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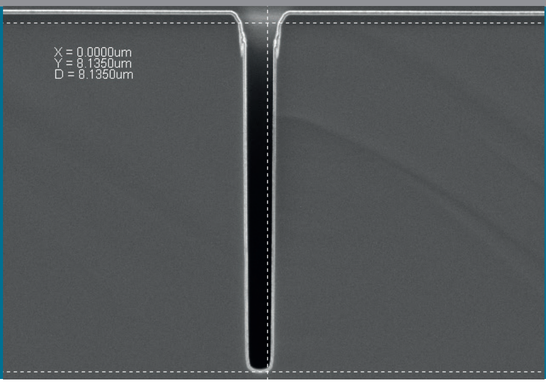
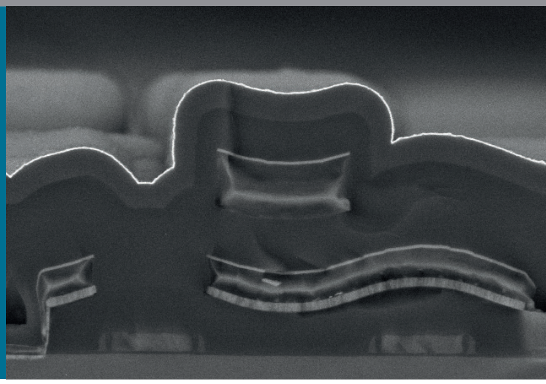




1 *Conformal ALD-layer deposited in a trench*

2 *ALD-Passivation layers on CMOS-Passivation*

ALD – CATALYST FOR NEW MEMS/NEMS DEVICES

Fraunhofer Institute for Microelectronic Circuits and Systems IMS

Finkenstraße 61
D - 47057 Duisburg
phone +49 203 37 83-0
fax +49 203 37 83-266
www.ims.fraunhofer.de

contact
Michael Bollerott
phone +49 203 3783-227
vertrieb@ims.fraunhofer.de

Atomic layer deposition (ALD): an advanced process technology as a catalyst for new MEMS and NEMS devices

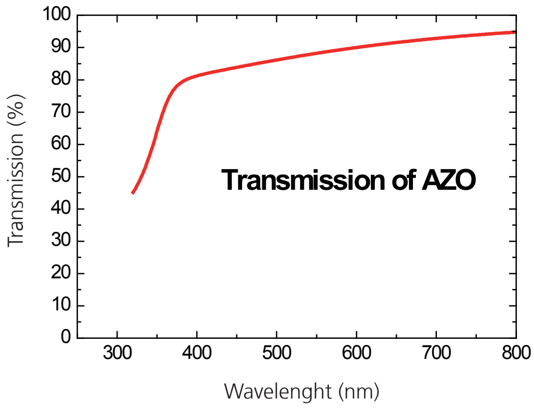
Protective media resistent layers for sensors, optical coatings, high C trench capacitors, new NEMS devices for gassensors, biosensors with nanowires, ultrathin freestanding membranes: all this is possible with the ALD-technique (Atomic Layer Deposition)

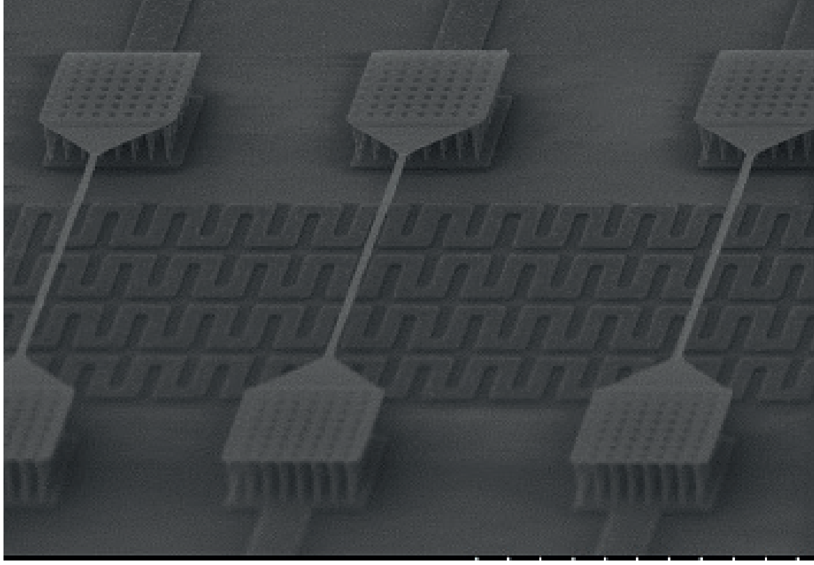
ALD is a thin layer deposition process that relies on chemical surface reactions of at least two chemical precursors that enable layer-by-layer growth of high quality films with thicknesses in the range of typical 1-50 nm. Due to the fact that an increasing range of precursors is available a wide range of materials for different application purposes can be addressed. The key advantages of this process can be summarized as follows:

