Making waves in MEMS

The MIMOMEMS project has established a European Centre of Excellence in microwave, millimetre wave and optical devices in Bucharest, Romania. **Professor Dan Dascalu** and **Dr Alexandu Müller** talk to *International Innovation* about the ways in which the project will propel research in this exciting field

Could you begin by outlining the purpose of the European Centre of Excellence in Microwave, Millimetre Wave and Optical devices, based on Micro-Electro-Mechanical Systems for Advanced Communication Systems and Sensors (MIMOMEMS) project?

The overall aim of the MIMOMEMS project was to bring research activity in Radio Frequency (RF) and Optical Micro-Electro-Mechanical Systems (MEMS) at the National Institute for Research and Development in Microtechnologies (IMT-BUCHAREST), Romania, to the highest European level, and create a European Centre of Excellence in microwave, millimetre wave and optical devices, based on MicroElectro-Mechanical Systems for Advanced Communication Systems and Sensors. The Microwave and Millimetre Wave Laboratory and the Microphotonics Laboratory have joined their efforts to create this European Centre of Excellence.

What inspired the creation of MIMOMEMS?

The inspiration for this initiative came from previous successes, including involvement in FP4, FP6 and FP7 EU projects. Our team coordinated one of the first European projects in RF MEMS – MEMSWAVE (1998-2001), which was nominated for the Descartes Prize 2002. The two labs have been involved in a few FP6 and FP7 projects, Specific Targeted Research Projects (STREPs) and Integrated Projects (IPs), and the research infrastructure of the institute had been constantly improving since 2006. Using national funds through the Capacities competitions, as well as the REGPOT project funding and the support of other national projects, we have been able to invest in new equipment and develop our facilities to the highest possible levels for our work.

What are the primary applications of radio frequency micro-electro-mechanical systems (RF MEMS) and Optical-MEMS?

There is a large number of applications, especially in communication systems. Sensors, mobile phone technology (in its evolution to the 4th generation), communications from satellites to the ground, inter-satellite communications and computer data transmissions are the main users of RF and Optical MEMS communication.

So what are the main technical and scientific objectives of the MIMOMEMS project?

MIMOMENS represents a support action for the development of microwave, millimetre wave devices and circuits, optical devices and sensors based on MEMS technologies, with applications in modern communication systems. The MIMOMEMS project workplan was targeted to support the development of:

- Millimetre wave reconfigurable filters for millimetre wave applications
- Micro-machined receiving modules based on silicon and GaAs micromachining
- Acoustic devices for GHz applications based on micromachining and nano-processing of wide band-gap semiconductors
- Polymer-based micro-photonic devices
- Sub-wavelength photonic structures

Together with the twinning partners – the Laboratory for Analysis and Architecture of Systems (LAAS-CNRS), Toulouse, France, and the Institute for Electronic Structure and Laser at the Foundation for Research and Technology – Hellas (FORTH-IESL-MRG), Heraklion, Greece – we have developed state-of-the-art research in each of these fields.

Can you offer an insight into the common tools and technologies used in the industry? How these have been improved and upgraded over the course of the project?

MIMOMEMS has contributed to increasing the competitiveness of IMT-BUCHAREST as a reliable European partner in micro and nanotechnologies. One of the important tasks was to upgrade the research equipment. With the support of MIMOMEMS project funding and that of other national projects, the research infrastructure of the Microwave laboratory was upgraded to 110 GHz; the photonics lab has purchased a near-field scanning optical microscope (SNOM) and a setup for measuring the responsivity of UV photodetectors, whilst the technology lab obtained a gold-plating facility. The presence of the MIMOMEMS Centre of Excellence will have a major impact on creating cooperation activities with the new high-tech industry that is now emerging in Romania.

How would you rate the current level of knowledge exchange between microtechnologies researchers in Europe? How can MIMOMEMS help to improve this?

There is a lot of common work between European research institutions, universities and industry promoted by FP4-FP7 EU programmes, on STREPs, IPs and support actions, European Space Agency (ESA) projects, intergovernmental bilateral cooperation, direct cooperation actions, etc. MIMOMEMS has facilitated common work between IMT-BUCHAREST and its twinning partners. We have also developed collaborative relationships and exchanges with other research and industry partners, facilitated scientific and strategic workshops, and disseminated our work through peer-reviewed journals and our own project website.

Systems of success

Through the support of FP7 REGPOT funding, **IMT-BUCHAREST** is a shining example of the way in which investment, vision and cooperation can bring research infrastructure and practice to a world-class level

EVEN THOUGH SOME of them are already widely used in communications systems, radio frequency micro-electro-mechanical systems (RF MEMS) and Optical-MEMS are still considered emerging technologies. Developments in such systems and their application are continually evolving, and constitute a significant field in both research and industry.

