

Piezo news

The newsletter of the Piezo Institute



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Piezo 2009

1 – 4 March 2009

Belvedere Hotel, Zakopane, Poland

Piezo 2009 will allow academia and industry to discover the latest developments in piezoelectric materials and devices. It will cover a diverse range of topics including energy harvesting, thin films and lead free materials.

Piezo 2009 will be held in Zakopane, near the Tatra Mountains in southern Poland. The location provides easy access to beautiful mountain trails, and an opportunity to enjoy winter sports.

The conference programme includes presentations and tutorials from international experts in piezoelectric materials and devices, including:

- Susan Trolier-McKinstry, Penn State University, USA
- Satoshi Wada, University of Yamanashi, Japan
- Carsten Schuh, Corporate Technology, Siemens AG, Germany
- Eberhard Hennig, PI Ceramics, Germany
- Richard Greaves, MEGGITT Sensors, UK & Switzerland
- Dragan Damjanovic, EPFL, Switzerland
- Andrzej Nowicki, IPPT, Poland
- Marc Lethiecq, LUSI, France
- Tomasz Zawada, Insensor A/S, Denmark
- Franck Levassort, University of Tours, France
- Barbara Malic, Jožef Stefan Institute, Slovenia
- Robert Dorey, Cranfield University, UK
- Takaaki Tsurumi, Tokyo Institute of Technology, Japan

Register at www.piezo2009.com



The founding members of the Piezo Institute are:

Industrial Ferroperm Piezoceramics (Denmark) • Siemens Corporate Technology – Erlangen (Germany) • Centro Ricerche Fiat (Italy)

Metrology and standards National Physical Laboratory (UK)

Academic University of Tours – LUSI (France) • Université François Rabelais – CNRS (France) • Laboratoire de Céramique, Ecole Polytechnique Fédérale de Lausanne – EPFL (Switzerland) • Jozef Stefan Institute (Slovenia) • Cranfield University (UK) • Instituto de Ciencia de Materiales de Madrid, Consejo Superior de Investigaciones Científicas (Spain) • Centrale Recherche SA, Ecole Centrale Paris (France) • Institute of Solid State Physics, University of Latvia

For more information please visit www.piezoinstitute.com

From the editor

2009 is the year that the Piezo Institute will really take its place on Europe's academic and industrial landscape. We are welcoming expert speakers and delegates from across the world to our flagship Piezo 2009 conference in Poland in March, and we are launching our industrial training and education. Later this year we will publish the Piezo Institute's comprehensive survey of global piezo research.

There couldn't be a better time to start a new institute, with research firm iRAP predicting double digit growth in the market for piezo devices over the next five years. We report in this edition of Piezo News on the novel application of piezo fibres in sports equipment, and the use of a piezo probe to monitor patients in a coma or under anaesthetic.

From the UK comes news of an exciting new centre for vehicle health monitoring, and in our technical

focus we report from Spain on an environmentally-friendly technique to limit lead loss in the production of piezo thin films.

It is ski season in the northern hemisphere, and many of you will have seen Head's new piezo-enabled skis. We have a story about the application of piezo technologies in sport.

I hope you enjoy this edition of Piezo News. We welcome suggestions for stories, articles and features, so please send us your ideas.

Happy New Year!

Markys Cain
Editor in chief



NPL

Robust growth for piezo device market

The global market for new piezoelectric devices will see robust double digit growth during the next five years, according to a report from Innovative Research and Products (iRAP), www.innoresearch.net.

Analyst Babu Lal Gupta said the global market for generic piezoelectric devices was expected to reach US\$19.5bn by 2012.

Information technology and robots are expected to form the largest market (31.7%), followed by semiconductor manufacturing and precision machines (18.6%), sonar (12.5%), and biomedical markets (11.1%). Ecology and energy harvesting will account for 7% of the global market for piezoelectric devices, with sensors and accelerators taking 5.8%.

New devices such as piezoelectric generators will see the highest growth, estimated to be 51.5% annually, Gupta said. Other fast-growing sectors include ceramic resonators.

Growth in the devices market will continue to be driven by increasing demand for applications including autofocus mechanisms in camera phones, energy harvesting devices, life science and medical technology, optics, photonics, nano-metrology, robots and toys.

