity of the metal used in the flexure was ultimately the key to supplier selection, as it was vital that potential fracture sites in the grain were eliminated, and this was only achievable with the consistency required through the use of chemical etching and Precision Micro's expertise.

#### **Conclusion**

Photochemical etching is precisely suited to applications where the requirement is for small, precise, complex, feature-rich parts with no burrs, and no stress-related changes in the metal which can occur using alternative metal forming technologies. Photochemical etching's use of digital tooling ensures that multiple tooling iterations that are often necessary to perfect the precise nature of such intricate metal parts are not costly in terms of time or money. In addition, the consistency of the process means no time-consuming and potentially costly retooling and revalidation are necessary.

## Skipping a lap lets you get to the finish more quickly

The NTS-Group develops, makes and improves opto-mechatronic systems and modules. We work for leading machine builders (OEMs) all over the world. Our methods enable our clients to innovate and respond to their customers' demands more quickly and radically shorten the time to market for new products. Do you want to move over to the fast lane? We would be pleased to make an appointment to become acquainted. www.nts-group.nl

The NTS-Group is a chain of companies in the Netherlands, the Czech Republic, Singapore and China specialised in developing and building opto-mechatronic systems and modules.



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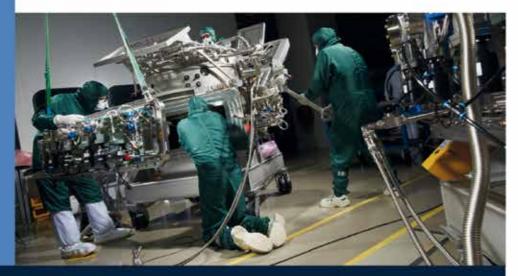
Vacuum process chambers

\*\*\*\*\*

## through cooperation

VDL ETG is a turn-key supplier, evolved from a build-toprint supplier to a build-to-spec supplier with support for total lifecycle management. VDL ETG specializes in high end vacuum equipment, fragile substrate handling and accurate positioning systems, applying (ultra-)precise manufacturing technology. It employs a systems engineering approach right from the start of design activities.

Want to know more? Please visit us at the Precision Fair in Veldhoven the 12<sup>th</sup> and 13<sup>th</sup> of November, stand 110.





## MECHANICAL SYSTEM APPROACHES LIMIT OF **TECHNICAL FEASIBILITY**

Nowadays, X-ray and tomographic methods help detect very fine structures inside objects; for spatial resolutions down to 100 nm, diffractive X-ray optics are available. For obtaining a three-dimensional image with volume resolution in this range, an extremely high mechanical accuracy and stability is required for the alignment of the optics and samples in the X-ray beam and for the entire experimental set-up. Even minute temperature changes or vibrations could degrade the desired resolution. Therefore, improvement of the X-ray optics must go hand in hand with mechanical perfection.

BIRGIT SCHULZE

t the X-ray light source PETRA III in the DESY research centre (German Electron Synchrotron) in Hamburg, Germany, the Helmholtz-Zentrum Geesthacht - Center for Materials and Coastal Research - (HZG) operates the Imaging Beamline P05, which includes two experimental hutches, one for nanotomography (Figure 1) and one for microtomography. Each name designates the attainable (spatial) resolution. In the nanotomography hutch, X-ray optics for three-dimensional micrographs with

- 1 The experimental set-up of the nanotomography hutch in the Imaging Beamline P05 at the X-ray light source PETRA III in the DESY research centre. (Images, unless otherwise indicated: PI/HZG)
- 2 One of the X-ray optics configurations: an imaging set-up in which the sample is positioned in front of the optics. (Image: HZG)
- **3** The substructure, which weighs several tons. is mounted on air bearings. Shown here is the assembly in the parking position outside the beam.

resolutions around 100 nm are used, that consist of up to many hundreds of diffractive lenses, which were developed at the Institute of Microstructure Technology (KIT) in Karlsruhe, Germany. The set-up also includes microscopy optics for visible light, used for further magnification of the X-ray micrographs and their transfer to a camera.

#### **High standards**

With the aim to carry out as many different experiments as possible, the HZG provides two different X-ray optics configurations: an imaging set-up, in which the sample is positioned in front of the objective optics (Figure 2), and a cone-beam set-up, in which the sample is placed in the diverging beam behind the optics. In both cases, high mechanical stability and precision positioning are essential in order to obtain micrographs of high quality. This is why the instruments used for the experiments at the P05 beamline must meet very high standards.

Thanks to the close cooperation with PI (Physik Instrumente), this complex task could be solved in a practice-oriented manner. The aim of a team of specialists, coordinated by PI miCos, was to develop applicationspecific solutions on the Beamline P05 that went beyond offering individual components and included system

#### **AUTHOR'S NOTE**

Birgit Schulze is in charge of Marketing & Products at Pl. b.schulze@pi.ws

integration as well as the complete instrumentation. A particular challenge was how to configure the control, which was based on an industrial controller. The challenge consisted in controlling almost fifty axes independently of one another while ensuring collision protection. The entire system was finally integrated into the TANGO interface customary for beamlines.

#### **Granite base**

To minimise the effect of vibrations and securely fasten the individual components and stabilise them, relative to one another, a granite base 6.8 m in length forms the basis of the instrument. Another four moving granite platforms driven by linear motors are arranged on this base on air bearings. This makes it possible to position all components with high speed and precision: the sample stage, the X-ray optics, and the detector. The substructure itself, which weighs several tons, is also mounted on air bearings. This allows the entire assembly to be moved out of the X-ray beam with minimal effort when the second experimental station is to be used, while maintaining a stable position as soon as the air flow is switched off (Figure 3).

