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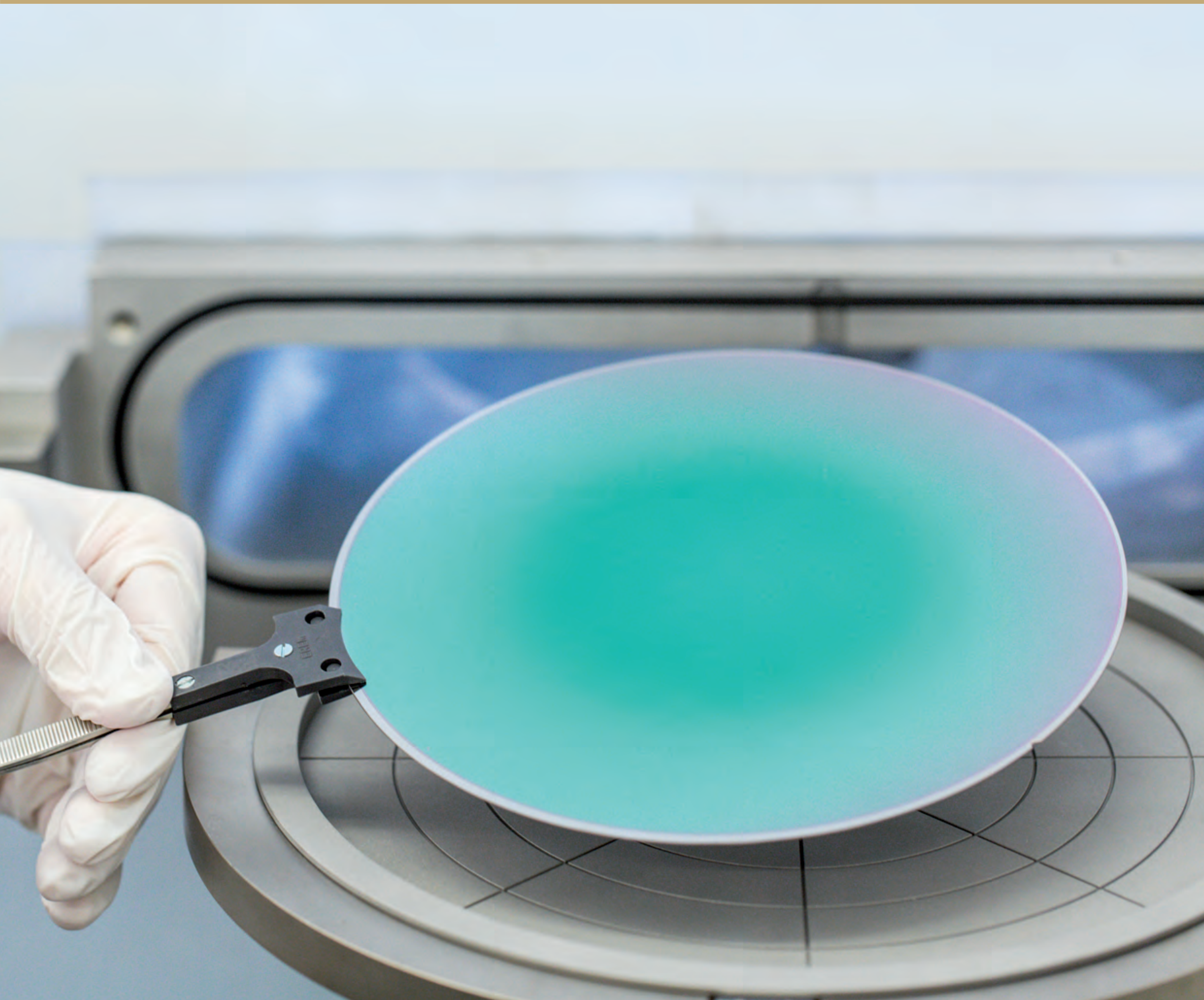
FRAUNHOFER INSTITUTE FOR ORGANIC ELECTRONICS, ELECTRON BEAM AND PLASMA TECHNOLOGY FEP

PRECISION COATING



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Precision coating

Many applications in the field of optics, electronics, sensors, energy and medical technology require highly precise coatings. Fraunhofer FEP develops deposition hardware and technologies for fabrication of those optically, electrically, acoustically and magnetically effective layers and layer systems. The pulse magnetron sputtering and magnetron PECVD processes are optimized concerning precision and long term stability as well as high deposition rate and uniformity even at large substrates. The combination of these processes with precise substrate movement and optical in-situ monitoring ensure reproducible coating properties and precise layer thicknesses.