There should also be significant growth opportunities for piezoelectric actuators in the biomedical, semiconductor, data storage, aerospace and automation arenas during the next few years, Gupta's report said.

Mobile phones, digital cameras, laptops accounted for \$2.44bn or about 23% of the total market for piezoelectric devices in 2007, and was predicted to reach \$5.29bn by 2012.



Sam Ogden/ Science Photo Library

Robots are expected to be a large proportion of the piezo market by 2012. This robotic flower, the Cobra Orchid, contains heat sensors that detect the presence of humans and reacts by moving its stem in a snake-like manner.

It's been a busy year for **Wanda Wolny**, the dynamic R&D managing director of piezoceramic materials manufacturer Ferroperm. She was involved in Ferroperm's acquisition by Meggitt, and still found time to develop the new Piezo Institute out of the EC-funded MIND research network.

Piezo News caught up with Wanda as she prepared to attend the IEEE International Ultrasonics Symposium in Beijing.

Tell us about the merger

It came at exactly the right time. We were doing perfectly well as an SME supplying a specialist product in small quantities. But we had ambitions to become a global niche supplier that could meet the fast-growing demands of new markets such as medical imaging and industrial monitoring systems. Our challenge was to produce much larger quantities at a lower price without losing quality. Ferroperm on its own wasn't big enough to be seen as a reliable supplier by very large customers. These issues were resolved by the merger.

"We had ambitions to become a global niche supplier. Our challenge was to produce larger quantities without losing quality."

How was your first year in the Meggitt family?

It's been a very welcome and successful partnership. A year ago we were an independent company and now we're part of an international aerospace, defence and performance sensors group. What matters is that we're still a world leader in the development of piezo materials for specialist sensor applications in vibration, pressure, underwater acoustics and medical ultrasound.

Did you have concerns about losing your independence?

Although we're 100% owned by Meggitt, we remain a Danish company. I was involved at each stage of the negotiations, and from the beginning it was clear Meggitt was interested in Ferroperm's strategic fit and its long-term potential. The aim was for Ferroperm to enhance Meggitt's ability to produce cutting edge sensor technologies, and by combining our strengths that's exactly what we're doing.

What was your customers' reaction to the merger?

Ferroperm is judged on its quality, performance and delivery, and that hasn't been affected. Customers now consider us to be a more serious partner and supplier.

What has been the impact of the global economic crisis?

The market has slowed a little, but we're still increasing production. We made two million components in the last 12 months, and we've started developing more products for integrated sensor networks. We're looking more closely at medical markets, particularly diagnostic, therapeutic and cosmetic devices, including some very interesting ultrasound technologies that rejuvenate aging skin by boosting its collagen content.

Energy harvesting is another very large new market. We can help to replace batteries by deploying sensors based on thick film piezo technologies. For example, Ferroperm ceramics are being used in a heart function sensor which harvests energy from the body's own vibration and heat and then uses this energy to transmit data to a monitoring base station.

How do you propose to compete with emerging low-cost suppliers of piezoceramics?

The low-cost competition isn't a threat. We can't compete on price, but we can compete on quality, and that puts us into a different market. The developers of sophisticated sensor systems need piezoceramics that they can rely on, and they can't get this from the cheaper manufacturers.

"The low-cost competition isn't a threat."

Tell us about your experience of joint European research

I've been doing research collaboration since the 1990s, and we've all learned a lot along the way. The European Commission has learned to do more than just hand out money – it is getting better at demanding tangible results and impact. This has made the process more bureaucratic, but that was necessary because despite increased integration we are still a collection of very diverse countries.

I am still sometimes surprised at how different we all are. What we have learned to do is harness these differences to introduce new angles into scientific research. What everybody has to recognise is that their own approach might be different, but that doesn't make it better.

"The European Commission is getting better at demanding results and impact."

What challenges have you faced in setting up the Piezo Institute?

Every country and every organisation has its own scientific, political and legal policies; so every partner has its own challenges to overcome. It takes a great deal of patience, combined with a commitment to making it happen and a belief that the result will make all the effort worthwhile.

Because most of us in the MIND Network have been working together for a long time, we can talk at a very personal level. This lets us focus on the advantages and benefits rather than the problems.

Wanda Wolny is the R&D managing director of Ferroperm, and a founding member of the Piezo Institute

Monitoring coma with a piezo probe

A piezo probe that measures tiny eye movements can be used to monitor coma patients and identify the likelihood of their regaining consciousness. The eye-monitoring piezo technology can also help anaesthetists to monitor patients undergoing surgery.

