Fraunhofer FEP

PRESS RELEASE

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Digitalization of coating processes for high-resolution ultrasonic sensors

Piezoelectric coatings play a key role in medical technology, microelectronics and sensor technology, for example in the manufacturing of ultrasound microscopes that examine ever smaller semiconductor components and biological cell structures. However, the increasing demands on the quality and reproducibility of these coatings place high demands on the complex coating processes, which require many parameters to be precisely coordinated. In order to meet this challenge, the Fraunhofer Institute for Electron Beam and Plasma Technology FEP is developing a digital twin of the coating process for piezoelectric thin films as part of the BMBF-funded DigiMatUs project (FKZ 13XP5187D). This enables the digital mapping and optimization of the processes and leads to a significant improvement in the performance and reproducibility of ultrasonic sensors.

Piezoelectric films play a key role in medical technology, microelectronics and sensor technology, particularly in the manufacture of ultrasound microscopes. Such microscopes enable the examination of ever smaller structures, such as semiconductor components or biological cells.

Piezoelectric thin films are highly crystalline layers whose material is deformed when an electrical voltage is applied, allowing sound pulses to be emitted, for example. Ultrasonic pulses can be emitted by adjusting film properties and thickness, as well as applying this voltage very quickly. For better resolution of the ultrasonic microscopes, higher frequencies are necessary. The requirements for the coating quality and corresponding process quality increase significantly as the target frequency increases.

In order to meet these growing demands, six partners are working on the digitalization of coating processes for the production of high-resolution piezoelectric ultrasonic sensors as part of the DigiMatUs joint project funded by the German Federal Ministry of Education and Research (BMBF). In this context, the Fraunhofer Institute for Electron Beam and Plasma Technology FEP in Dresden is developing a digital twin of the coating process for piezoelectric thin films based on aluminum nitride (AlN) and aluminum scandium nitride (AlScN). The coating deposition takes place at the Fraunhofer FEP cluster facilities using pulse magnetron sputtering processes. The various process parameters and influencing factors and their effects on the layer properties are investigated and digitally recorded. The data analysis is based on an ontology for thin-film materials and processes developed jointly with the project partners. An ontology describes a formal system for classifying and structuring knowledge in a specific subject area in order to clearly depict relationships and properties.

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The resulting digital mapping of materials and processes enables precise modelling and optimization of process sequences. This allows detailed analysis of process and material properties, which leads to improved performance and reproducibility of the ultrasonic sensors and also enables further development steps to be implemented more efficiently.

"The development of the models poses a particular challenge, as a large number of process parameters and their interactions have to be taken into account. In particular, the comparatively small number of data points combined with a large parameter space places high demands on the development of a robust representation of reality. The Fraunhofer FEP is contributing its many years of expertise in thin-film processing and characterization, thus creating the basis for more efficient and digitally supported production," explains Dr. Stephan Barth, project manager at the Fraunhofer FEP.

The project uses state-of-the-art technologies such as ontologies and artificial intelligence (AI) to analyze and describe the correlations between the process parameters. For example, predictions can be made about the effect of changes in the coating process - such as the adjustment of cathode voltages, substrate temperature or coating pressure - on the material properties. This enables targeted optimization of the coatings and improves the efficiency of process development.

In the course of the project to date, a first version of the thin-film ontology has been developed together with the project partners, the digital recording and processing of system and process parameters of the systems at Fraunhofer FEP has been expanded, and various material properties of the thin films on the glass bodies of the lenses have been determined as a function of these parameters. Test substrates were coated at the Fraunhofer FEP facilities and shipped to the project partners to enable characterization along the rest of the value chain. The collected data forms the basis for the development of the AI models of the project partner Otto -von-Guericke University Magdeburg. Over the course of the project, the ontology and AI models will be successively developed further in order to better reflect reality. Based on the models developed, further coatings of test substrates for characterization will be carried out at Fraunhofer FEP and at the project partners to improve the models.

In addition to the optimization of ultrasonic sensor technology, the project results also open up new possibilities for other applications based on thin-film technologies. The digital mapping of the material and process data by the thin-film ontology and the AI models can be reused and transferred to similar coating processes, which will greatly accelerate the research and development of new materials in the future.

Project information

DigiMatUs – Digitalization of materials research on thin-film materials using the example of high-resolution piezoelectric ultrasonic sensors

Funding authority: Federal Ministry of Education and Research
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Project duration: 01.04.2023 – 31.03.2026

Project partners:

- PVA TePla Analytical Systems GmbH
  Digitalization of coating processes and material research of piezoelectric ultrasonic sensors
- scia Systems GmbH
  Definition of the hardware interface to the sensor system
- Plasus GmbH
  Digitalization of process diagnostics for vacuum deposition processes
- Fraunhofer FEP
  Digital description of deposition processes for piezoelectric thin films
- Otto-von-Guericke-Universität Magdeburg
  Ontology development and neurosymbolic predictions for piezoelectric thin-film deposition processes
- Technische Universität Bergakademie Freiberg
  Characterization and simulation-driven optimization of thin-film systems for ultrasound microscopy

More information: www.materialdigital.de/project/16

Cluster systems of the Fraunhofer FEP for pulse magnetron sputtering processes
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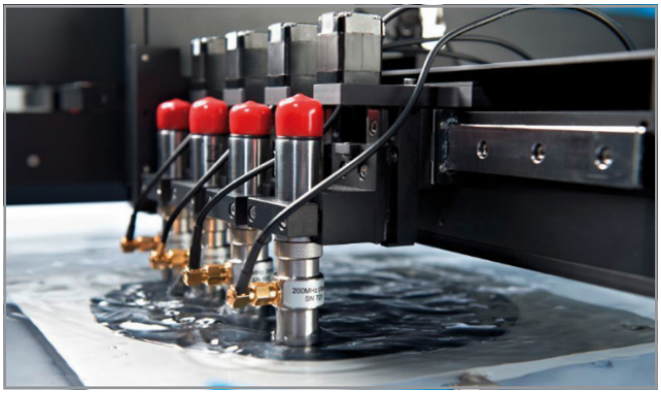

Ultrasonic transducers with integrated piezoelectric thin films
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