Reactive pulse magnetron sputtering (PMS) and magnetron PECVD

With reactive PMS, it is possible to deposit compound layers with a high layer quality at high deposition rate.
In this process, electrically conductive targets are sputtered while reactive gas (e.g. O_2, N_2, F_2, NH_3) or a mixture of them is introduced. The layer is formed out of the atomized target material and its reaction with the reactive gas on the substrate surface. The deposition rate is usually one magnitude higher than the one achieved by RF sputtering from the compound target.
In contrast, during the magnetron PECVD process, a precursor is introduced (e.g. SiH_4, HMDSO, TEOS). The plasma causes chemical reactions and the deposition of inorganic, organic or hybrid layers on the substrate. No or only a very low quantity of the target material is atomized and incorporated into the layer. The deposition rate is up to one magnitude higher than the one achieved with reactive PMS.

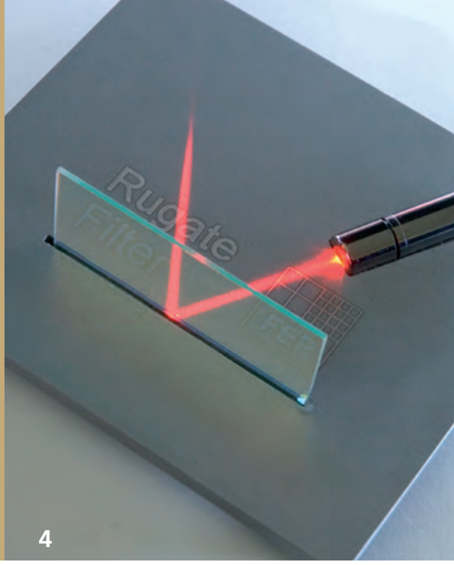
Dynamic / stationary coating

During dynamic sputtering a substrate passes by the sputtering station. This procedure is usually preferred if large substrates or a large number of small substrates arranged on a carrier are to be coated in in-line deposition plants. The substrate remains in front of the sputtering station during stationary sputtering processes. This process is usually preferred for deposition of layers on single substrates (currently for substrates with a diameter up to 300 mm and for substrates with a diameter up to 450 mm in future) or on several small substrates arranged on a carrier in cluster deposition plants.

New possibilities for demanding layer property portfolios

Pulse magnetron sputtering may be carried out reactively, using metallic targets, or non-reactively, using electrically conducting ceramic targets. Thereby, a broad range of materials can be deposited. Beside standard optimization parameters such as process pressure, substrate temperature and substrate bias, new degrees of freedom have been made accessible at the Fraunhofer FEP by developing key components and corresponding technologies.

Using pulsed powering the appropriate setting of pulse mode (unipolar, bipolar, pulse package) and pulse parameters (frequency, duty cycle) allows controlling energy input into the growing layers. Thus, previously unachievable layer properties and property combinations may be set simultaneously with high coating rates. System integrated controlling of process parameters (pressure, reactive gas flow and magnetic field strength) over target lifetime ensure long term stability and reproducibility of the plasma conditions and thus of the layer properties.



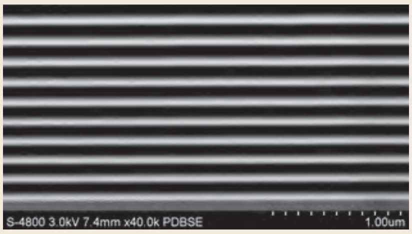
Application examples

Optical interference coatings

- optical filters for laser optics, spectroscopy applications
- anti-reflex layers on lenses for glasses

- SiO_2, Si_3N_4, Ta_2O_5, TiO_2, Al_2O_3, HfO_2, Nb_2O_5
- low thermal load on the substrate
- good adhesion and durability even on plastic substrates
- very low absorption and scattering losses
- deposition rates 1 ... 4 nm/s

SEM image of a $Si_XTa_YO_Z$ gradient-coating system (rugate design)

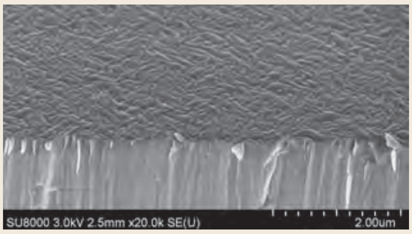


Piezo-electric layers

- for micro-systems (MEMS), BAW, SAW
- for ultrasound microscopy
- for energy harvesting

