Metrology for energy harvesting
European Metrology Research Programme

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Project news

In April the project delivered its first metrology training modules to an energy harvesting industry audience as one of IDTechEx's Masterclasses at the *Energy Havesting & Storage, Europe conference* in Berlin. The modules were focused on metrology principles applied to piezoelectric and thermoelectric devices and were delivered by the **National Physical Laboratory's** Dr Paul Weaver and **Physikalisch-Technische Bundesanstalt's** Dr Ernst Lenz respectively.

Fig 1. From Right to Left - Dr Harry Zervos (technology analyst with IDTechEx) with NPL's Dr Paul Weaver and PTB's Dr Ernst Lenz at the annual IDTechEx conference - the world's largest energy harvesting event.

"The Masterclass was very well received and several people came forward afterwards to say that it was excellent." said Dr Weaver. "We also had a queue of people with good detailed questions after the talk, and because it was mostly attended by industry developers and end users, it provided an excellent platform to deliver the project's key messages around the importance and simple application of metrological principles for the benefit of the energy harvesting field as a whole."

The trip to Berlin secured over 20 new contacts for the project, including representatives from chemicals company Johnson Matthey and Shell Global Solutions. Each new contact will receive further project updates, join the e-newsletter subscription and gain invites to future research dissemination and industry engagement events.

In May Alexandre Bounouh and colleagues from the **Laboratoire national de métrologie et d'essais** presented their latest research around a brand new experimental set up to gain accurate information on the mechanical properties of MEMs devices through electrical measurement.

The technique developed at LNE works by applying a current across the device with a varying frequency that allows you to analyse the output voltage of the component parts. With some additional calculations the technique electrically determines all the mechanical characteristics of the MEMs device including the damping factor (its negative impact on the amplitude of oscillations), and the frequency that determines the maximum electrical power generation from mechanical vibrations of MEMS transducers.

Parallel work at NPL has seen the application of a MEMS device, developed at NPL, to the measurement of piezoelectric properties at the microscale. The combination of these techniques with NPL's energy harvesting workbench provides a powerful suite of measurement techniques for the development of micro-scale energy harvesters.

Visit our homepage at http://projects.npl.co.uk/energy_harvesting

Contents

Project news

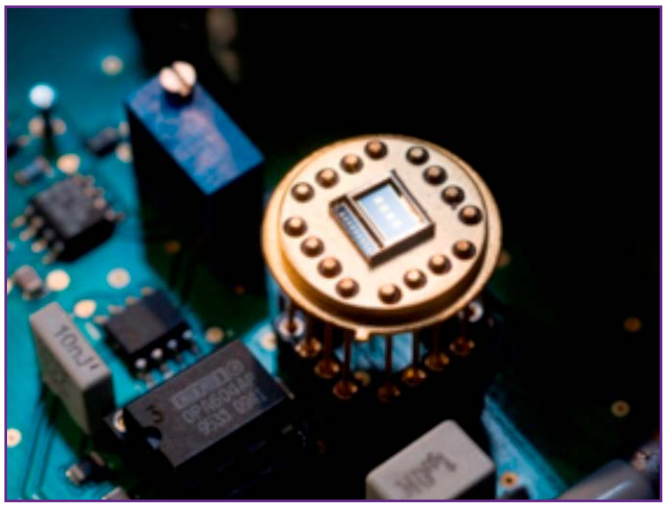

Fig 2. a) Example of MEMS device whose accurate resonant frequency was measured by the harmonic distortion technique

Earlier this month the team headed to Washington DC, to TechConnect World, which is jointly hosting the Nanotech, Microtech, Biotech and Cleantech Conferences and in July they will present the paper to IMEKO 2013 in Barcelona.

The Metrology for Energy Harvesting project received glowing recognition in March following the publication of an *interview* with Dr Kamal Hossain, **The National Physical Laboratory's** Director, Research & International, and EURAMET chairperson in the latest issue of the NCSL International journal. The interview saw Dr Hossain talk through his views on the role of EURAMET with over half a page of discussion devoted to the Metrology for Energy Harvesting Project. During a hugely positive interview section Dr Hossain references various significant accomplishments from the project thus far including the work by NPL to address losses piezoelectric cantilevers published in *Applied Physical Letters* last year.

