Micro-abrasive blasting

SENTER IOP

Micro machining using air jet technology

Subject:
Erosion of a mask-protected substrate by a high-velocity powder beam

Purpose:
To increase the capability, reliability and fundamental understanding of the process of micro-abrasive blasting for a wide sustainable introduction in the industrial environment
To provide a more cost-effective alternative for chemical etching, laser machining and conventional micro-cutting operations

Market application:
Biomedical, microfluidics, fuel cell technology, photovoltaic technology used in solar energy

Potential use:
Generating fast and inexpensive three-dimensional microstructures, with a minimum of 30 µm in width and an accuracy down to 1 µm in depth

Research period: March 2001 - March 2005

Total budget: EUR 362,600, of which EUR 287,000 funded by IOP

Research institutes: Delft University of Technology, Energy Research Centre of the Netherlands

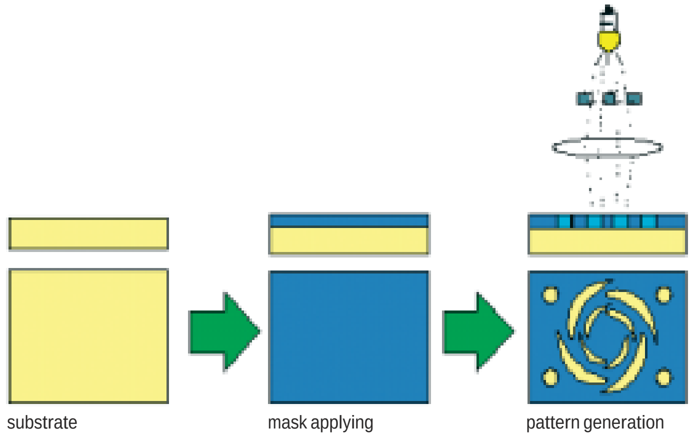
Project leader: André Hoogstrate

Since 2001, two Dutch institutes have been working in close cooperation on research and further development of micro-abrasive blasting. This process, in which sharp small particles accelerate in an air jet and bombard a brittle surface to generate microstructures, was developed more than 20 years ago by Philips. At the time, the intention was to use the technique for the production of television flat screens. Public knowledge on the subject is scarce, which motivates the project team to study and enhance the capability, reliability and fundamental understanding of the process. 'We want to make this available to small and medium industries, as it is accurate and inexpensive and can be used on a great diversity of products.'

'The principle of micro air blasting is not new', says André Hoogstrate, Assistant Professor at the Production Technology and Organisation section of the Faculty of Design, Engineering and Production at the Delft University of Technology. 'A lot of research has been done by Philips, and all of the big Japanese electronics manufacturers are using it, but little is known in the public domain.' Together with the Energy Research Centre of the Netherlands (ECN), a proposal was written for funding by the IOP Precision Technology. ECN's Technology Services & Consultancy department, which designs, engineers and realises experimental installations and prototypes, had worked on abrasive blazing in an earlier project with the Philips Centre for Industrial

Project team from left to right: Bernard Karpuschewski, André Hoogstrate, Bas Wardenaar (ECN), Marcel Achtsnick. Jaco Saurwalt (ECN) is absent

Technology (CFT). André Hoogstrate: ‘For me it is a logical next step, because my PhD study centred on abrasive water jet cutting. Delft has a strong tradition in the engineering and development of production machines, and at PTO we are extremely interested in research and development with real production circumstances in mind.’
Possible applications for this technique are the production of plasma displays and lab-on-chips used in biomedical analysis. ECN wants to use it in fuel cell technology to enhance the surface, in micro reactors and in the production of solar cells when making grooves in thin-film photovoltaic material.