A person's state of consciousness can be detected by the tiny involuntary tremor of their eyes – known as ocular microtremor (OMT). It is constant in healthy people at a frequency around 80 Hz.

OMT slows when people go into a coma but rises again if they are likely to regain consciousness. This gives it excellent potential as a diagnostic and prognostic tool. Doctors say only piezo technology has sufficiently high resolution to monitor OMT accurately.

Another OMT application is in surgery, where it can help anaesthetists to maintain patients at the right level of unconsciousness.

“OMT's relationship with consciousness is not widely appreciated because the microtremor is so difficult to measure,” says Dr Gerard Boyle, a medical physicist at St James' Hospital in Dublin. “The amplitude is tiny – just one micrometre – so piezo is the only system with high enough resolution to gather clinical data.”

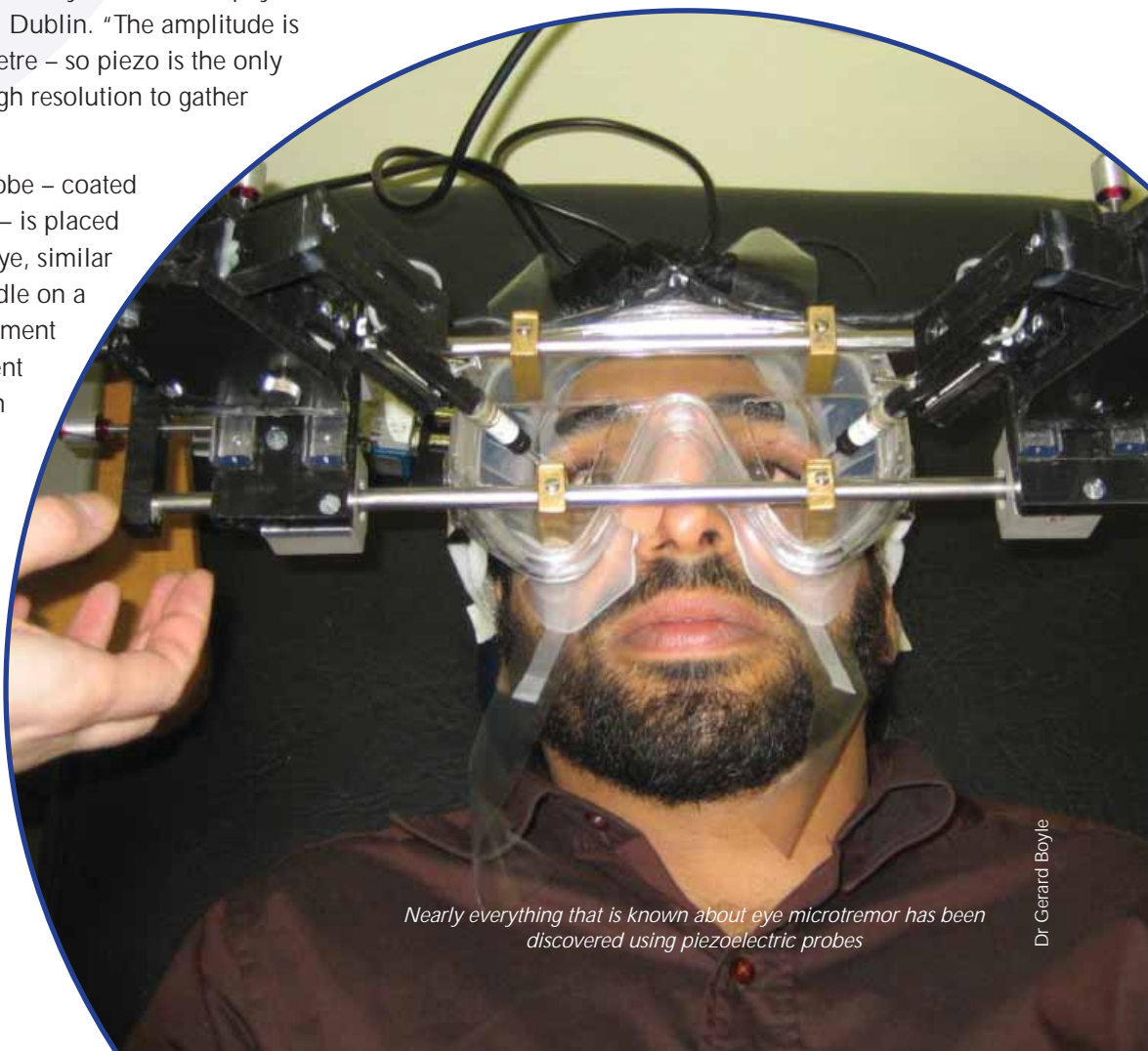
The tip of the piezo probe – coated in silicone for comfort – is placed onto the white of the eye, similar to the placing of a needle on a record. The eye's movement generates a small current that can give resolution to 20 nm.