The **National Physical Laboratory** has contributed to a new set of reports on Energy Harvesting soon to be issued by the Technology Strategy Board's *Energy Harvesting Special Interest Group*. Three reports have been produced in total, covering:

- Standards
- New materials
- Materials security

Alongside NPL, the reports have received input from Cambridge University (Centre for Smart infrastructure and Construction) and Perpetuum. They will be published on the Energy Harvesting SIG website in the coming weeks and aim to provide an industrial audience of SME's and larger companies with the tools to successfully adopt EH technologies and update them on the latest research of commercial benefit.

In July Dr Paul Weaver and colleagues from the **National Physical Laboratory** will deliver a poster presentation for piezoelectric harvester efficiency measurement at the 2013 Joint *UFFC, EFTF, and PFM Symposium* that runs from July 22nd – 25th in Prague, Czech Republic.

The poster will describe recent work looking at an experimental method of measuring efficiency for resonant piezoelectric cantilever energy harvesters based on a damped oscillator response to an impulse input. The presentation will include experimental results for typical energy harvesting devices.
Dr Weaver also plans to submit a Proceedings Paper to the 2013 Joint UFFC, EFTF, and PFM Symposium website which will be published later in the year.

View from industry:

Frédéric Pimparel, Technical Manager at Morgan Advanced Materials

Who are Morgan Advanced Materials?

Morgan Advanced Materials is a global materials engineering company offering a wide range of high specification engineered products with extraordinary properties. It combines leading edge material science and sophisticated application engineering to solve complex challenges in technically demanding applications, from transport and telecommunications to smart metering and energy harvesting. Working in partnership with customers from concept and feasibility through prototyping to full production the company provides added value to its customers' products and processes enabling them to perform more efficiently, more reliably and for longer.

In 2012 the Group had revenue of over £1bn and employed around 10,000 people worldwide serving customers in more than 100 countries. Morgan Advanced Materials headquarters is based in the UK and is listed on the London Stock Exchange.

What is your role?

I have worked at Morgan for over 13 years and currently work as a Technical Manager, overseeing the manufacture of piezoelectric products across two specialist manufacturing sites in the UK. My role is to look at the development and the introduction of new products into our operations.

What industries do you serve?

Morgan Advanced Materials provides its products and solutions to seven key markets; Industrial, Electronics, Healthcare, Energy, Transportation, Security & Defence, Petrochemical and Energy.

In relation to piezoelectric products specifically, the business has provided innovative solutions to industrial and commercial and defence SONAR markets for over 75 years. In addition to these markets we provide advanced products to the healthcare market with the USA proving to be major user of piezoelectric components for use in diagnostic equipment and other healthcare devices.

We also provide a number of sensors and other solutions to the automotive sector, with parking sensors being the largest application for the business within this sector. Morgan also has a keen interest in tyre pressure monitoring systems, where there is a technological advantage in using piezoelectric energy harvesting solutions.

What types of areas do you work in outside of energy harvesting?

Morgan develops and manufactures a range of components used in energy management and distribution. The business is also developing materials to optimise the manufacture of poly-silicon high efficiency solar panels and wind turbine performance. Using piezoelectric ceramic products we are also providing solutions for use in smart grids to monitor gas and water and that has the potential to save an estimated £14bn.

How long have you been interested in energy harvesting?

For me it's been an area of interest since I joined the business. I remember reading the first paper from MIT featuring a piezoelectric patch that could go inside a shoe and send a small wireless signal to a computer.

Interest in energy harvesting within the organisation started following the acquisition of a Netherlands based business from Phillips in 2000, which

View from industry

manufactured tyre pressure monitoring systems. This presented the first potential high volume commercial product that could generate an attractive return on our investment. The business was relocated to the UK in 2008 and following the move we started developing the first prototypes.

What challenges has energy harvesting faced gaining acceptance?

The question is always "how much energy can we generate from our components?" People often think they can recharge a mobile phone, whereas in reality you can only generate up to a few milliwatts of power and even then only under specific conditions.

The cost of the device, its operation and how this compares to an alternative battery solution is the key driver. As companies become more knowledgeable on the subject they start to focus on environments where energy harvesting can provide real advantages, such as in remote locations or within complex engineering systems.

Where do you think energy harvesting technology has potential for growth in the future?

I see the medical industry as a major growth area. In the US we are looking at harvesting devices to power sensors inside the body. The first products have been produced but there are a lot of approvals to go through before it can progress. Also there is significant development of Piezoelectric harvesting devices in recharging pacemaker batteries as this is matched to the low power requirements, these devices are tuned to resonate with the human heartbeat for maximum efficiency and will hopefully prevent further battery replacement surgery. Early work is on-going for research and military energy harvesting in breathing apparatus for respiratory monitoring.

