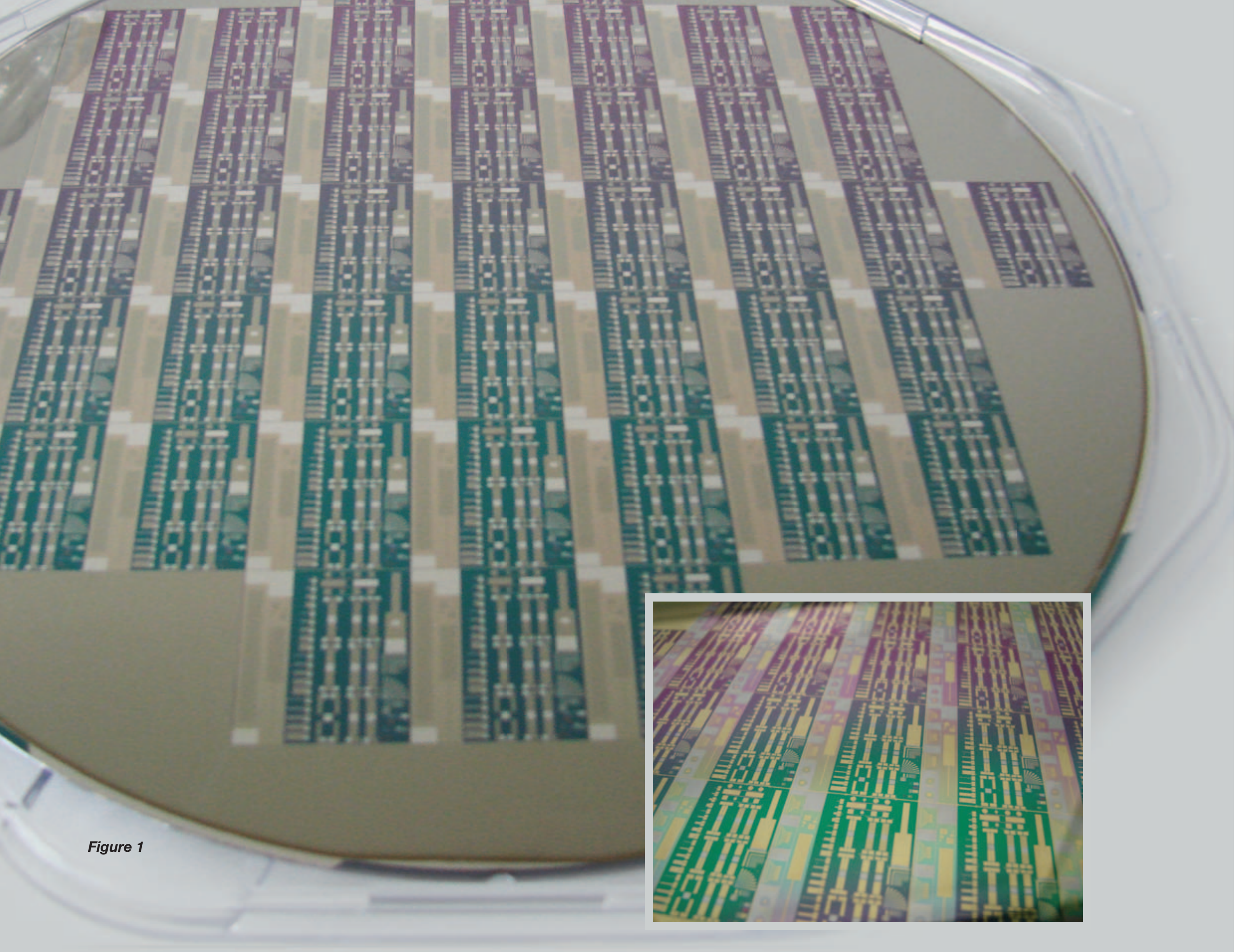


Figure 1

MARTIN KRATZER
Oerlikon Senior Scientist

Cooperating on PZT Films for MEMS

Oerlikon Systems is working closely with the Fraunhofer Institute for Silicon Technology (ISIT) and the Ceramics Laboratory at the EPFL Lausanne (EPFL-LC) to help make volume production of in-situ sputtered PZT films on an 8" wafer a reality.

Piezoelectric MEMS – with their low power requirements, small size and high performance – are perfect for the emerging generation of smart devices. For this reason, MEMS manufacturers with in-house thin film coating capabilities or foundry service providers that supply PZT-coated wafers to MEMS manufacturers are urgently looking for a production solution able to mass-produce PZT films on 150mm and 200mm substrates.

