



IOP
Precision Technology

SAW motor

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Using surface acoustic waves for actuation

Subject:

Positioning by means of surface acoustic waves

Purpose:

To obtain insight into the opportunities for using surface acoustic waves as an actuation principle, resulting in knowledge on various design parameters

Market application:

Electron microscope, wafer stepper, space applications, pharmaceutical research, eventually mass products such as CD players

Potential use:

Situations where vacuum conditions are required
Situations where electric motors cannot be used because of their electromagnetic fields or where the motor position needs to remain fixed without external power supply

Research period: January 2001 – January 2005

Total budget: EUR 258,000, funded by IOP

Research institute: Drebbe Institute of Mechatronics (University of Twente), Philips Centre for Industrial Technology

Project leader: Peter Breedveld

In close cooperation with the Philips Centre for Industrial Technology (CFT), researchers at the University of Twente are looking into the feasibility of positioning by means of surface acoustic waves (SAW). The SAW principle has been used in sensors and filters for decades, but until now little research has been done worldwide into using it for positioning purposes. The SAW motor, as the project is called, is very promising in the long term in applications where there is a need to work in a vacuum (in space, for instance) because no lubrication is necessary. Another promising area of application is in situations where the use of an electromotor would create disturbances because of the motor's magnetic fields. 'For the SAW motor to be applied in consumer products, we have to wait until it can be mass-manufactured.'

'In this IOP project we study the generation of motions by piezoelectric ultrasonic motors', says Peter Breedveld, associate professor in the Control Engineering Group of the Drebbe Institute in Enschede. 'The term "acoustic" is misleading. It refers to the wave type rather than the wave frequency. We work with frequencies of around 2 MHz, which is not within the range of human hearing.'

The purpose of the SAW motor is to bring a slider, which rests on top of a surface, into movement by generating waves in the surface, thereby changing electrical energy into mechanical energy. 'Normally, electric motors based on the Lorentz effect are

Project team from the University of Twente. From left to right: Herman Soemers, Philippus Feenstra, Peter Breedveld, Job van Amerongen. Marc Vermeulen and Felix Peeters (Philips CFT) are absent.



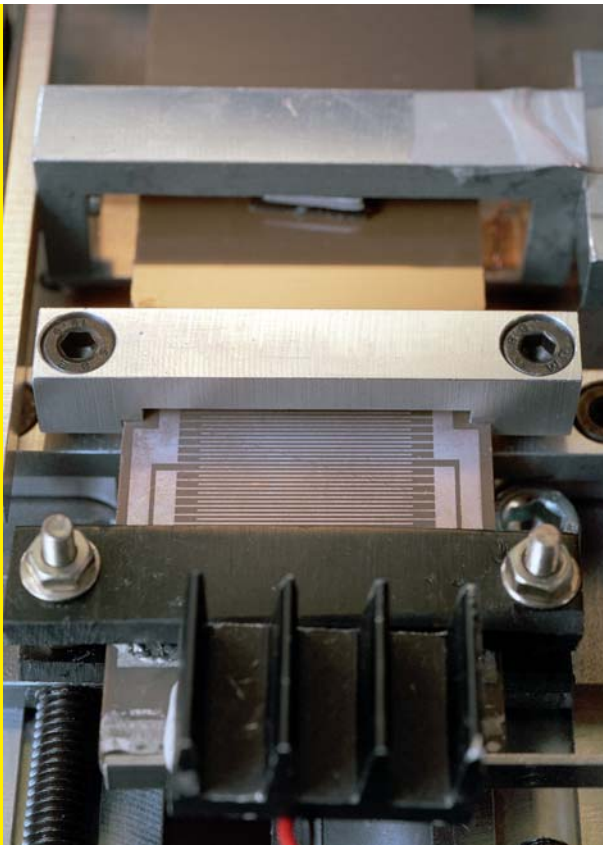
used for this purpose, but these have certain disadvantages’, explains Peter Breedveld. ‘The electromagnetic fields are not suitable for a number of applications, because these fields can be a source of disturbance.’ He cites examples such as an electron microscope, where the object under study needs to be positioned accurately. Another application is lithography, where the wafers have to be moved with high precision. ‘A second disadvantage of an electric motor is that a rotor or slider moves easily, for instance under the influence of gravity, when the motor is not activated. This means that to block the rotor or slider at a certain position, the motor needs to be activated all the time. This is not the case with a motor based on SAW, because the slider will “stick” to the surface when the motor is not powered, due to the rather large static normal force that is required for the SAW actuation.’ Last but not least, lubrication is not necessary when using SAW as a motion principle, which makes it suitable for vacuum applications - in space for instance - or for use in environments where pollution caused by lubricants is unwanted, as in pharmaceutical research.

