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Editorial

The field of electroceramics provides a vast number of materials for sensors, actuators, and electrical and electronic components. Electroceramic thin films can add therefore many useful functionalities into MEMS (Micro-Electro-Mechanical-Systems). At the same time, because electroceramic fabrication is a high temperature process, because most ceramics are inert and corrosion resistant materials, and because their properties are very sensitive to the processing conditions, the integration of electroceramics onto silicon and other substrates as well as their patterning into functional elements are a complex matter that is not yet fully mastered. This is well reflected in the position of electroceramic MEMS in the market: While the potential is enormous, first devices have been commercialized only very recently.

The area of electroceramic MEMS being still very young, advancement in processing and demonstration of prospective applications are equally important. For this reason we have chosen to emphasize in this special issue these two aspects, fabrication and applications. The first part is devoted to central issues in fabrication technology: thin and thick film processing and patterning techniques. The second part includes reviews on selected applications: sensors, actuators, high frequency electronic components, and optical microsystems.

In contrast to bulk ceramics, *ceramic thin films* are always a part of a composite system (i.e. substrate-film): the first paper, by Trolier-McKinstry and Muralt is centered on this aspect in piezoelectric thin films. It shows how the knowledge accumulated during the past 15 years in the control of growth processes in ferroelectric compositions and in polar materials such as AlN resulted in improved piezoelectric properties towards various MEMS applications.

Ceramic thick films of 10–100 μm thickness are desired in certain MEMS e.g. for improved sensitivity. In contrast to thin films, they are usually prepared by powder techniques. Dorey and Whatemore review thick film deposition techniques: screen printing, electrophoretic deposition, hybrid powder—sol gel technique, and direct writing. An emphasis is given to common issues in thick film facbrication: interfacial reactions, and onstrained sintering.

Patterning is a crucial technology in any MEMS and since electroceramics are new comers, we felt the topic merits special emphasis. Three reviews are given: Baborowski discusses the 'hard core' micromachining and patterning techniques, namely the adaptation of standard silicon and metalisation patterning methods to patterning of ceramic thin and thick layers on silicon substrates. Methods for stress compensation are of a particular importance due to the higher processing temperature of ceramic films in comparison to standard materials, processing parameters in dry etching are significantly modified, Silicon-on-Insulator (SOI) or poly-SOI substrates can be used to improve the uniformity of the structure thickness on the wafer scale. Martin and Aksay describe, discuss, and compare various low cost, high throughput soft lithography emerging techniques for micron and submicon scale patterning: these are alternative techniques to the IC standard lithography techniques and include techniques such as microtransfer molding, micromolding in capillaries, embossing. and microcontact printing. Alexe, Harnagea, and Hesse focus on nano scale patterning methods. They discuss and compare various top down techniques: focused ion beam patterning, electron beam direct writing, and nano imprint, and comment on potential bottom up techniques which promise smaller lateral sizes but are still far from being mature.

The second issue is devoted to applications. By no means comprehensive, the volume presents the diversity and potential of the field and at the same time features some of the recently commercialized and near-to-market applications:

Maeda, Tsaur, Lee and Ichiki introduce the area of *microactuators*. This area, until now limited practically to electrostatic and capacitive devices may benefit from the high force output with low power dissipation of actuators based on piezoceramic thin films. A related topic, perhaps of a higher complexity is that of micro-machined ultrasonic *transducers* (MUT) and acoustic sensors**.** Muralt reviews this topic and compares such

transducers based on piezoelectric films (PMUT) to the better known capacitive type miniaturized ultrasonic transducers (CMUT).

Another field that is likely to benefit from electroceramic thin films is that of *rf MEMS*, microsystems for high frequency mobile electronics: One of the first group of electroceramic microdevices that entered the market were thin film bulk acoustic resonators based on piezoelectric films. They are currently revolutionizing the field of filters and resonators for high frequency mobile communications allowing for the first time the integration of these components with the IC on one substrate. Loebl, Metzmacher, Milsom, Lok, van Straten, and Tuinhout review this topic addressing material and electrical performance. Miniaturized tunable capacitors based on tunable ferroelectrics open interesting perspectives for new active rf components such as tunable phase-shifters. Auciello, Saha, Kaufman, Streiffer, Im, and Bachmann review recent advances in materials for these applications.

Finally, Kim, Barbastathis and Tuller discuss key features of mems technology that enable new functionalities of microphotonics, present an overview of various cases, and discuss materials related challenges and future trends for *optical MEMS* research and commercialization.

In addition to the specific information regarding fabrication and applications of electroceramic MEMS, we hope the reader will find the issue informative also in relation to the added value the MEMS approach brings to the area of electroceramic devices: the facilitated fabrication of arrays of sensors and actuators, the possibilities for direct integration of the functional elements with IC, the cost reduction due to batch processing, the possibility to have a number of different functions on one substrate using various ceramic thin film elements, and of course the improved sensitivity in many cases are some of the advantages that promise to make Electroceramic MEMS a viable and highly useful field.

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Guest editor
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