Oerlikon Systems, ISIT and EPFL-LC are all participants in the "piezoVolume" project coordinated by SINTEF, which began in 2010. Funded by the European Commission's 7th Framework program (FP7), this project brings together various industry and academic partners to establish and promote an effective European MEMS production technology based on PZT thin films. One of the main project milestones is to develop the production technology, consisting

Figure 2

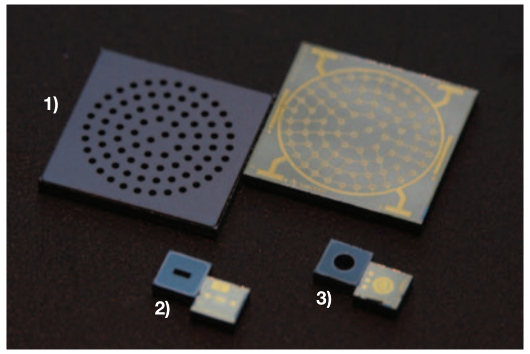


Figure 1: Piezoelectric demonstrator devices on a 200mm substrate fabricated at Fraunhofer ISIT. Courtesy of Dirk Kaden (ISIT).

Figure 2: piezoVolume piezoMEMS devices fabricated by SINTEF. Courtesy of Hannah Tofteberg (SINTEF).

of tool equipment and processes, capable of volume production of in-situ sputtered PZT films on 6" (150mm) and 8" (200mm) substrates for piezoelectric MEMS. The resulting platform will enable cost-effective medium and large scale production. ISIT will demonstrate a pilot process by the end of this year that will confirm the ability to produce PZT layers on 25 consecutive wafers.

The MEMS applications under development by the "piezoVolume" consortium include *(see photo above)*:

1. Ultrasonic medical imaging transducers (VERMON)
2. Ink-jet printing heads (OCE)
3. Micro-machined transducers for ultrasonic indoor location systems (SONITOR)

piezoVolume
www.piezovolume.com

The three "piezoVolume" project partners working on the development of a platform and process for in-situ sputtered PZT thin films have split up the work:

EPFL Lausanne / Ceramic Labs (LC) began initial R&D work on 6" substrates and continue to develop a PZT process on the smaller substrate; the resulting PZT films will be used at EPFL to develop novel MEMS devices, such as energy harvesters. The LC development team under Prof. Paul Muralt is widely recognized in the scientific community for their R&D of piezoelectric & ferroelectric materials. Thanks to their extensive experience and profound material know-how, Prof. Muralt's team is an outstanding partner for tailoring the thin film properties to the specific requirements of MEMS applications.

Fraunhofer Institute for Silicon Technology (ISIT) is working on a complete CLUSTERLINE® tool to deposit PZT layers, developing not only the 8" (200mm) PZT process but also investigating production relevant parameters: throughput, target lifetime, target and chamber conditioning procedures and shield change intervals. ISIT is also working on the electrode layers and a specific test structure defined by the piezoVolume project. This is used to measure the relevant dielectric, ferroelectric and piezoelectric properties of PZT.

Oerlikon Systems provides extensive experience in PVD technology and is working on the further development of the necessary sputter platform (CLUSTERLINE® 200) – along with process development for volume production of 8" PZT films. This will enable both project partners to apply their optimized process sequences on an optimized tool.

"With all the work going on with the hardware and the deposition process, all three partners are working very closely to best facilitate progress in their R&D efforts," explains Prof. Bernhard Wagner, Head of the MEMS department at ISIT. "The basic PZT deposition process on 200mm wafers is already complete. We are now focusing on process integration to establish a technology platform for piezo-MEMS components."

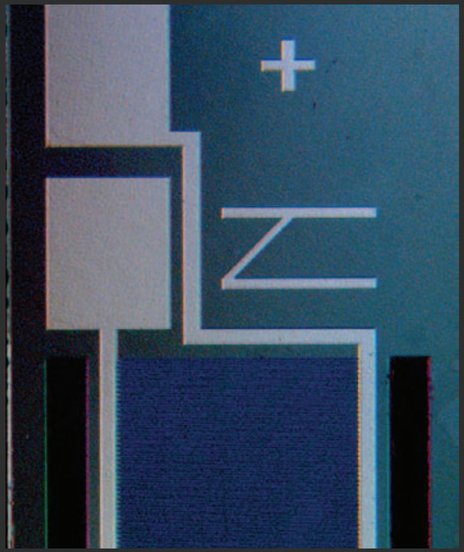
Thanks to CLUSTERLINE®

Both the LC at the EPFL Lausanne and the ISIT are using the CLUSTERLINE® 200 system from Oerlikon as the R&D platform. The EPFL-LC currently has a RF single module R&D station; the ISIT is using a complete CLUSTERLINE® system, including a dedicated process module for PZT thin films.