Principle of operation

The actuation principle of an SAW actuator is based on generating Rayleigh waves through an elastic solid medium, called a stator. These travelling waves cause particles at the surface to move elliptically. A ‘slider’ placed on a number of wave tops experiences a tangent force, which causes it to move. Peter Breedveld adds: ‘By generating waves from two opposite directions, the slider can move both ways.’

The stator is made of piezoelectric material with interdigital transducers (IDTs) at both ends, which convert electrical energy to

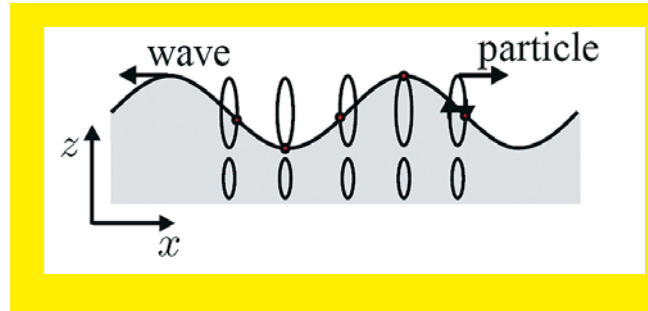
Detail of one end of the stator. The interdigital transducers are visible in the middle



surface acoustic waves. An IDT consists of a galvanic finger-shaped pattern applied in a layer of a few μm through a lithographic process.

To make effective contact between the slider and stator surface possible, the slider - which is made of silicon - has a surface with small hemispheres to prevent an air film and thus generate sufficient traction.

Elliptical motion of the particles at the surface and the tangent force at the wave top



Verifying the model

The force with which the slider is pushed to the stator is an important design parameter. ‘A first set-up developed at Philips CFT, acting as a project partner, was based on a sandwich construction of a stator with a slider on top and a slider at the bottom, where the mechanical preload was applied by means of a spring’, says Philippus Feenstra, the PhD student working on the project. ‘I am currently researching the use of a magnetic field to generate the preload. In the long run, another solution will have to be found because one of the advantages of the SAW motor is that it does not generate electromagnetic fields.’

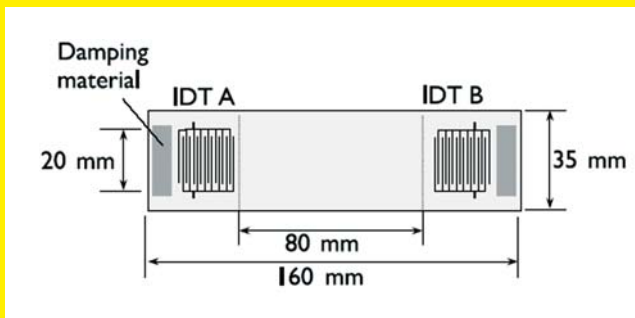
Future research will also address the modelling of contact behaviour, the behaviour of the surface acoustic waves in different stator materials, and the choice of material for the slider. ‘I now understand how the principle works’, says Philippus Feenstra, ‘and the set-up is ready, so we can start validating the model on the basis of measurements. My PhD thesis will contain design recipes such as the size of the IDTs and the power needed.’ In Feenstra’s opinion, possible follow-up developments in terms of preparing the principle for specific applications should be carried out at a development centre, not in a research project like this one.