Dr Boyle's group is also investigating light scattering and other non-contact methods to measure OMT, but he says

“as yet other techniques don't match the sensitivity to movement that we can get from piezo – nearly everything that's known about OMT has been discovered using piezoelectric probes”.

OMT and consciousness

Eye muscles are controlled by part of the brainstem located near the centres responsible for consciousness and alertness. Anything that changes a person's level of alertness changes their OMT rate.



Nearly everything that is known about eye microtremor has been discovered using piezoelectric probes

Dr Gerard Boyle

New member profile: IPPT in Poland

The Piezo Institute has a vital role in the education and training of European piezo scientists, technologists and engineers for the future, says new member Prof Andrzej Nowicki at the Institute of Fundamental Technological Research.

IPPT, part of the Polish Academy of Sciences in Warsaw, recently became a Contributing Associated Member of the Piezo Institute. Nowicki says the institute enables more movement of researchers across Europe and stimulates collaboration between academic groups.

"The most important benefit is the opportunity it gives the next generation of researchers to work and study at different European centres of excellence," he says. Three young researchers from Ferroperm recently spent three days in an IPPT lab learning to validate quality of transducers. "This experience will demonstrate how rewarding a career in piezo materials research and application can be – and it will help Europe to develop the piezo skills we need for the future."

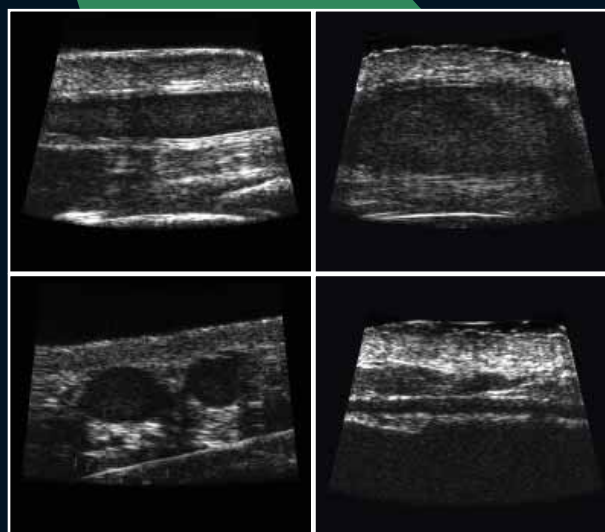
Prof Nowicki and IPPT already have valuable collaborations underway with Piezo Institute members.

A new thick film ceramic developed by Ferroperm for high-frequency medical imaging is being validated by IPPT for different applications. "We are a natural partner for developers of piezo materials," Nowicki says. "We are able to test and apply new materials to different applications before they go on to market."

IPPT is also working with Piezo Institute founding members Prof Marc Lethiecq at the University of Tours and Prof Nava Setter at EPFL, on electrical characterisation of high-frequency thick films.

The new high frequency ceramics, coupled with applications research by Piezo Institute partners, is enabling high resolution ultrasound imaging of skin and eyes to a depth up to 6 mm and resolution between 50 and 100 micrometres.

"We're getting a new view of tiny cancerous skin lesions or other dermatological diseases, and a whole new technique for medical examination of the eye," Nowicki says. "This would not be possible without the Piezo Institute."



Images taken with a device using thick film transducers developed by Ferroperm. Clockwise from top left: bloodcells in flowing blood; vein in hand; vessel fingertip; section of two vessels in a hand

Prof Andrzej Nowicki is a Professor at the Polish Academy of Science, head of the Ultrasound Department, and the Deputy Director of Research for the Institute of Fundamental Technological Research.