A particular challenge was the construction of the sample stage, since it had to be mechanically stable in the range below 100 nm, in order to achieve the required spatial resolution. To this end, several positioning systems have to work hand in hand with maximum precision, to ensure that always the same volume element is investigated when the sample is rotating.

#### Complex sample positioning sequences

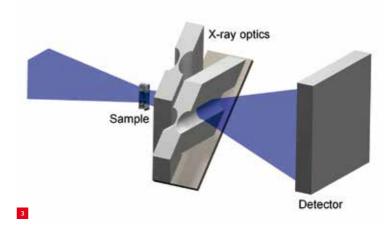
The basis of sample positioning is a horizontal positioning unit which moves the sample stage into the beam. It has a travel range of 20 mm, can be subjected to a load of 300 kg and works with a repeatability of 30 nm. What drives this high-precision positioning unit are stepper motors

#### Helmholtz-Zentrum Geesthacht

The Helmholtz-Zentrum Geesthacht – Center for Materials and Coastal Research – (HZG) uses synchrotron radiation and neutrons to carry out non-destructive investigations on materials and biological systems and to produce three-dimensional images in high quality. To this end, the HZG operates test installations both at DESY in Hamburg at the PETRA III storage ring and at the FRM-II research reactor in Garching near Munich, Germany.

WWW.HZG.DE





#### PI and ALT

In the past four decades, PI (Physik Instrumente), with headquarters in Karlsruhe, Germany, has become a leading manufacturer of nanopositioning systems with accuracies in the nanometer range. All key technologies are developed in-house, precision mechanics and electronics as well as position sensors. The required piezoceramic elements are manufactured by subsidiary PI Ceramic in Lederhose, Germany, a specialist for piezo actuator and sensor products. PI miCos in Eschbach near Freiburg, Germany, is a specialist for positioning systems for ultra-high vacuum applications as well as parallelkinematic positioning systems with six degrees of freedom and custom-made designs.

In the Netherlands, PI is represented by ALT (Applied Laser Technology), supplier of lasers, light sources, (fibre) optics, products for nanopositioning and fine-mechanical components from top manufactures for science, research and industry. ALT is based in Best, near Eindhoven.

WWW.PI.WS WWW.ALT.NL







combined with high-resolution optical linear encoders. When driven accordingly, this allows closed-loop step sizes of a few nanometers. The precision crossed-roller guides and ball screws used also contribute to the high positioning accuracy.

This displacement unit is equipped with three lifting elements which perform the height adjustment, tilt correction, and orthogonal alignment, relative to the beam (Figure 4). It is based on three identical, symmetrically arranged, and position-controlled stepper motors, combined with worm gears and spindle drives. Mounted on this Z stage is an air-bearing-supported rotation stage (Figure 5). In developing this stage, the designers had to push the limits of technical feasibility. What was required was a really 'pure' rotary motion of the sample with minimal wobble, radial run-out or eccentricity. Only in this case can sharp pictures over 360 degrees be made which all refer to the same volume element and can all be clearly assigned when reconstructing the picture. This is why the rotation stage, which rotates at a velocity of 36 °/s, works with flatness deviations of less than 100 nm at a resolution of 0.5 µrad. The air bearing does not produce any friction; over time, friction would lead to a deterioration of these values.

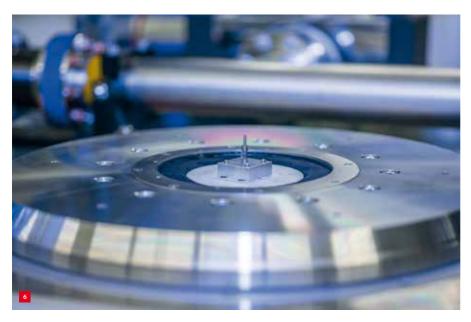
#### **Parallel kinematics**

The actual sample holder is located in the aperture of the rotation stage on the moving platform of a six-axis parallel kinematic machine (Figure 6). The SpaceFAB (see the box) clearly makes work easier for the researchers, since the small samples - only a few 10 to 100 micrometers in size - plus the holder can initially be inserted into the stage with

- 4 The Z lifting stage performs the height adjustment, tilt correction, and orthogonal alignment, relative to the beam.
- 5 An air-bearingsupported rotation stage is mounted on the combined tilt and Z stage (consisting of three differentially controlled lifting elements).

low precision. They can then be aligned automatically using software commands. Thus, no additional mechanical components are required for correct alignment. The samples are positioned with six degrees of freedom. Essential features are the freely selectable pivot point of the parallel-kinematic system and its high stiffness. A six-axis parallel-kinematic machine of this type is also used for the positioning of the optics. In nanotomography, which allows three-dimensional micrographs with resolutions below 100 nm, this machine is used to align compound refractive lenses (CRLs) in the beam with high precision.

A wide range of areas, from industrial research to materials science and examination of bones in biology, can benefit from the investigation results obtained by means of these high-resolution tomographic methods on the Imaging Beamline P05. The tailor-made positioning solutions used to align the small samples and optical components with high precision, make an important contribution.



- 6 The actual sample holder is located in the aperture of the rotation stage on the moving platform of a six-axis parallel kinematics.
- **7** Assembly principle of a SpaceFAB, based on three XY stages that jointly position a platform using three struts of constant length and a suitable joint configuration. (Image: PI)

#### Parallel-kinematic positioning systems

PI's parallel-kinematic positioning systems offer a series of advantages over serially stacked assemblies, such as a lower moving mass, resulting in improved dynamics, less space required in combination with higher stiffness. Thus, for motions with six degrees of freedom, either the strut length of the hexapods can be changed, or in the SpaceFABs the angle can be varied if the strut length is constant. The SpaceFAB principle is based on three XY stages that jointly position a platform using three struts of constant length and a suitable joint configuration (Figure 7). It is the principle of choice in particular when long distances have to be covered in the X and Y directions or a low-profile design is required.