Equipped with RF magnetron sputtering and a high temperature substrate holder (Very Hot Chuck), the CLUSTERLINE® platform provides a very reliable high temperature deposition process with a high throughput capability for the deposition of PZT layers, currently close to the "piezoVolume" project goal of 3.6 wafers/hour @ 1µm. One notable performance advantage is the remarkably high piezoelectric coefficient $-e_{31,f}$ of 18-20 C/m^2 that we've achieved with PZT films deposited on the CLUSTERLINE® – an outstanding result for PZT thin films.

Overall, the CLUSTERLINE® can reliably deposit various ferroelectric ceramic thin films with perovskite structures. In addition to the preferred PZT thin films for production of MEMS devices, compounds based on $BaTiO_3$ for tunable capacitors etc., are gaining interest and can also be deposited with the CLUSTERLINE®.

Figure 3



EPFL: Partner with extensive R&D expertise for piezoelectric films

Ranked among the top universities in the world, the EPFL Lausanne also enjoys a formidable reputation within the scientific community regarding piezoelectric and ferroelectric thin films used for piezoMEMS applications. The EPFL team directed by Paul Muralt is a key partner in the “piezoVolume” project.

As part of the Materials Science & Research Department at the EPFL, the Ceramics Laboratory (LC) focuses on research and education of the technology of functional ceramics – piezo-electrics and ferroelectrics, polar materials, para-electrics, high-K dielectrics, multi-ferroics, and ferro-elastics. LC investigates the fundamental mechanisms, theory and modeling, processing and fabrication of thin films and bulk ceramics, structural and functional properties, device design, fabrication and testing.

ANDREA MAZZALAI
EPFL Scientist

Figure 3: PZT coated micromachined cantilever for piezoelectric energy harvesting.

Figure 4: Microscopic view of PZT actuated optical devices fabricated at Fraunhofer ISIT. Courtesy of Dirk Kaden (ISIT).

Both the LC at the EPFL Lausanne and the ISIT are using the CLUSTERLINE® 200 system from Oerlikon as the R&D platform.

Challenges and goals

Rapid progress has been made in the project; key technical challenges have been met for both the *hardware* and *deposition process*:

- *Very Hot Chuck*: enables thin film deposition at very high wafer temperatures (>600°C) and excellent uniformity
- *RF magnetron sputtering*: optimally deposits PZT from a single ceramic target at a high throughput
- *Perovskite crystal structures*: mandatory structures achieved with a complex high temperature deposition process
- *Material mix*: the correct ceramic target composition with an excess of PbO to compensate the loss of lead, which occurs during high temperature deposition

Results*

The high temperature RF magnetron sputter process enabled in-situ growth of the targeted perovskite PZT. The PZT films were produced at deposition temperatures of about 600°C, with a (100) or (111) orientation as a function of the substrate and optional seed layer.

Applying an optimized poling procedure to the test device structures helped to achieve the highest piezoelectric coefficients $-e_{31,f}$ of 20 C/m2 for the films. This transversal response is the key property for most applications, but values up to 150pm/V were also measured for the longitudinal response $d_{33,f}$ of the PZT films.

All in all, the excellent results underline the successful cooperation between hardware and process development, which now allows the direct growth of a high quality piezoelectric PZT perovskite phase.

Prof. Muralt at the EPFL-LC, summarizes: “These transverse piezoelectric coefficients exceed any results achieved so far for PZT thin films. They are close to theoretical values derived from PZT ceramics, which are processed at much higher temperatures and exhibit much larger grains. Industrial requirements include still further requirements, such as low leakage and high break down voltages. We are very confident that our progress up to now will lead to even better results.