Project partner

Marc Vermeulen is a mechatronics designer at Philips CFT. ‘Some of our activities are based on the development of new technologies. We use the knowledge in various design and development projects for other Philips companies and third parties,’ he explains. ‘My colleague Rien Koster, now retired, came with the initiative to study SAW in piezoelectric materials as a means of actuation. This was inspired by the results of a two-student MSc project, supervised by Peter Breedveld, to compile an inventory of actuation principles for linear motion. In 2000, Philips CFT started with preliminary MSc research by another University of Twente student to find out what competencies were needed to construct a motor based on this principle. Rien Koster was also professor at the University of Twente at the time, and he

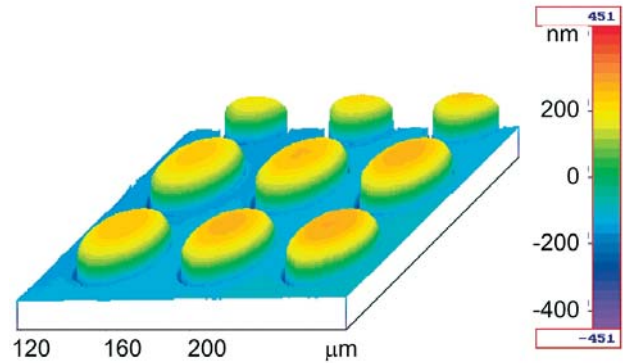
suggested that Peter Breedveld submit an IOP project proposal to parallel the development activities at Philips CFT. The PhD student who started working on this project, Philippus Feenstra, frequently visited Philips CFT to get up to speed and become acquainted with the knowledge already available there. 'At Philips CFT they can manufacture the sliders and the stators, being experienced in the use of the piezoelectric material PZT', he says.

The position of the interdigital transducers (IDTs) at both ends of the stator



As manager of the Advanced Development department, he is responsible for new technologies and their use in future products. 'I act as chairman because I am a member of the programme committee of IOP Precision Technology', he says. 'The committee regularly organises a conference where universities and companies can team up on potentially interesting topics.' The resulting research proposals are judged for their industrial

Small hemispheres at the bottom of a silicon slider



'At the University of Twente, I study all the design aspects. I want to know exactly how this method of transduction works.'

Marc Vermeulen is enthusiastic about the value of joining an industrial user group: 'It gives me the opportunity to react to the findings at the university and to help develop ideas concerning problems that the researchers encounter.' What will Philips CFT do with the results of a project like this? 'We are currently looking around for high-tech pilot projects where the principle can be used, e.g. in electron microscopes. For applications in consumer products, such as using the SAW motor to open and close the drawer in a CD player, we will have to wait until the motor is developed further and can be mass-manufactured in a cost-effective way. Right now this would be too expensive.'

Industrial involvement

In order to encourage knowledge transfer between research institutes and companies, industrial user groups are formed with interested companies. 'At the beginning of our project we attended a conference organised by Senter where we were invited to explain our research plans to the industry', says Peter Breedveld. 'We were impressed by the number of people attending our presentation, including representatives from several companies we had not had contact with previously. In fact, this generated significant added value, and we were able to constitute a varied industrial user group. It has had a great impact on our ideas for possible applications of the SAW motor.' In hindsight, the only disadvantage of recruiting in this way is that there is currently little contribution from a theoretical background. 'It would have been good to invite someone with theoretical knowledge on surface acoustic waves.'

Sjef van Gastel from Assembléon is chairman of the industrial user group. Assembléon, a Philips company, designs and builds pick-and-place machines for surface-mounted devices such as printed circuit boards in mobile phones, televisions or CD players.

relevance and support. By working in this way, every subsidised project is ensured of early feedback from the industry. 'Members of the industrial user group can influence the direction that the research takes.' Another advantage of joining an industrial user group is that members get to know new companies: 'We try to meet at different locations and learn more about the other members. Last year we visited the NMi Van Swinden Laboratory and had a meeting at CFT. I think that's a big plus!'

Members of the industrial user group

- ASML
- Assembléon Netherlands
- Janssen Precision Engineering
- Multin Design & Development
- NMi Van Swinden Laboratory
- Stork Product Engineering
- Philips Centre for Industrial Technology (CFT)
- TNO TPD
- University of Nijmegen

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Project team for SAW motor

- Job van Amerongen
- Peter Breedveld
- Philippus Feenstra
- Felix Peeters (Philips CFT)
- Herman Soemers
- Marc Vermeulen (Philips CFT)

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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Senter is an agency of the Ministry of Economic Affairs



The University of Twente is an entrepreneurial research university. It was founded in 1961 and offers education and research in areas ranging from public policy studies and applied physics to biomedical technology.



Ministry of Economic Affairs

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