Under FP7 REGPOT funding, a research facility in Bucharest, Romania, has been established as a Centre of Excellence in MEMS research, an achievement which Professor Dan Dascalu, General Manager of IMT-Bucharest, where the Centre is based, is very proud of: "The success of the MIMOMEMS team in European cooperation is almost unique in Romania. It is not just pure chance that MIMOMEMS was the first Centre of Excellence to be financed from European Programmes after Romania acceded to EU," he enthuses.

MIMOMEMS

Dascalu has seen the development of MIMOMEMS over the course of a three year project. The main objectives involved:

- Exchange of know-how and experience with twinning partners, the Laboratory for Analysis and Architecture of Systems (LAAS-CNRS), Toulouse, France, (which has strong expertise in silicon-based RF and millimetre wave microsystems, photonic devices, circuits manufacturing and characterisation), and the Institute for Electronic Structure and Laser at the Foundation for Research and Technology, Hellas (FORTH-IESL-MRG), Heraklion, Greece, which has excellent knowledge of IIIVs, GaAs and related semiconductors, and wideband gap semiconductor processing
- Recruitment of incoming experienced researchers

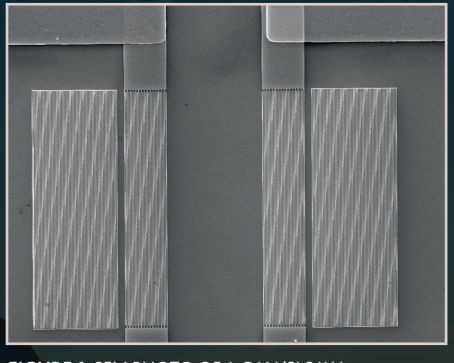

FIGURE 1. SEM PHOTO OF A GAN/SI SAW STRUCTURE WITH 200 NM WIDE FINGERS AND INTERDIGITS SPACING

- Acquisition, development/upgrading of research equipment
- Organisation of workshops and conferences
- Dissemination and promotional activities

KNOWLEDGE FROM THE START

Project Coordinator Dr Alexandru Müller and his team began the project with a period of knowledge exchange between IMT-Bucharest and its twinning partners before setting to work in a common laboratory environment. Here they established a set of procedures to be undertaken, and worked in partners' laboratories, sharing findings, skills and experience.

WORKING TOGETHER

Whilst IMT-Bucharest is the lead organisation in the MIMOMEMS project, the role played by twinning partners LAAS-CNRS and FORTH-IESL-MRG cannot be underplayed: collaborative scientific work and state-of-the-art devices and technologies have been developed in collaboration with said partners, and co-authored papers in high-ranked journals have been published. In addition, a common European laboratory including IMT-Bucharest, LAAS and FORTH has been created (LEA SMART MEMS). Strong cooperation has also been harnessed with other important European research centres in the field, including VTT Helsinki, Finland, as well as with a number of European industrial partners.

THE VALUE OF PARTNERSHIP

Bringing together a number of research bodies at the forefront of this field, MIMOMEMS has demonstrated the importance of working with innovative and influential partners. Benefits of this have included:

- The creation of a strong multidisciplinary research team with complementary competences and facilities
- The creation of opportunities to participate collaboratively in FP7 proposals
- Sharing industry contacts with partners
- The facilitation of knowledge transfer
- Opportunities for sharing access to facilities
- The collaborative development of research work

The response to the setting-up of the Centre of Excellence has been incredibly positive, and has paved the way towards future projects and

MIMOMEMS

European centre of excellence in microwave, millimetre wave and optical devices, based on micro-electro-mechanical systems for advanced communication systems and sensors

OBJECTIVES

The overall aim of the MIMOMEMS project is to bring the research activity in RF and Optical-MEMS at the National Institute for R&D in Microtechnologies (IMT-Bucharest) to the *highest* European level, and create a European Centre of Excellence in microwave, millimetre wave and optical devices, based on micro-electro-mechanical systems (MEMS) for advanced communication systems and sensors.

COORDINATING INSTITUTE

IMT-BUCHAREST, Romania (coordinating institute)

TWINNING PARTNERS

Laboratory for Analysis and Architecture of Systems (LAAS-CNRS), Toulouse, France

Institute for Electronic Structure and Laser at the Foundation for Research and Technology – Hellas (FORTH-IESL-MRG), Heraklion, Greece

FUNDING

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CONTACT

Dr Alexandru Müller
Project Coordinator

Micromachined Microwave and Millimeter Wave Circuits
IMT-Bucharest
32B, Erou Iancu Nicolae Street
077190 Bucharest, Romania

T +40 21 2690775
E alexandru.muller@imt.ro

DR ALEXANDRU MÜLLER is head of the RF-MEMS laboratory IMT-Bucharest. His recent research work focused on Silicon and IIIVs, microwave and millimetre wave devices and circuits based on micromachining technologies, and acoustic and photonic devices based on WBG semiconductors. He has coordinated the IMT team in FP4-FP7 EC funded projects and has authored or co-authored about 100 papers in journals and conference proceedings.

