FEP

FRAUNHOFER INSTITUTE FOR ORGANIC ELECTRONICS, ELECTRON BEAM AND PLASMA TECHNOLOGY FEP


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1 *Sensor coatings on glass subtrates*
2 *PreciTurn 200 turntable system with clean room connection and substrate transfer station (for substrates up to 200 mm diameter)*
3 *PreSensLine inline deposition plant with clean room connection and substrate transfer station (for substrates of up to Ø 550 mm or 650 mm × 750 mm, up to 120 mm thickness)*

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ELECTRICALLY INSULATING COATINGS

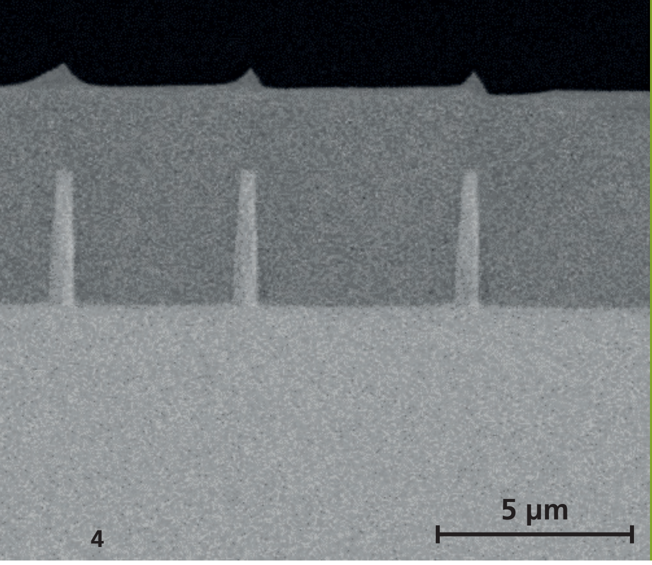
FOR APPLICATIONS IN ELECTRONICS, SENSOR AND MEDICAL TECHNOLOGY

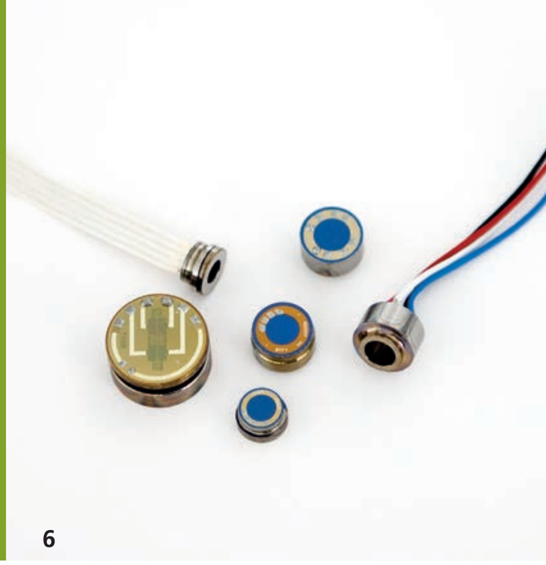
Deposition of highly insulating layers by magnetron sputtering

Some materials, like aluminum oxide (Al_2O_3), silicon dioxide (SiO_2) and silicon nitride (Si_3N_4) show excellent electrical insulation properties with high specific resistance and high dielectric strengths of some MV/cm (megavolts per centimeter). At Fraunhofer FEP, we have developed reactive magnetron sputter processes to deposit such insulating layers with high deposition rates of 2 – 4 nm/s. This allows economical deposition of layers from a few hundred nanometers up to several (ten) micron thickness, with break down voltages of more than 2000 V. This was proven on very different substrates, ranging from Silicon wafers to hardened steel or rough Cu substrates (see Table 1). The reactive magnetron sputter process uses metal targets, like silicon or aluminum in a mixed argon-reactive gas atmosphere. Different deposition plants are available at Fraunhofer FEP equipped with two types of magnetron sources for layer deposition: a double ring magnetron source (DRM 400) for stationary coating of substrates up to Ø 200 mm and a rectangular magnetron (RM 800) for dynamic coating of larger substrates up to 650 mm × 750 mm. Substrates to be coated can be flat or 3D parts.