He is an Honorary Professor at Drexel University's Biomedical Ultrasound Research and Education Centre.

Prof Nowicki is active in medical ultrasound, cardiac imaging, transcranial and tissue flow Doppler, and high frequency ultrasonic imaging. He has published over 120 scientific papers and is author of four books on ultrasonic medical imaging and Doppler. Prof Nowicki is a Corresponding Member of Polish Academy of Sciences, Fellow of the Polish Engineering Academy and President of the Polish Ultrasound Society.

High-tech health checks

An ambitious new vehicle health research facility has been launched at Cranfield University with funding from some of Europe's biggest engineering companies.

The multi-million pound Integrated Vehicle Health Management (IVHM) Centre, the first of its kind, will lead new research in vehicle condition monitoring and management for aircraft, ships, high-speed trains and high-performance cars. Future energy applications include the monitoring of gas turbines and machinery generating power from natural resources.

IVHM works through a distributed network of sensors including thermocouples, transducers and accelerometers measuring temperature, pressure and vibration. Data about the condition of a vehicle's components and subsystems is used to assess the vehicle's health and predict its future life and possible deterioration.

IVHM aims to avoid potential component malfunctions, reduce operating costs, increase competitiveness and enable companies to better assess the effectiveness of their fleets.

"We are developing the ability to do a total health check on high-value technology assets and complex vehicles such as ships and aircraft," said IVHM Centre director Prof Ian Jennions.

The centre features an electronics laboratory, experimental facilities and an analysis centre with space for industrial partners to join research projects. This makes it easier to transfer technology back into industry, says Jennions.

Connectivity

The centre connects Cranfield's laboratories to partner facilities across the globe through direct high-speed

online links. Jennions stresses the importance of global communication and connectivity in IVHM, something already demonstrated with live simultaneous online data transfers from laboratories in the US and Australia.

"We don't need to repeat a test which somebody else is doing, but we do want to be able to access and analyse their data," he says. During a recent demonstration, a fuel rig was installed in St Louis (US) with an accelerometer monitoring the opening and closing of a fuel valve. The signal was streamed to Cranfield with live video of the process, enabling remote condition monitoring from the UK of an industrial process on the other side of the Atlantic.

The IVHM Centre was initiated by Cranfield and Boeing with a £3m investment from the East of England Development Agency and £500,000 from the Engineering and Physical Sciences Research Council. Industrial partners, which have committed £1m each over five years, include Boeing, BAE Systems, Rolls-Royce, Thales and Meggitt.

A Rolls-Royce TP400-D6 turboprop for military transport aircraft



The location of the Integrated Vehicle Health Management Centre at Cranfield, a founding member of the Piezo Institute, gives it access to world-leading research into new sensors based on piezoelectric research and technology. Expertise in integration and structuring of piezo materials will provide opportunities for new designs and capabilities in sensor technology.

Avoiding PbO-excess in lead-based ferroelectric films

Piezo Institute researchers have developed an environmentally-friendly technique, PCSD, to minimise lead loss in the production of piezoceramic thin films.

Lead is used in piezoelectric compounds because it results in high spontaneous polarisation and electromechanical activity. However, recent European Directives promote the production of environmentally-friendly piezoceramics, where the use of lead is minimised.

Developing lead-free piezoceramics with similar performances to lead-based components is therefore a key area of focus for the Piezo Institute.

The problem with piezoceramics

Piezoceramic production traditionally requires a very high annealing temperature – well above 800 °C. This is the level at which lead oxide becomes gas and is irreversibly lost. This loss adversely affects the performance of the material. Excess lead oxide (up to 30% over the desired composition) is added to compensate for the lead that will be lost through volatilisation.

Production of thin films using chemical solution deposition (CSD) methods also requires high temperature thermal processing. This removes residual organics before crystallisation of the piezoelectric film.

The solution

Piezo Institute researchers have developed a chemical deposition technique called PhotoChemical Solution Deposition (PCSD) for ferroelectric thin film production. With PCSD a thermal processing temperature of 450 °C can be used to obtain high performance films, avoiding lead oxide loss. This removes the need for a lead oxide excess.

PCSD is an ultraviolet assisted sol-gel annealing technique. The photoactivation of the sol-gel amorphous deposited film increases activity of the precursor solution. This allows the chemical reactions needed for the crystallisation of the piezoelectric film at much lower temperatures than those currently used both in academic and industrial laboratories.