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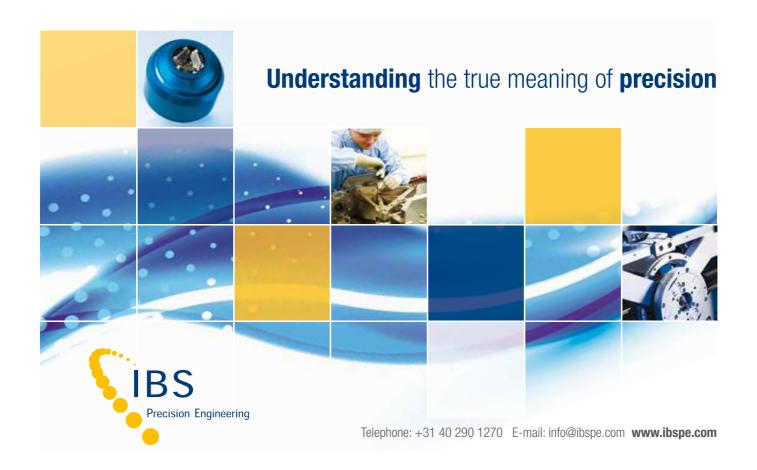




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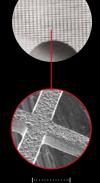
To create even smaller, even finer components, we combine photo-etching with laser direct imaging, electro-forming, additive layer techniques and fine-wire EDM.

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**MEGGITT** 

# "REVOLUTION VS. EVOLUTION"

During the two-day DSPE conference, I was pleased with, as well as surprised by, the large number of young precision engineers participating and presenting. Hopefully, this is evidence of an evolution of our beautiful precision engineering community, and something that promises many new developments and fresh impulses – revolution?! – from a scientific, technological and business point of view. At the very least, it provided a fitting backdrop for the conference theme, "Revolution vs. Evolution". A personal report.

JOS GUNSING

iscussing a wide number of subjects from the broad field of precision engineering is not an easy task. I will focus on the keynotes delivered at the DSPE Conference on 2-3 September 2014 in Sint-Michielsgestel, the Netherlands, and on the award winners.

#### Keynotes

The opening speech at the conference was delivered by Hans van Duijn, Rector Magnificus of the Executive Board of Eindhoven University of Technology. He talked about the university's new High Tech Systems Centre, an initiative that will potentially boost the development and engineering power of the Netherlands. In my opinion, several disciplines joining forces is an excellent move. For the future, I suggest that the initiative be extended by forging closer ties with the universities of applied sciences (contacts with high-tech SMEs). I also recommend integrating systems engineering into the mix, and not just in terms of optimisation tools.

#### "Nanopatterning Steppers and Large Area Patterning Tools Based on Jet and Flash Imprint Lithography"

Prof. S.V. Sreenivasan (University of Texas at Austin, and Canon Nanotechnologies)

In my view, this presentation on jetting and imprinting technology was the most surprising one. Having already heard of imprinting technologies several years ago, things in this area seemed a little bit quiet on the development frontier.

#### **AUTHOR'S NOTE**

Jos Gunsing is a technology innovator at MaromeTech, a professor in Robotics and Mechatronics at Avans University of Applied Sciences, and a DSPE board member.

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The conference attracted some 160 participants. (Photos: Jochem Treu)

This presentation, however, provided a great overview of an ongoing quest in this field, throughout which innovation has remained a constant. It seems now that the technology has reached a stage where, in a certain mix of productivity, flexibility and accuracy, it can become a feasible alternative for existing manufacturing technology. In particular, the very precise dosing of imprinting liquids with the aid of jetting technology represents a big leap forward in controlling the quality of the imprinting results (e.g., it will help avoid deformation of the imprinting moulds). One noteworthy aspect was the use of an ASML stage during the development, especially considering the fact that Prof. Sreenivasan's company is now part of Canon.



#### YOUTHFUL DSPE CONFERENCE ON PRECISION MECHATRONICS

#### "Planar Stage 2.0"

Dr. Xiaodong Lu (University of British Columbia) Xiaodong Lu gave an overview of progress in the planar motion field, with special attention to the developments in the Eindhoven area. He also presented many notable results of developments at his university in Canada, which focus on one type of moving-magnet planar stage using linear magnet arrays and linear coil arrays instead of clusters of small coils. There were numerous slides, pictures and video clips to show the results of his research and developments in the field of planar motion stage concepts based on moving magnets. He outlined several benefits of these developments, e.g. low manufacturing costs and low torque/force ripple, which lends itself to greater accuracies. Interesting was also his approach of generating a whole family of concepts with different mixes of speed/accuracy/ range/price/... in order to let the evolutionary forces of the market decide on the survival of the best mix.

#### **Awards**

Three awards were presented at the end of the conference. Two of the awards were related to systems-oriented design, while the third award was related to optimising an existing system by taking into account physical phenomena that have not yet been considered for many other applications.

#### Best presentation

"Ultra-high precision metrology of 3D surfaces with wavelength scanning interferometry", by Ivo Hamersma (IBS Precision Engineering), Haydn Martin and Hussam Muhamedsalih (University of Huddersfield)



Prof. Sreenivasan delivering his keynote.

poster session.

n tl Lively discussions during a p

A wavelength scanning interferometer for fast areal surface measurements of micro- and nanoscale structures was introduced. Measuring traceable step height specimens, the system achieves uncertainty within the nanometer range. In my opinion, putting reliable measurement methods and equipment high up on the precision technology map is a smart thing to do. I still stand by my belief that if you can't measure it, you cannot make it, something I believe is even more valid when you consider the increases in precision and accuracy. This may not be right from a philosophical point of view, but it is in the technological/practical world; you should be able to prove the level of accuracy obtained.