We could also expand further into the transport sector harvesting the extensive vibrations from the moving parts of trains and commercial vehicles. We are investigating harvesters that could collect energy from the road in order to light up LEDs.

What do you see as the main challenges for piezoelectric energy harvesting devices?

Matched impedance coupling of the energy source and transfer from the transducer to the recovery electronics is the first issue. Furthermore, energy sources in the form of mechanical vibrations can vary in frequency, so the design of the transducer element and accompanying charge control electronics is critical to success.

The solution is a broadband harvesting device which receives energy from a variety of frequencies simultaneously but at the moment no such product exists. I know it is currently the focus of a lot of academic research, and our ambition is to take some of this academic work and create a broadband piezo-solution that we can turn into a commercial product at low cost. This is our goal over the next two to three years.

How would you describe Metrology's importance to energy harvesting?

Answering questions from customers over how much energy you can generate is a very confusing process due to the lack of standard units. We often see this on enquiry forms we receive at Morgan with people talking to us in terms of Joules or watts per cubic centimetre.

To try and address some of these concerns we have supplied the National Physical Laboratory with various components to provide us with standardised energy outputs specific to each, which the whole of the market can understand. We expect to receive these results shortly and we believe they will help us define and characterise the product range we will be putting out this year and provide potential customers with a clear understanding of the output of a device in their environment.

Are there any other areas where education of the market is a priority?

The majority of people are completely unaware of the energy potential within their own environment or how important this factor is in the effectiveness of energy harvesting solutions. We almost need a consultancy service to help them understand this before we can provide them with a suitable solution.

Are there any areas within the metrology of energy harvesting that you would like to see further research?

The ISA100.18 Working Group is preparing standards and information documents on power sources for Wireless Sensor Networks. The key objectives are to define specifications for the inter-changeability of various power sources, help users compare different harvesters and choose the optimum power source for each application. This is certainly something we are monitoring as we believe it will create a better working space for both piezoelectric and other forms of energy harvesting.

Where do you feel that European capability ranks in terms of developing innovative EH products?

There are some shortfalls in the UK supply chain, notably the production of energy harvesting specific control IC's and specialist energy storage devices such as; batteries and super capacitors, which are mainly sourced through Far East suppliers. The research base is strong.

In terms of commercial solutions there are a few established companies such as Perpetuum, EnOcean and Arveni. However, with the exception of Germany, the UK and France there is little commercial activity in Europe at this time. Despite this there are certainly a lot of potential requirements and we are receiving an increasing number of enquiries from customers however the commercial base is not widespread.

Outside of Europe, Japan is very active in energy harvesting applications and a dedicated event has been set-up in Tokyo this July where several academic institutions and companies will be showcasing their latest advances in this field.

Upcoming events

In June, the **National Physical Laboratory** will host a webinar looking at the industrial measurement requirements for emerging PiezoMEMS technologies and the barriers faced by product developers in establishing online metrology for quality assurance in high volume commercial applications. The one hour, internet accessible event is being organised by NPL's Dr Jenny Wooldridge and Professor Markys Cain and will also feature the presentation of a MEMS-based tool for the d33 parameter that can accurately evaluate the functional properties of piezoelectric materials in micro-scale materials.

Further details including how to register can be found *here*.

A project dissemination event and workshops have been planned for 28th and 29th August.
The event will be held at **Physikalisch-Technische Bundesanstalt** in Braunschweig and will present the main outcomes of the project with a focus on industrial application of the metrology.

Two workshops will be held alongside the event providing in-depth coverage of the metrological tools and best practice developed during the project. One workshop will focus on electromechanical energy harvesting, including piezoelectrics, while the other will focus on thermoelectrics metrology.

IMEKO TC-4 Symposium on Measurements of Electrical Quantities
Barcelona, Spain
18th -19th July 2013
www.imeko2013.es

2013 Joint UFFC, EFTF, and PFM Symposium
Prague, Czech Republic
21st – 25th July 2013
http://ewh.ieee.org/conf/uffc/2013/

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We welcome feedback, opinion and suggested articles. Please send your comments to *paul.weaver@npl.co.uk* *and* *james.romero@proofcommunication.com*

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