Process steps of micro-abrasive blasting

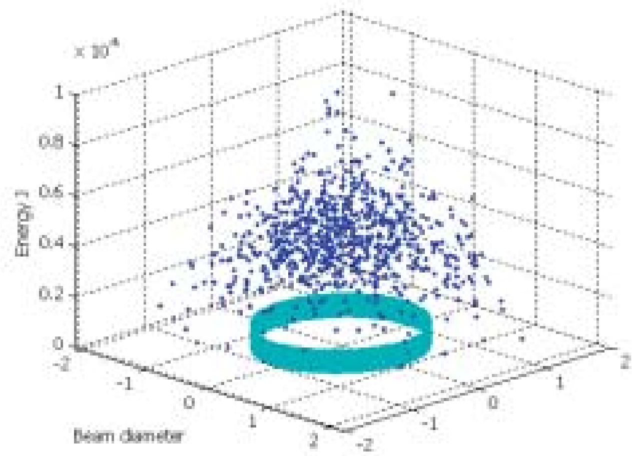
Air jet machine

Micro-abrasive blasting is becoming an important technique to produce optical, electronic and precision mechanical equipment. The process is based on the erosion of a mask-protected brittle substrate by a high-velocity particle beam. ‘Because otherwise the entire surface is exposed to the particle beam, the substrate has to be shielded by a wear-resistant mask that is patterned with the desired contour’, explains André Hoogstrate. The mask determines the accuracy of the plane dimensions of the desired structure. To control the third dimension of the structure, its depth, the surface has to be covered homogeneously with abrasive particles. The scan strategy and the particle beam profile of the nozzle are also of great importance. ‘The beam needs a uniform movement and the powder flow needs to be constant. That is why we have decided on a moving work piece and a fixed nozzle instead of a nozzle scanning the surface.’ During blasting, the work piece is exposed to an air jet with a pressure between 0.2 and 0.8 MPa and hard angular particles with a diameter between 10 and 100 µm. The nozzle is designed at the university and the particles reach a velocity between 180 and 330 m/sec. The last process step contains mask removal and cleaning. André Hoogstrate: ‘Further research is needed on all of these areas.’ In order to do this, a powerful air jet machine has been built by ECN, with a carefully closed and exhausted machining area.

Air jet machine built by ECN

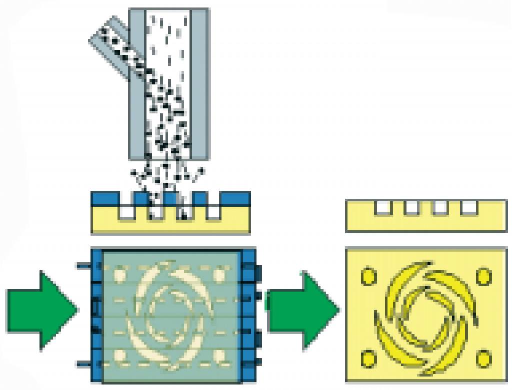
Testing, testing, testing

‘The interaction of the particles, which are blasted at high speed at the surface of the work piece, and the surface itself are our first subject of interest. Silicon, glass and ceramics are brittle and the bombardment with particles causes them to crack, thereby removing material’, explains André Hoogstrate. A broad range of particle materials and work piece materials will be studied.
The masks used to protect the underlying material should be



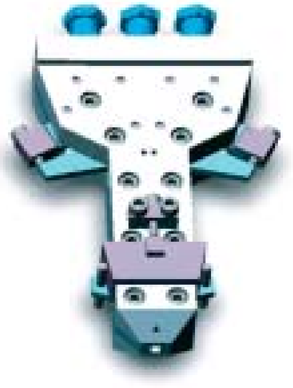
Model to calculate the erosion rate, using a combination of a deterministic method to model the single particle impact and the stochastic Monte Carlo method to simulate multiple impacts

elastic, so that they do not crack under the particle flow. That is the second research area: which masking technique gives the best results in which application area. Three groups of materials are being tested: ductile materials such as metals, elastic materials such as polymer foils, and photo resists as used in the IC industry. Important factors are wear resistance and pattern transfer accuracy. The results are compared in terms of erosion resistance and transfer accuracy of the pattern. ‘We find that each type of mask material has its own economic and technological relevance.’ Thirdly, several factors influence the powder flow, such as which powder is used, how the powder is added to the air beam, the acceleration, the distance between nozzle and surface, and the angle between beam and surface. ‘What is the relationship between the beam structure and the accuracy of the process that can be reached? We are looking in particular into the smallest structures we can manage. Our aim is to reach an aspect ratio depth versus diameter greater than 10.’
The scanning strategy (i.e. the way the work piece moves under



MAB mask removal

the nozzle) and mask removal and cleaning are the final important factors for research.
The IOP project consists of four phases, lasting roughly one year each. André Hoogstrate: 'The first year ECN built the air jet machine, while we did research on modelling and literature study.' After that the nozzle was redesigned to reach a higher velocity of the air beam. 'We found that the nozzle geometry is of great importance for the accuracy and the efficiency of the machining process. We have prototypes made by ECN, but currently they have a very short life expectancy. Further development should make the nozzle more reliable, robust and less prone to wear.'
Two years into the project, the experiments on masking materials are in full swing. The final year will be spent on documenting the findings and working on industrial cases.