INFORMATION

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#### Best demo

"A Novel Master-Slave System for Reconstructive Microsurgery", by Raimondo Cau and Ferry Schoenmakers (Eindhoven University of Technology) Looking at mere accuracy, the development of medical

robotics is not that much to write home about, but it is quite impressive when examined in terms of the number of degrees of freedom, operator/patient friendliness and the accuracy limitations of classic precision surgery. Master/ slave systems in medical robotics also provide a solution for surgeons suffering from tremors (i.e. shaking hands), which can be a 'job-stopper' for precision surgeons (e.g. working in reconstructive, brain or eye surgery). Compared with the DaVinci robot from Intuitive Surgical, haptic feedback is an important advantage, especially for microsurgery. The forces used in cutting human tissue are

Sharing enthusiasm for precision engineering.

The inspirational conference location



very minute. An adjustable reinforcement level of these forces can give the surgeon more control and improve the surgical results.

#### Best poster

"In the quest for nm improvements, ASML needs to explore new physical effects", by Sander Kerssemakers and Hans Butler (ASML)

This poster presentation outlined several effects, such as air pressure variations due to moving components affecting the motion behaviour/accuracy, cooling liquid inertia in moving parts and magnetostriction effects. The presentation also covered ways to calculate and mitigate these effects. The higher the required accuracies, the more physical effects come in that disrupt them. For instance, I have some experience with inkjet printers with moving heads where the acceleration/deceleration effects affected the droplet formation behaviour in the nozzle area. Thus, the maximum/peak accelerations/decelerations had to be restricted, and not just the nominal values.

#### **Presentations**

Apart from the above-mentioned presentations, the very balanced conference programme also included other highquality presentations that touched on the majority of issues in the field of precision engineering. I sincerely hope that many of them will be extended to papers and articles, for example in this very magazine. From discussions with VDE/GMM (a DSPE-like chapter within VDE, the German Association for Electrical, Electronic & Information Technologies) and euspen, I can conclude that a magazine like Mikroniek is unique in the way it combines scientific matters, development issues and practical applications.

#### Final word

In my humble experience, I believe that DSPE's 2014 conference was a huge success. There was a great and open atmosphere on the two conference days, and both the inspirational conference location and the mild Indian summer weather helped enormously. Needless to say, I enjoyed the conference very much, as did many others. I would like to thank all the authors, the programme committee, and everyone else who supported the conference, especially the organisers Annemarie Schrauwen and Adrian Rankers.

Last but not least, I would like to thank those who came to the conference; it was great meeting you all. Seeing familiar faces and new ones all sharing their enthusiasm for precision engineering made for a wonderful conference experience.

Looking forward to the third DSPE conference in two years' time.



## Faculty Position in Ultra High Precision Robotics & Manufacturing

at the Ecole polytechnique fédérale de Lausanne (EPFL)

The Institute of Microengineering (IMT) within the School of Engineering at EPFL invites applications for a faculty position at the level of **tenure track assistant professor** in **ultra-high precision robotics and manufacturing.** Recruitment to a tenured senior position may be considered in exceptional cases.

This new position is aimed at reinforcing the leading position of the Swiss microengineering industry by giving it the means to further strengthen its competitiveness by continuous innovation.

Specific areas include, but are not limited to:

- Design of innovative ultra-high precision machining, manipulation and metrology systems targeting additive manufacturing;
- New kinematics, quasi-perfect guidings, actuators, transmission systems, sensors and methods targeting ultra-high precision additive manufacturing;
- New calibration techniques and new metrology devices for nanometric precision and sub-tens of nanometers accuracy;
- Design of tools targeting high-precision with excellent cleanness, e.g. microfactories and vacuum chambers.

Experience in successful collaborative research programs with industry is highly desirable. The IMT-EPFL offers a particularly advantageous position thanks to its historically very strong links to the diverse and well-established local high-technology industry.

As a faculty member of the School of Engineering, the successful candidate will be expected to initiate an independent research program, participate in undergraduate and graduate teaching and establish strong links with indus-

trial partners. Internationally competitive salaries, start-up resources and benefits are offered.

The EPFL is a dynamically growing and well-funded institution fostering excellence and diversity. It has a highly international campus at an exceptionally attractive location boasting first-class infrastructure. As a technical university covering essentially the entire palette of engineering and science, EPFL offers a fertile environment for research cooperation between different disciplines. The EPFL environment is multi-lingual and multi-cultural, with English often serving as a common interface.

Applications should include a curriculum vitae with a list of publications, a concise statement of research and teaching interests, and the names of at least five referees. Applications must be uploaded in PDF format to: http://go.epfl.ch/imt-search

Formal evaluation of candidates will begin on

December 1st, 2014.

Enquiries may be addressed to:

Prof. Christian Enz

Search Committee Chair

e-mail: imt-search@epfl.ch

For additional information on EPFL, please consult the web sites: www.epfl.ch, sti.epfl.ch and imt.epfl.ch.

EPFL is committed to increasing the diversity of its faculty, and strongly encourages women to apply.





## **MIKRONIEK**

Mikroniek is *the* professional journal on precision engineering and the official organ of the DSPE, The Dutch Society for Precision Engineering.

Mikroniek provides current information about technical developments in the fields of mechanics, optics and electronics and appears six times a year.

Subscribers are designers, engineers, scientists, researchers, entrepreneurs and managers in the area of precision engineering, precision mechanics, mechatronics and high tech industry. Mikroniek is the only professional journal in Europe that specifically focuses on technicians of all levels who are working in the field of precision technology.