PROFESSOR DAN DASCALU is General Director of IMT-Bucharest and coordinator of 'Centre of nanotechnologies', part of IMT. He is also a full member of the Romanian Academy and the author of *Transit-time Effects in Unipolar Solid-State Devices* and *Electronic Processes in Unipolar Solid State Devices* (Abacus Press, Kent, UK, 1974 and 1977, respectively), and of technical papers published in scientific periodicals.

further cooperation with partners in research and industry across Europe.

INVESTING IN RESEARCH INFRASTRUCTURE

MIMOMEMS has brought the level of RF and MEMS research at IMT-Bucharest on a par with its partners and collaborators. As an illustration of the extensive funding from which the Centre has benefited, the new infrastructures of IMT-Bucharest (including the new nanolithographic equipment, the new Low-pressure chemical vapor deposition (LPCVD) and Plasma-enhanced chemical vapor deposition (PECVD) equipment, the nano-identer, the new MA6 mask aligner, the mask fabrication equipment from Heidelberg, equipment, the new scanning electron microscope (SEM), and the new clean room, etc.) represent investments of around 3 million euros. Müller is confident of the lasting effect that such investments will have for further collaborative opportunities: "The presence of the MIMOMEMS Centre of Excellence will have a major impact on creating cooperation activities with the new high-tech industry that is developing in Romania," he affirms.

MEASURING SUCCESS

MIMOMEMS has been a great success for IMT-Bucharest. It has enjoyed a number of individual achievements – the most crucial, perhaps, being the successful gauging of wafer measurements at 77 GHz. This would not have been possible without the project's support, which saw equipment capacity upgraded from 65 to 110 GHz. Another key development has been Müller's publication in *IEEE EDL* of a paper on the GaN-based GHZ SAW resonators nano-processed IDTs. This paper is a tangible marker of the success of MIMOMEMS, and is a marker of the common work produced in collaboration with the project's twinning partners (in this instance, FORTH).

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MAKING WAVES

Dissemination is an important part of the MIMOMEMS project, which has funded the organisation of two scientific and one strategic workshop in RF and optical MEMS. Reaching key players in the field, these took place alongside the IEEE organised International Semiconductor Conference (CAS) in Sinaia, Romania. Müller explains the thinking behind the workshops: "The scientific workshops have evidenced the main technical results obtained by IMT-Bucharest and its partners supported by the MIMOMEMS project, together with results obtained by other teams in RF and Optical MEMS. The strategic workshop had a lot of invited lecturers from industry and could give some important directions in the topics," he states. The papers presented from the strategic and scientific workshops are available on the project webpage, and the research work has also been disseminated in important peer-reviewed journals.

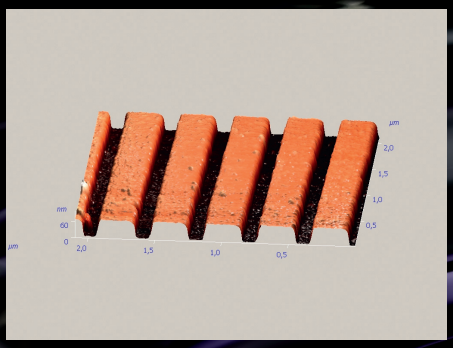

FIGURE 2. DETAIL OF THE NANOLITOGRAPHIC PROCESS (AFM IMAGE)

LOOKING TO THE FUTURE

The MIMOMEMS Centre has already been made a permanent department of IMT-Bucharest, proof not only of the strength of Müller's project, but of its future sustainability. It also symbolises the importance of MEMS research for the institute, as Dascalu points out: "The new structure of the institute also marks a clear shift in strategy: from microtechnologies to nano-biotechnologies (or convergent technologies)", he remarks. Whilst in the past, the absence of industrial partners in Romania prohibited productive cooperation, European projects like MIMOMEMS have provided valuable opportunities for IMT-Bucharest to connect with European industrial partners. "What is indeed important is the fact that this success was consolidated during the last three years and the future looks bright: new projects will be financed from FP7, as well as from European Public-Private Partnerships in the years to come," explains Dascalu. Today, IMT-Bucharest is involved in four European Nanoelectronics Initiative Advisory Council (ENIAC) projects, working together with industrial partners (NXP, the Netherlands; Thales, France; and Volvo, Sweden) to research emerging solutions for true ground speed measurements at 77 GHz, and sensors for poisonous gases based on GHz acoustic devices. Another ENIAC project involves Infineon Ro, an important high-tech entity established in Romania, which specialises in emerging technologies related to the electric car. As well as with Infineon, IMT-Bucharest has established relations with companies like Renault TRT and Honeywell Ro. The IMT team is one of the partners in the SMARTPOWER and NANOTEC Integrated Projects (call FP7 ICT-2011-7), which are coordinated by Thales SA France. This is a sure sign that the Centre of Excellence is continuing to further facilitate and strengthen common projects.