- crystalline AlN and AlScN layers with high c-axis orientation
- deposition rates: 2 … 4 nm/s
- piezoelectric coefficients up to d_{33} = 30 pm/V

SEM image of an AlN layer with strong c-axis orientation

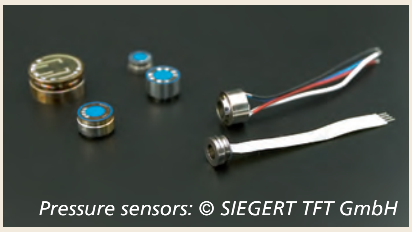


Electrical insulation layers

- for sensors (also component-integrated)
- for microelectronics
- for photovoltaics

- Al_2O_3, SiO_2, Si_3N_4 as thin-film insulation with very good insulating properties
- high deposition rate: 2 ... 4 nm/s (10 times higher than by RF sputtering)
- effective deposition of thick insulation layers with electric strength of up to 1500 V
- on flat and 3-dimensional substrates

Pressure sensors with electrical insulation layers



Layer type	Examples	Deposition rate [nm/s]
metals	Al, Cr, Cu, …	15 … 25
alloys	Ni/Al, NiV_7, CoNiCr…	10 … 15
binary compounds	Al_2O_3, AlN, AlF_3, SiO_2, Si_3N_4, TiO_2, Ta_2O_5, Nb_2O_5, TaN, HfO_2, ….	2 … 4
ternary compounds	$Si_XO_YN_Z$, $Al_XO_YN_Z$, $Si_XTa_YO_Z$, $Al_XSc_YN_Z$	2 … 4
gradient-coating systems	$SiO_2 \rightarrow Si_XO_YN_Z \rightarrow Si_3N_4$ $Al_2O_3 \rightarrow Al_XO_YN_Z \rightarrow AlN$ $SiO_2 \rightarrow Si_XTa_YO_Z \rightarrow Ta_2O_5$	2 … 4
hybrid compounds	$Si_XC_PO_QH_R$, $Si_XC_PO_QN_R$, $Si_XTi_YC_PO_QH_R$	5 … 15

Passivation, protection and barrier layers

- for sensors
- for electronic components

- Al_2O_3, SiO_2, Si_3N_4
  - as diffusion barriers for sensor elements, for photovoltaics and for organic electronics
  - as an etching-stop layer
  - as a passivation layer

Titanium-dioxide layers

- photocatalytic, antibacterial
- photo-induced superhydrophilic
- for gas and moisture sensors

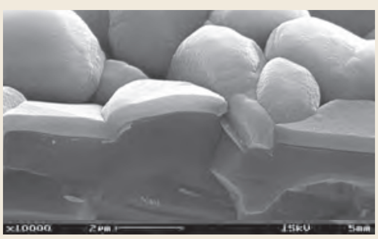
- hardness may be adjusted from 7 … 14 GPa
- refractive index (VIS): n = 2.4 … 2.7 adjustable
- structure: amorphous, crystalline (anatase, rutile)
- superhydrophilic after 30 minutes of UV-A irradiation (1 mW/cm²)

Functional layers

- for surface-wave components
- for electronic and MEMS components

- SiO_2 layers for improved temperature stability in SAW components
- TaN layers for thin-film resistors

SiO_2 as a passivation layer for thin-film resistors



Superhydrophilic titanium-dioxide layer (right)