#### **Publication dates 2014**

nr.: deadline: publication: special:

07-11-2014 12-12-2014 Additive Manufacturing

(+report Precision Fair 2014)

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#### **TAPPING INTO EACH OTHER'S EXPERTISE**

## Ter Hoek Vonkerosie – co-engineers with practical know-how

Completing orders for the construction and machining of tools and components whose complexity demands leading-edge solutions bordering onto the impossible is a challenge that Ter Hoek thrives on. With a high level of technical know-how and high-tech machinery, Ter Hoek has become the European market leader at the very highest level. Through co-engineering, Ter Hoek solves issues in which extreme dimensions, accuracy (to 1 µm) and materials play a major role.

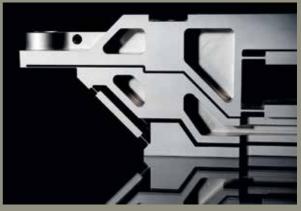
he most important markets are the industry, energy and offshore. For these hightech industries Ter Hoek has distinguished itself as a 'problem solver' because it is able to translate a client's request into a technically practical solution. Apart from the technical processes, Ter Hoek also controls the logistics. Using fully-acclimatised rooms, Ter Hoek delivers on its promises: short lead times for precisely defined machining and end results.

Ter Hoek has been machining all electrically conductive materials for 24 years, and the recent purchase of the Laser MicroJet technology from Synova enables it to machine non-conductive materials to within microns. This laser cutting technology is completely different from conventional lasers. As the laser is surrounded by a 30-µm

possible. This new technology substantially reduces the lead times for certain products.

Ter Hoek has also invested in two new die-sinking electrical discharge machines and one new wire electrical discharge machine: the Form 400, Form 30 and the Cut 1000 from AgieCharmilles. The Form 400 is the largest die-sinking electrical discharge machine produced by AgieCharmilles and has a working range of X-900, Y-700, Z-500 mm; the weight of a workpiece can be up to 4,000 kg. Thanks to the special hole in the machine's clamping bed, which is Ø 650 mm and 750 mm deep, it is possible for workpieces to be machined vertically. The Cut 1000 is a special thin-wire machine for wire diameters of between Ø 0.02 and Ø 0.03 mm. Because traceability is becoming increasingly important for Ter Hoek, it has also invested in a laser engraving machine, which ensures

In order to take the company to an even higher level certification and is aiming to be granted this certificate in its 25th anniversary year (2015). ■



#### **INFORMATION**

WILLEMJAN@TERHOEKVONKEROSIE.NL (WILLEM JAN TER HOEK) WWW.TERHOEKVONKEROSIE.NL

#### **UPCOMING EVENTS**

#### 9-14 November 2014, Boston (MA, USA)

#### 29th ASPE Annual Meeting

Meeting of the American Society for Precision Engineering, introducing new concepts, processes, equipment, and products while highlighting recent advances in precision measurement, design, control, and fabrication.

#### ASPE.NET

#### 12-13 November 2014, Veldhoven (NL)

#### **Precision Fair 2014**

Fourteenth edition of the Benelux premier trade fair and conference on precision engineering, organised by Mikrocentrum. Some 275 specialised companies and knowledge institutions will be exhibiting in a wide array of fields, ranging from optics and motion control to precision tools and software.



#### WWW.PRECISIEBEURS.NL

#### 13 November 2014, Veldhoven (NL)



#### **DSPE 60 Years Event**

Event during the Precision Fair (see above), to celebrate the 60th anniversary of DSPE. See page 56.

#### WWW.DSPE.NL

#### 19-20 November 2014, Den Bosch (NL)

#### Bits&Chips Smart Systems 2014

First edition of the annual event on embedded systems and software, focussed on the development of networked technical information systems. Combination of Bits&Chips Embedded Systems (since 2002) and Bits&Chips Hardware Conference (since 2008). The target group includes academia, researchers, designers, engineers and technical management. The conference features fracks on model-based development, system on chip, the vehicle of the future, and the Square Kilometre Array.



#### WWW.BC-SMARTSYSTEMS.NL

#### 19-20 November 2014, Padova (IT)

#### Special Interest Group Meeting: Structured Freeform Surfaces 2014

Topics include replication techniques (such as embossing and imprinting), structured surfaces to effect function, precision freeform surfaces, and large-scale surface structuring (including roll-to-roll and printed electronics).

#### WWW.EUSPEN.EU

#### 20 November 2014, Utrecht (NL)

#### **Dutch Industrial Suppliers** Awards 2014

Event organised by Link Magazine, with awards for best knowledge supplier and best logistics supplier, and the Best Customer Award.

#### WWW.LINKMAGAZINE.NL

#### 25-27 November 2014, Nuremberg (DE)

#### SPS IPC Drives 2014

International exhibition and conference on electric automation, systems and components.

### sps ipc drives



**Electric Automation** Systems and Components International Exhibition and Conference



#### WWW.MESAGO.DE/EN

#### 3-5 March 2015, Veldhoven (NL)

#### RapidPro 2015

The annual event for the total additive manufacturing, rapid prototyping and rapid tooling chain, divided into RapidPro Industrial and RapidPro Home Professional.



#### WWW.RAPIDPRO.NL

#### 17-18 March 2015, Huddersfield (UK)

#### Lamdamap 2015

Event focused on laser metrology, machine tool, CMM and robotic performance.

#### WWW.LAMDAMAP.COM

#### 25-26 March 2015, Den Bosch (NL)

#### High-Tech Systems 2015

The third edition of this event focusses on the high-tech systems industry in all European areas with significant high-tech roadmaps. It entails advanced system engineering and architecture, precision engineering, mechatronics, high-tech components system design as well as advanced original equipment manufacturing (OEM).