Other benefits

Microelectronic devices cannot tolerate the high temperatures used in traditional piezo processing. Interdiffusion and contamination of component elements takes place, resulting in loss of the microelectronic properties. Integrating piezoelectric thin films with microelectronics components has therefore been a problem.

“The reduced temperature and time required by PCSD is low enough for microelectronic devices to retain their properties,” says Prof Lorena Pardo from Instituto de Ciencia de Materiales de Madrid (ICMM), an associated member of the Piezo Institute. “This makes it possible to integrate piezoceramics with microelectronics.”

“We’re also continuing to try to reduce the amount of lead used in piezo compounds,” says Pardo. “Our aim is to obtain an integrated and environmentally-friendly piezoelectric component.”

PhotoChemical Solution Deposition (PCSD) for production of ferroelectric thin films was developed at ICMM, an associated member of the Piezo Institute, in cooperation with the European project on Microfabrication with Ultraviolet Assisted Sol-gel Technology.

I Bretos et al. Chemistry of Materials 20, 5731–5733 (2008)

Piezo performance on the piste

Sports equipment company Head is using piezoelectric materials to increase stability and allow more precise turns and control on its high-performance skis.

Modern skis made of titanium alloy are wider, shorter and more flexible than older models. They enable the skier to have more fun with less effort, but the wider design also creates a greater surface area. It subjects the skis to more torsional forces and twisting during a turn, which can cause the ski's edge to lose contact with the snow.

Head set out to make a ski that is stable and responsive in all snow conditions and at all speeds. The mechanical energy created by the force of a skier's turn is transformed into electrical energy by piezo fibres embedded in the Intelligence downhill skis. The energy is captured inside the ski material and sent through a circuit to a microchip beneath the ski binding, described by Head as the world's first electronic ski management system.

The energy is amplified in the chip and fired back to the piezo fibres in less than five milliseconds. The fibres straighten instantly, creating a counterforce that stabilises the ski without reducing its liveliness.

"The higher the force on the skis, the more energy is created," says Prof Marija Kosec, a founding member of the Piezo Institute from Slovenia's Jozef Stefan Institute. "When a skier makes a really hard turn, the skis are pushing back up off the slope and generating a really comfortable feeling of control."

Piezo sports revolution

Further exploitation of piezo technology has the potential to provide added functionality to sports equipment in terms of vibration damping, sensing capability or energy harvesting, says Chris Bowen at the University of Bath's Materials Research Centre.

A karate scoring system has already been patented using flexible piezo fibres, for example. It includes a vest, shoes, gloves and head protector, and it converts energy generated by kicks and punches into electricity that powers a scoring mechanism.

Head is also deploying its piezo fibres in tennis rackets, where mechanical energy from the impact of the ball is converted to an electrical response that stiffens the racquet and gives it more power.

"Sport represents a massive market, and we've already seen how it benefits from the application of emerging technologies. We look forward to working with researchers and developers to introduce piezo technologies to more and more parts of the sports equipment industry."

Prof Marija Kosec, Jozef Stefan Institute

Research Road Map for 2009

Europe's first comprehensive survey of global research in piezoelectric materials and devices will be launched in 2009 by the Piezo Institute.

The Piezo Institute Research Road Map, developed by institute members, will help industry to identify opportunities for collaboration with academics and exploitation of research. It will identify research gaps and guide policy makers and funders in the development of future projects.

The road map will cover a range of multifunctional materials, including processing and chemical, physical, functional, and structural characterisation and modelling. Applications of piezo materials in sensors, transducers, actuators and motors will be explored in healthcare, energy management and telecommunications, among other sectors.

The report will include an analysis of the market and industrial demand for piezo materials and devices, as well as a chapter on current and future standards for multifunctional materials.

"Policy makers, academics and industrial researchers will benefit from a single comprehensive source of information about piezo research, markets and future applications," said road map coordinator Marc Lethiecq, a founding member of the institute at the University of Tours.

Academics and industrial research groups interested in contributing to the Piezo Institute Research Road Map are asked to contact Marc Lethiecq marc.letiecq@piezoinstitute.com

Piezoelectric materials are being used to increase stability and allow more precise turns and control on Head's high-performance skis