Nozzle used in micro-abrasive blasting

Industrial involvement

The research at the Delft University of Technology is carried out in close cooperation with ECN Technology Services & Consultancy, the institute's technical support and development section. Jaco Saurwalt, manager of the department: 'Because we also work for outside customers, we knew about the development of micro-abrasive blasting at Philips. At ECN we have several applications where we hope to use the process, so we were interested to get involved in the project.' He is very satisfied with the cooperation and the way the work is divided between the two institutes. 'Our strong points are engineering of prototypes, combined with a practical view on relevance of the research done with it. In the project's next phase we will do in-house tests on usability in the production of solar and fuel cells.'
In order to stimulate knowledge transfer between research institutes and companies, the Senter IOP programmes offer interested companies the possibility of joining an industrial user group. This is the most direct means of knowledge transfer and implies close involvement in one or more projects. Louwers Glass and Ceramic Technologies specialises in the development and production of technical glass and advanced ceramic components. These are used in, for instance, copiers and printers, the semiconductor industry, analytical equipment and laboratory set-ups. In order to meet the requirements of customers in a wide range of industries, production is tailor-made. 'I read a publication about this research taking off and contacted André Hoogstrate. For us this is the perfect opportunity to work with both the university and ECN', says Jan Vervest, Technical Director. For Louwers, the most promising application of micro-abrasive blasting is in the production of lab-on-chips: 'These are glass plates, the size of an old-fashioned slide, with several micro channel structures, buried in the surface. It is used to analyse materials such as proteins, DNA or blood in very small quantities. Currently the micro channels are etched into the surface, but this is an expensive and environmentally unfriendly operation. We are extremely hopeful that we will be able to use micro-abrasive blasting within a year.'
As a member of the industrial user group, he has regular contact with the project team. 'For us this research is extremely important! We have customers who I cannot help at the moment. We are a small company with 60 employees and cannot afford this type of Research & Development. It is in our own interest to invest time and products to improve the knowledge about this process. And above all: we enjoy working together.'

Members of the industrial user group:

Energy Research Centre of the Netherlands (ECN)
Louwers Glass and Ceramic Technologies
Micronit Microfluidics
Philips Centre for Industrial Technology (CFT)
TNO Industrial Technology
University of Twente

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IOP Precision Technology

Precision technology is needed when products are to be built with high demands on the accuracy of their shape or size, and also when products or parts need to be positioned with high precision. Examples are laptop computers (especially data storage), cd players, dvd recorders, optical and medical instruments, space engineering and mobile phones. Further miniaturizing makes it impossible to build these functions in a purely mechanical way; a multidisciplinary systems approach is needed.

The IOP program in this field of technology started in 1999. Currently 16 projects have received grants for research on one of three central themes.

- In the field of systems-oriented design, subjects for research include design topics such as piezo actuators, precision movements in vacuum and high algorithmic mechanics. These topics all have movements with great speed and/or high precision.
- The second theme covers the constant raising of the precision of production processes by improving process control or using new production techniques. Not only conventional methods like precision machining are included but also new technologies such as lithographic etching, the use of laser or X-ray bundles and chemical vapour deposition.
- Micro system technology is the third area in this IOP program. Sensors and actuators coupled with a control system are of interest here. Examples are wet chemical etching and packaging of MST devices like an optical chip to a glass fibre.

Further questions on IOP Precision Technology

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IOP

An innovation-driven research program (IOP) awards grants to innovative technological research projects at universities and other non-profit research organizations. Through this approach, the Dutch government wants to make the research world more accessible to the business community and improve and intensify contacts between the two. A precondition is that projects must fit in with the long-term research needs of the business community. The program stimulates interaction between the research world and business community through the latter's involvement in research projects, knowledge transfer and network activities. Major efforts are made to ensure that each completed program leads to lasting co-operation between the Dutch research institutes and business community with a view to fulfilling technological developments.

Business participation

In order to build a bridge between research and industry, an IOP provides opportunities for companies to take part in innovative research. The possibilities are as follows:

- Joining an industrial user group.
  As the most direct means of knowledge transfer, joining an industrial user group means close involvement in one or more projects. The business is kept up to date on the latest research developments, and, in some cases, can contribute practical experience that steers the course of the research work.
- Taking over patents or licenses that have resulted from IOP projects at universities and non-profit research institutes.
- Providing work experience placements for researchers, so that new know-how is passed on to the business quickly and can be tested in and adapted to practical conditions.

Colophon

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The micro-abrasive blasting project is conducted in the Faculty of Design, Engineering and Production of the Delft University of Technology in close cooperation with the Energy Research Centre of the Netherlands (ECN).

The Energy Research Centre of the Netherlands (ECN) develops technologies for a safe, efficient, reliable and environmentally benign energy supply.

Ministry of Economic Affairs