#### **NEWS**

## Successful 'Advanced Mechatronic A Course in Lens System Design' pilot course

he 'Advanced Mechatronic System Design' (AMSD) course for (future) system architects is set up in a master class manner. It includes a mix of presentations and exercises by renowned system architects, in combination with a conceptual design case study of a precision system, which will be worked on in teams throughout the course, including a customer presentation at the end. Participants will gather physical insights, working methods and design concepts for the development of precision systems. Special attention will be given to lessons learned from the past, in terms of approach and application of specific technical problems and solutions.

Upon completing the course the participant will be able to apply an agile systems engineering approach during the conceptual phase of an innovative project, make conceptual trade-offs

and estimate the implications at system level, and perform a risk assessment including mitigation. Furthermore, the participant will be aware of the roles that the various stakeholders in the customer organisation play during the process and how to set up a convincing customer presentation despite all uncertainties that are inherent to the conceptual phase.

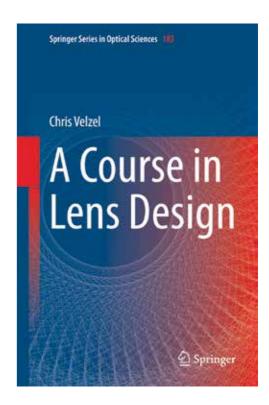
This Mechatronics Academy course, offered to the market by The High Tech Institute, has been certified by DSPE and is part of the Certified Precision Engineer (CPE) programme. For the full CPE course calendar, see page 17.

A successful AMSD pilot was completed last July. The next AMSD training course will take place in Eindhoven in Summer 2015.

WWW.MECHATRONICSACADEMY.NL

## Design

his new book by Chris Velzel, former senior scientist at Philips Electronics, provides instruction in the design of image-forming optical systems. The book introduces geometrical optics, optical instruments and aberrations. It describes the lens design process and the strategies used within it. Half of its content is devoted to the design of sixteen types of lenses, described in detail from beginning to end. The focus is on the initial phases of the design process: (paraxial) lay-out and (thin-lens) pre-design. An extensive review will be published in a forthcoming Mikroniek issue.



■ Chris Velzel, "A Course in Lens Design", Springer Series in Optical Sciences, vol.183, ISBN-13 9789401786843, Springer, Dordrecht 2014

### Efficient cleaning of precision mechanical components

DuPont de Nemours has launched a new extremely powerful and environment-friendly solvent for precision cleaning, DuPont™ Vertrel® Sion™. With this new generation of solvents and through various techniques such as ultrasonic, rinsing and vapour, superior cleaning performance will be achieved. It has the strongest solvency strength of any fluid in its class. Another major advantage is that Vertrel Sion is much better penetrating in components than water, allowing to clean any blind holes of < 1 mm through low surface tension and higher density. Fast drying and optimum boiling point results in cleaned parts immediately ready for use and further handling. Vapours of this precision cleaning solvent are always completely clean and do not leave any residue on the surface, it always evaporates completely. Ideally DuPont™ Vertrel® Sion™ is used in combination with a vapour degreaser.

FenS will present the new DuPont™ Vertrel® Sion™ solvent and a new vapour degreaser with low energy consumption, small footprint and environmentfriendly refrigeration unit at the Precision Fair 2014.

WWW.FENS.NL

#### **NEWS**

### Angle measuring modules

Angle measuring modules from
HEIDENHAIN simplify the set-up of
high-precision rotary axes by significantly
reducing the time and effort for mounting and
adjusting. In place of numerous individual
components, the angle measuring modules are
a combination of highly accurate angle encoder
and precision bearing that are specifically
matched to each other. HEIDENHAIN has
already completed the necessary assembly and
adjustments of all individual components. This
means that the properties of the angle

measuring modules have already been defined and tested according to the customer's specifications. Simple mechanical interfaces eliminate all critical mounting processes. The elaborate matching of all individual components to each other as well as to the machine environment is no longer necessary, nor is the time-consuming testing.

At the same time it is ensured that the specified accuracy is attained in the application (typical repeatability for an angle measuring module:  $< 56 \times 10^{-6}$  degree).

Typical applications for angle measuring modules include laser trackers for metrology, high-precision rotary tables in measuring machines, and wafer-handling machines in the electronics industry. They can also be used on machine tools where only slight loads occur,

such as on electrical discharge machines or in micro-precision manufacturing.

HEIDENHAIN will present these angle measuring modules at the Precision Fair 2014.

WWW.HEIDENHAIN.NL

# Novel ultrasonic cleaning technology

leaning with microbubbles has been used in ultrasound baths for many decades. However, for various present-day industrial processes and small structures, the ultrasound baths are not always effective enough. The main problem is that the microbubbles appear at random and therefore there is a lack of control over the cleaning process.

Microbubbles are generated by ultrasonic sound waves (frequencies > 20 kHz). In fact, it is not the ultrasound that is doing the cleaning, but the collapse of these bubbles (cavitation). The tiny bubbles collapse with huge velocity on a very small scale and are therefore ideally suited for generating large forces for cleaning. As a secondary effect, water molecules can be split, which generates highly reactive radicals that can contribute chemically to cleaning.

Bubclean – founded in 2013 as a spin-off from the University of Twente, the Netherlands – has developed a novel ultrasonic cleaning technology that gives full control over the generation of microbubbles for cleaning purposes. This allows to clean fast, controlled and efficiently on various surfaces. The technology is also suitable for enhancing sonochemical processes as well as surface treatment. Read more in the forthcoming issue of Mikroniek.

WWW.BUBCLEAN.NL

### 3D Systems acquires LayerWise

Last month, US company 3D Systems, a pioneer in 3D printing since the late 1980s, issued a press release announcing that it has acquired Belgium-based LayerWise, a leading provider of advanced direct metal 3D printing and manufacturing services. LayerWise delivers quick-turn, 3D-printed metal parts, manufactured on its own proprietary line of direct metal 3D printers, for aerospace, high-precision equipment and medical and dental customers.