Achieving complex layer properties

Our expertise covers process development and optimization for highly complex customer requirements, in addition to high electrical insulation. The layers can get high scratch resistance and high barrier properties. They can be used in demanding





environments, such as in chemically aggressive media, at high temperatures, under mechanical loads and in contact with electrolytes. Some already realized complex requirements are:

- High insulating and temperature stable layers for pressure sensors based on a metal sensor body
- High insulating layers on 3D steel components for integrated sensors (e. g. for torque measurement)
- Combination of high electrical insulation with high thermal conductivity, with e. g. thick AlO_XN_Y layers
- Insulating high-k dielectrics by Ta_2O_5 or HfO_2 layers
- Moisture barriers with very low water vapor transmission rate (WVTR) even at low film thicknesses of around 100 nm by e. g. Al_2O_3, $AlSi_XO_Y$, SiO_2 or Si_3N_4 (e. g. $Al_2O_3 \leq 2 \cdot 10^{-3}$ g/m²d at 38°C 90% r.h. on clean PET surface)

Electrical insulation on structured or rough surfaces

Implementation of good electrical insulation of structured surfaces or rough substrates is becoming more and more important for many applications. Fraunhofer FEP has developed processes to improve the coverage of layers on those substrates because only partially covered structural parts can result in much lowered insulation properties. Challenges are especially prevalent in humid or aqueous environments, because moisture can penetrate in small cracks and pores, which in turn can create conductive paths that negatively impact the performance or may even destroy the insulating property. To prevent some of this, suitable process control developed by Fraunhofer FEP has made it possible to deposit insulation layers using one or more smoothing step(s) that fills trenches and structured areas needed to be backfilled. This can be done up to an aspect ratio of approximately 1:1 as demonstrated for the structured surface shown in image 4.

Our offer

Complete project chain from feasibility studies and technology development to transfer of hardware and technology to customer:

- R&D of processes and materials as well as coatings for electrical insulation or other application fields
- Development of application-specific layers and layer systems on flat and 3D substrates, including adapted stress management in the layer and layer systems
- Development and supply of hardware and technology, e. g. DRM and RM sources for industrial coating equipment

Substrate	Deposition material	Layer thickness [µm]	Break down voltage [kV]
Si wafer	$AlSi_XO_Y$	1	0.6
	Al_2O_3	5	> 2.0
	$AlSi_XO_Y$	5	> 2.0
Sensor body	Al_2O_3	5	0.8
	$AlSi_XO_Y$	5	1.2
	$AlSi_XO_Y$	10	2.0
	AlO_XN_Y	10	2.0
Cu submount (rough)	AlO_XN_Y	10	1.9

Table 1: Break down voltage of Al_2O_3, AlO_XN_Y and $AlSi_XO_Y$ on different substrates in dependence on layer thickness

Material	Electrical resistivity [Ω*cm]	Dielectric strength [MV/cm]	Deposition rate [nm/s]
Al_2O_3	$1 \cdot 10^{15}$	4.1	2.5
SiO_2	$9 \cdot 10^{15}$	6.2	4
$AlSiO_X$	$2 \cdot 10^{15}$	5.4	3
Si_3N_4	$1 \cdot 10^{14}$	3.0	2
Ta_2O_5	$2 \cdot 10^{14}$	3.7	2.5

Table 2: Overview of the insulation properties of various sputtered layers measured with a layer thickness of 1 µm on silicon wafers

4 *SEM image of smoothening effect of 5 µm SiO_2 onto structured Si wafer with feature height 3 µm*

5 *Rectangular magnetron RM 800*

6 *Electrically insulation layer systems for pressure sensors*

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