Surface-acoustic-wave (SAW) components

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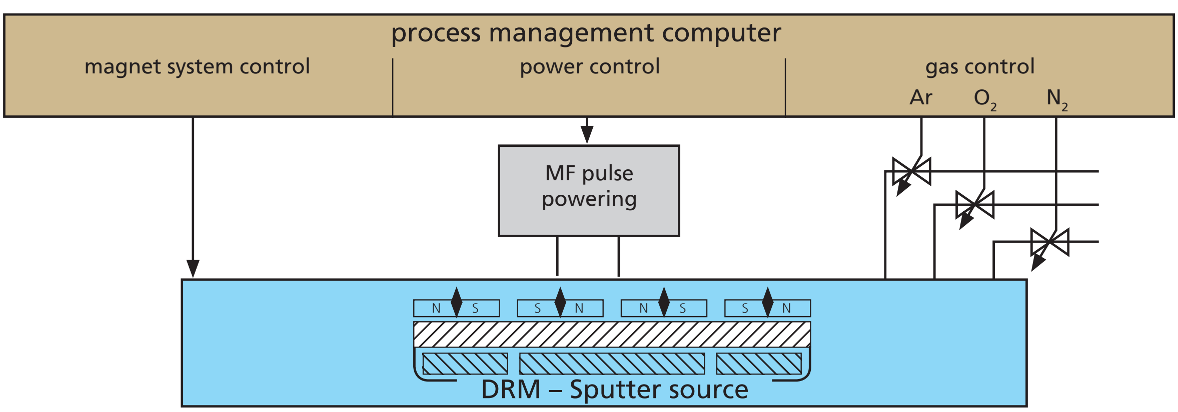
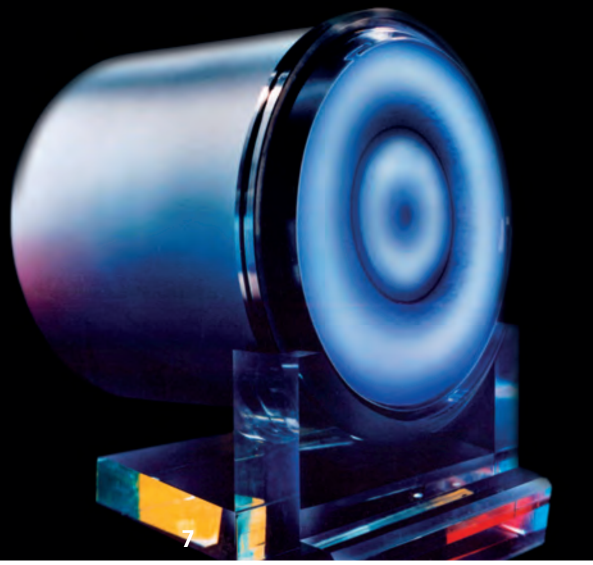
Integrated package with double ring magnetron (DRM) (schematic)





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Integrated hardware packages

Fraunhofer FEP develops key components for reactive pulse magnetron sputtering. Together with the processes and technologies adapted for coating, these key components (integrated packages) can extend the capabilities of new and existing coating systems.

Sputtering sources

- rectangular magnetron (RM), up to 2 m, for dynamic coating
- multiple ring magnetron (MRM) sources for stationary coating
    - homogeneous layers regarding thickness and layer properties currently up to 200 mm diameter, in future up to 450 mm
    - separately controllable concentric plasma discharges, two or three rings, possible
    - adaptation of layer thickness distribution to curved surfaces

Pulse power supplies

Two types of pulse-power supplies – UBS-C2 and i-PULSE® – have been developed for different applications and performance ranges (up to 60 kW). They enable new freedom degrees with regard to control of layer properties by adjustment of pulse mode and pulse parameters.

Process-control units

The PCU*plus* and S-PCU devices are used to control reactive sputtering processes. They enable stabilization of the reactive sputtering process in the transition mode between metallic and reactive mode. In addition, they allow deposition of stoichiometric layers at very high coating rates, 5 to 10 times higher than in fully reactive mode. For reactive process control the actual values of characteristic process parameters are measured and are used to adjust the reactive gas introduction with a closed loop control. With S-PCU, optical emission spectroscopy is also possible.

Our offer

- development and optimization of coating technologies, reactive sputtering processes and coating systems for your applications
- coating of samples and pilot production
- development of key components such as magnetron sputter sources, plasma-etching sources, process-control units adapted to the requirements of the coating tasks
- transfer of integrated packages, consisting of key components, fully automatic process and control systems as well as technology, into production plants
- assistance with cost estimation and technical implementation into deposition plants

TITLE PHOTO

Application examples

1 *Functional coating on 300 mm wafer*

2 *CLUSTER 300 – test facility for stationary magnetron sputtering*

3 *Plastic lenses for eyeglasses with and without anti-reflective coating*

4 *Rugate filter for narrow-band laser reflection*

5 *Dichroic filter with reflection in the blue spectral range*

6 *PreSensLine – test facility for precision coating on large substrates*

7 *Double ring magnetron (DRM) with plasma discharge*

8 *Rectangular magnetron RM800*

9 *Integrated package with DRM 400, UBS-C2 and PCU*plus

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