Since 2008, LayerWise has designed and built its own direct metal 3D printers. Its proprietary powder-to-solid metal printers can produce functional metal parts at convincing production scale. LayerWise's direct metal printers deliver relative part density of up to 99.98% and match conventional metal mechanical properties, at substantial unit weight reduction. These capabilities have led to rapid adoption of LayerWise manufacturing services by medical device, transportation and precision equipment customers for whom weight-reduction, strength and accuracy are paramount.

WWW.3DSYSTEMS.COM WWW.LAYERWISE.COM

### **Team Netherlands scores at EuroSkills 2014**

uroSkills 2014, the largest European skills competition, took place on October 2-4 at Lille Grand Palais, France, when 450 young skilled workers from 25 countries competed over three days in 41 skills for the Best of Europe title. The event was hosted by WorldSkills France, a member of WorldSkills Europe, and the Nord-Pas de Calais region. WorldSkills Europe is a non-profit member association that promotes excellence in the field of skills and competence development. The organisation raises awareness of the importance of professional excellence and high-quality vocational education and training throughout Europe.

Thirteen Dutch participants qualified for EuroSkills 2014 in the national VakkanjerWedstrijden (Vocational Virtuoso Competitions) hosted by TechniekTalent.nu. These Vocational Virtuosos – upcoming talents within the metal, installation, electrical and refrigeration engineering sectors – participated, along with 19 other Dutch Intermediate Vocational Training talents in the EuroSkills. Team Netherlands won nine gold, two silver and two bronze medals.

The Dutch robotics pair Arjan Henst (Vessem) and Fer van Maasakkers (Westerhoven) scooped silver in Lille. Alas there was no place on the podium for the mechatronics team of Mitchel Mulder (The Hague) and Diewer van der Schoor (Delft); they did however win a medal for Excellent Craftsmanship with their high points total. At the end of November, both duos may qualify for the WorldSkills 2015 in Brazil.

With the VakkanjerWedstrijden (for engineering talent from regional training centres and companies), TechniekTalent.nu aims to contribute to the influx of well-educated craftspeople within engineering.

WWW.EUROSKILLS-TEAM.NL WWW.TECHNIEKTALENT.NU WWW.WORLDSKILLSEUROPE.ORG



■ The Dutch robotics duo. (Photo: TechniekTalent.nu/Olivier Huisman)





## **University of Huddersfield, UK**

17th-18th March 2015

#### **Conference topics:**

- Novel Manufacturing Technologies & Machine Tools
- New Developments in Measurement Techniques
- Performance Evaluation for Machine Tools & CMMs
- New Developments in Process Technology
- Roughness & Machine Tool Standards
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#### **NEWS**

## Bringing your 5-axis machine tool to the next level

A the end of September the "Bringing your 5-axis machine tool to the next level" seminar took place in Eindhoven; an initiative by IBS

Precision Engineering and Teclab, supplier of specialised engineering training courses at Intermediate Vocational Training level 4. The seminar included a number of lectures and demos, focussing particularly on the exact measurement of machine precision. The day had an international theme to it with participants from Japan, Korea, China and Canada, in addition to a guest speaker from the US, Eric Marsh, professor at Penn State University and an expert in spindle metrology.

Following the morning lecture session, it was straight to Teclab's training room for the necessary demonstrations. Teclab's two 5-axis milling machines were particularly ideal in demonstrating the subject. In-house know-how at IBS was shared by specialists Henny Spaan (CEO) and Guido Florussen (metrology expert). Emphasis rested on the nuts & bolts and progress of 5-axis machine tool metrology, as well as ISO standard improvement and performance. Specialist Alban Tilanus from Edgecam informed the participants about 5-axis machine optimisation using CAD-CAM software.

The partnership between Teclab and IBS came about earlier this year. In collaboration with Teclab, IBS carried out tests with the 'machine tool calibration probe', by which rotation axes can be measured with a high degree of accuracy. IBS' idea to organise a machine tool seminar for (inter) national customers and other interested parties was embraced by Teclab, which made its training room available and took care of the practicalities. In turn, Teclab teachers and instructors all learn about the latest in advanced measuring techniques, which they then pass on to the students.

#### WWW.IBSPE.COM

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■ Demonstration by Henny Spaan, CEO of IBS Precision Engineering. Photo: Teclab



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## Ultrasonic cleaning machines for precision optics

CM AG is a 100% subsidiary of the German Dürr Ecoclean Group, a global leader in industrial cleaning technology. UCM (Ultrasonic Cleaning Machines) stands for more than 25 years of accumulated know-how and experience in industrial precision surface cleaning, and for Swiss precision engineering and solutions to highest cleanliness standards.

UCM is a manufacturer of multi-stage immersion-type ultrasonic cleaning lines. All equipment meets the highest standards of substrate cleanliness. The sophisticated modular design allows these systems to be cost-efficient and individually adapted to any application and requirement.



In most applications these systems operate fully automatically, relying on automated loading and unloading units and an automatic robot-based movement of parts along the line. The systems are designed to meet optical industry standards. They incorporate special fixtures matched to the dimensions and properties of the parts to be cleaned. Drying is achieved by infrared light, hot-filtered air, centrifugation or vacuum. UCM AG will present ultrasonic cleaning machines for precision optics, as well as solutions for precision cleaning of implants and medical devices at the Precision Fair 2014.

WWW.UCM-AG.COM

### New release by MathWorks

This month, MathWorks, a leading developer of mathematical computing software, has launched Release 2014b including new features in MATLAB and Simulink. MATLAB is the high-level language and interactive environment for numerical computation, visualisation and programming. The new MATLAB capabilities offer a new graphics system, increased support for big data, features for packaging and sharing code, and source control integration. Simulink is the block diagram environment for multi-domain simulation and model-based design. The new features in Simulink allow for the running of faster consecutive simulations and accelerating model building.