* The research leading to these results has received funding from the European Community’s Seventh Framework Programme (FP7/2010-2013) under grant agreement no. 229196

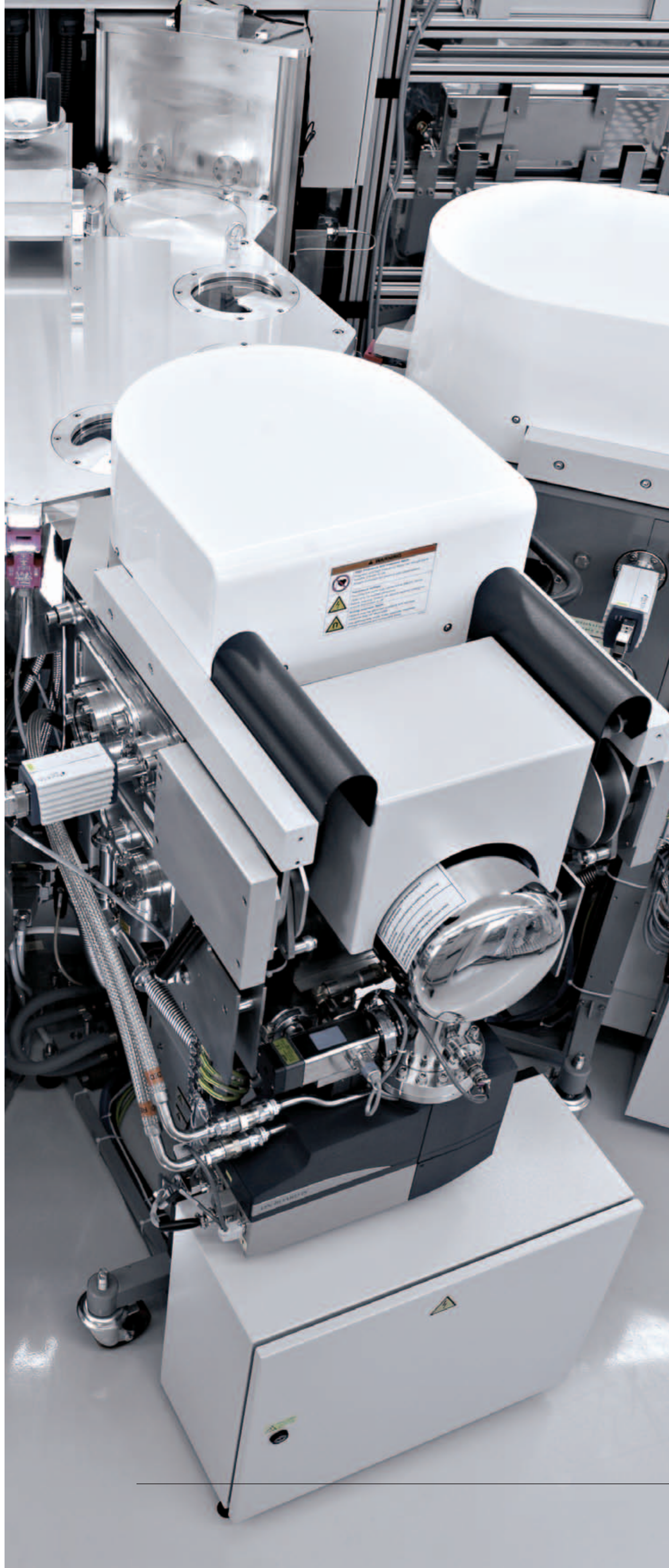
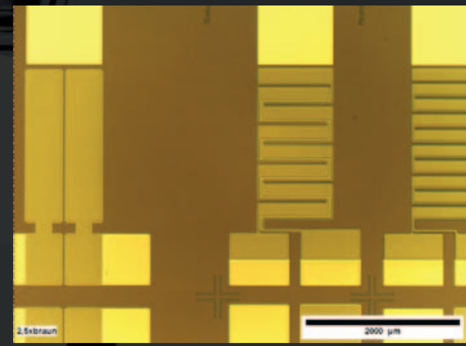


Figure 4



ISIT: Partner with R&D and Production Capabilities

Located in Itzehoe, Germany, the Fraunhofer Institute for Silicon Technology (ISIT) is one of Europe’s most modern research facilities for microelectronics and microsystems technology. The 150 scientists at ISIT work closely with industrial partners – from the design phase (including system simulation) to prototyping and fabrication of samples, all the way to series production. They help develop power electronic components and microsystems, with tiny movable structures for sensors (pressure, motion, biochemical analysis, etc.) and actuators (switches, micro-mirrors, ultrasonic transducers, etc.). These miniaturized components are used in medicine, environmental engineering, communication systems, automotive industry, and industrial applications.

In cooperation with industrial partners, ISIT operates a professional 200mm wafer production line for power electronics and also a MEMS foundry. The wafer fab is also used by ISIT for R&D projects to develop new components and processes. This cooperation model enables ISIT to offer a quick transition from research to production at the Itzehoe facility.

DIRK KADEN
ISIT Scientist