- Very high conformity of the deposited films (see figure 1). A very good side wall coverage of high aspect ratio trenches and holes with ALD-films enables applications for 3D-technologies.
- The deposited films are of high quality and nearly pin hole free
- A growing material diversity is available covering metals, insulators, high-k dielectrics, sensor and optical materials and transparent conductive oxides.

Since the deposition temperatures are comparatively low, ALD-layers can be deposited on CMOS-wafers without any harm to the circuitry. FhG IMS can offer you both from one source.
Thus the atomic layer deposition technique can be utilized for various MEMS- or NEMS (MEMS/NEMS: Micro/Nano Electro Mechanical Systems) and CMOS related applications such as:

- Protective media-resistant layers for sensor devices such as pressure sensors or for encapsulations of medical implants. In figure 2 an additional ALD layer stack on a non planarized CMOS-passivation is depicted as an example.





- Aluminium oxide and tantalum pentoxide are available. Further ALD-materials can be implemented at IMS.
- Electrical or optical shielding can be achieved by metallic layers as ruthenium. Furthermore ALD-layers can be utilized as transparent conductive electrode layers e.g. for optical sensors or solar cell applications (see figure 3).
- Due to its high conformity ALD can be used as an insulating material in trench capacitors. Advantageously high- and medium-k dielectrics are available for trench capacitors. IMS currently develops trench capacitors for high temperature (more than 250°C) applications on basis of ALD layers.
- A very cost effective 3D-NEMS-technology has recently been developed at IMS that enables the creation of free standing Nanostructures on CMOS-surfaces with only few additional lithographic masks (patent pending). This technology is based also on ALD-deposition.

This novel technology offers the possibility to create freestanding 3D-MEMS or NEMS-structures with wall thicknesses in the nm-range on top of CMOS-surfaces. Due to the availability of a multitude of ALD-materials with different physical and chemical properties and due to the properties related to the free standing structures e.g. nanoscale wall thickness, the low mechanical and thermal mass etc., such structures are ideally suited for advanced sensor applications such as gas- or biosensing e.g. by nanowires or mechanical sensing ultra-thin membranes or cantilevers. In figure 4 free standing Ruthenium-Nanowires generated on a CMOS-passivation are depicted as an example.
A special advantage of this novel technique is connected to the possibility of post-CMOS integration, that enables the development of novel intelligent CMOS integrated sensors or actuators.

At IMS the ALD-technique is available for 200 mm-wafers which is compatible to the IMS 200 mm CMOS wafers. Special solutions for arbitrarily shaped devices as packaged sensors or special materials can be implemented upon request.

3 *Transmission of ALD-deposited aluminum doped zinc oxide (AZO) serving as a transparent conductive oxide*
4 *free standing 3-D nanostructure based on ALD*

Available ALD-Materials

Material	Typical deposition temperature	Film Homogeneity	Film resistance (typical)	maximum thickness	Typical Application
Al2O3	200 °C 300 °C	98 %	-	50 nm 75 nm	Protection layer, medium-k dielectric
Ta2O5	275 °C	90 %	-	15 nm	Protection layer, high-k dielectric
ZnO	200 °C	96 %	5240 µΩcm	75 nm	Transparent, conductive layer
AZO	200 °C	96 %	2075 µΩcm	75 nm	Transparent conductive layer
TiAlCN	400 °C	80 %	560 µΩcm	100 nm	Conductive layer, barrier function
[illegible]	400 °C	75 %	140 µΩcm	10 nm	Conductive layer, barrier function
[illegible]	350 °C	85 %	20 µΩcm	75 nm	Conductive layer, electrical and optical shielding