#### WWW.MATHWORKS.COM



## 15<sup>th</sup> International Conference & Exhibition

of the European Society for Precision Engineering & Nanotechnology

Monday 1<sup>st</sup> June to Friday 5<sup>th</sup> June 2015 **Leuven, Belgium** 

#### **Conference topics:**

- Precision Mechatronic Systems and Control
- Ultra Precision Machines
- Nano & Micro Manufacturing & Assembly Processes
- Metrology
- Precision Engineering for Medical Products
- Precision Mechanics for Micro-Biology
- Renewable Energy Technologies
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#### **DSPE**

### **60 YEARS EVENT**

A special DSPE 60 Years Event is organised on the second day of the Precision Fair 2014, Thursday 13 November, 10.00-12.30 h, in Veldhoven (NL), to celebrate the 60th anniversary of DSPE.



#### **Programme**

#### Hans Krikhaar

President of DSPE and Director of Hurli

Into the future as a guild society

#### **Dick Harms**

Board member of DSPE and Director of Leidse instrumentmakers School

60 years of DSPE

#### Volkert van der Wijk

Director of Kinetic Art and researcher, Faculty of Electrical Engineering, Mathematics & Computer Science, University of Twente

'De Taaie Tiller': a machine that encourages the spectator to never give up hope

#### **Timo Overboom**

Ph.D. student, Department of Electrical Engineering, Eindhoven University of Technology (TU/e)

The innovative Ceiling Robot

INFORMATION
www.dspe.nl
www.precisiebeurs.nl



■ The Ceiling Robot is the world's first 'flying' planar motor in which a robotic platform is magnetically and contactlessly suspended underneath a ceiling. A prototype of this unique and complex mechatronic system was constructed in the TU/e research group of prof. E.A. Lomonova.

#### Award ceremonies at the Precision Fair 2014

Wednesday 12 November, 16.15 h **Ir. A. Davidson Award 2014**(young precision engineering talent)



Thursday 13 November, 16.15 h **Wim van der Hoek Award 2014** (best graduation work)



#### **TAPPING INTO EACH OTHER'S EXPERTISE**

## Schout Design for Manufacturing (DfM) – for optimising product design

A product can be considered successful when it fulfils market demands. This implies functioning well and entering the market on time, in the right numbers and for a competitive price. Schout DfM specialises in consulting and advisory services to optimise product design using the Design for Manufacturing (DfM) method, as well as in teaching the method. Clients include Philips, ASML and FEI.

ake the Model T-Ford, for example. Its functionality was valued by the public and it entered the market in sufficient amounts and at a good cost price (much lower than the selling price). The DfM method can be applied for developing such successful products. This is a product development method that ensures a smooth transition from design phase to production. The goals are cost reduction and timely market introduction. This means making the right design choices at every step in the development process, taking into account product details as well as materials and manufacturing processes (Figure 1), since every design or material choice limits the options for the

The three key criteria for every design decision in this DfM approach are (Figure 2):

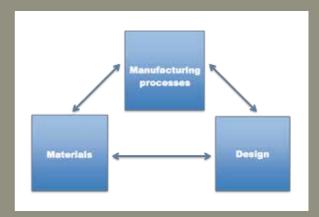
- Good product functionality.
- Total development lead-time.
- · Integral costs.

Good product functionality is always within the scope of the designer and management, but the manufacturability criteria (total lead-time and integral costs) are often forgotten or suffer from a lack of attention. Focussing the right amount of attention on these manufacturability criteria during the design process leads to making the right choices, establishing the manufacturing process and ensuring that the product is aligned to that process. This is the aim of the DfM-method.

The design of a successful product is only complete when the manufacturing process is well defined and optimised. Schout DfM offers a first-time-right approach. By estimating the effect of every design decision on total development time and integral costs, a complete design can be made instead of a 'prototype-like' design. This will making the product manufacturable afterwards.

#### Schout DfM offers:

- · Knowledge of production processes.
- Product cost calculation and optimisation.
- Assessment of suppliers and their quotations.
- Total development time calculations and optimisation.
- Teaching of the DfM approach. ■



Project target:	DfM	matrix		
Evaluation Criteria	Design alternatives			
	Alternative A	Alternative B	Alternative C	-
Requirements	++			
Total throughput time (still needed)	-	++		0
Integral costs (from now)	+	+		旗



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The LiS is founded in 1901 by the famous scientist prof. Kamerlingh Onnes. Nowadays the LiS is a modern school for vocational training on level 4 MBO-BOL. The school encourages establishing projects in close cooperation with contractors and scientific institutes, allowing for high level "real life" work.

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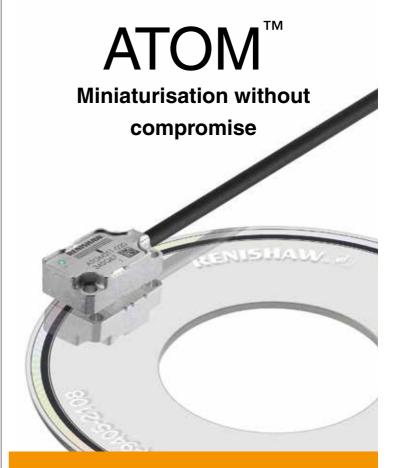
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#### **New! Miniature optical encoder system**

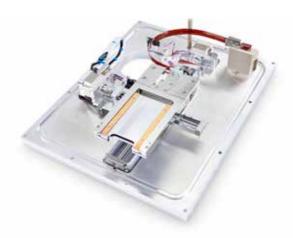
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