Fraunhofer ISC

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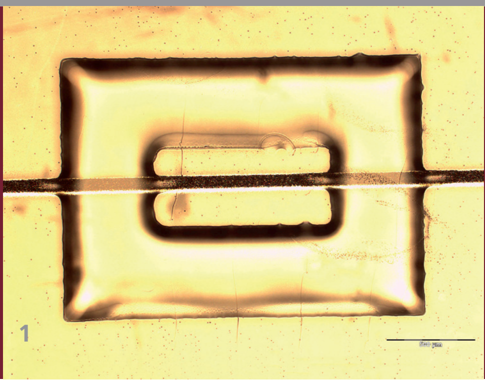


Typical material properties of ORMOCER® dielectrics	
Viscosity	> 0.1 Pa*s
Surface tension	25 mN/m – 40 mN/m
Spec Resistivity	10^{-13} Ω cm
Diel permittivity (@ 1 MHz)	2.5 - 5
Layer thickness	100 nm – 100 µm
Patternable by UV light (negative tone behaviour)	
Soluble in a wide range of different solvents	

1 *Examples of ORMOCER® patterns manufactured by ink-jet printing*

GATE DIELECTRICS AND PASSIVATION MATERIALS FOR PRINTED ELECTRONICS

Motivation

Besides organic semiconductors, gate dielectrics and passivation materials play a crucial role for the performance of electric components in respective devices. As is the case in conventional microelectronics, the properties of dielectrics have to be discussed even more when thinking about printed electronics.

This is due to 3 reasons:

- In order to address low-cost production (reel-to-reel, high throughput techniques), the material has to be processed by certain fast application methods, but yielding a high degree of reproducibility.
- Due to the high sensitivity of many printable semiconductors, the dielectric interface has to be adapted exactly on to the used semiconducting polymer in order to achieve the best performance.
- In contrast to conventional microelectronics, the requirements on the (dielectric) material differ considerably when built-up or process sequence for electronic devices is changed.

In consideration of these aspects the Fraunhofer ISC is skilled to develop higly tailored dielectric materials on basis of inorganic-organic hybrid polymers (ORMOCER®s), a material class which excels by its flexibility with respect to applicable chemical groups and the chemical and thermal stability.

Concept and features of ORMOCER®S

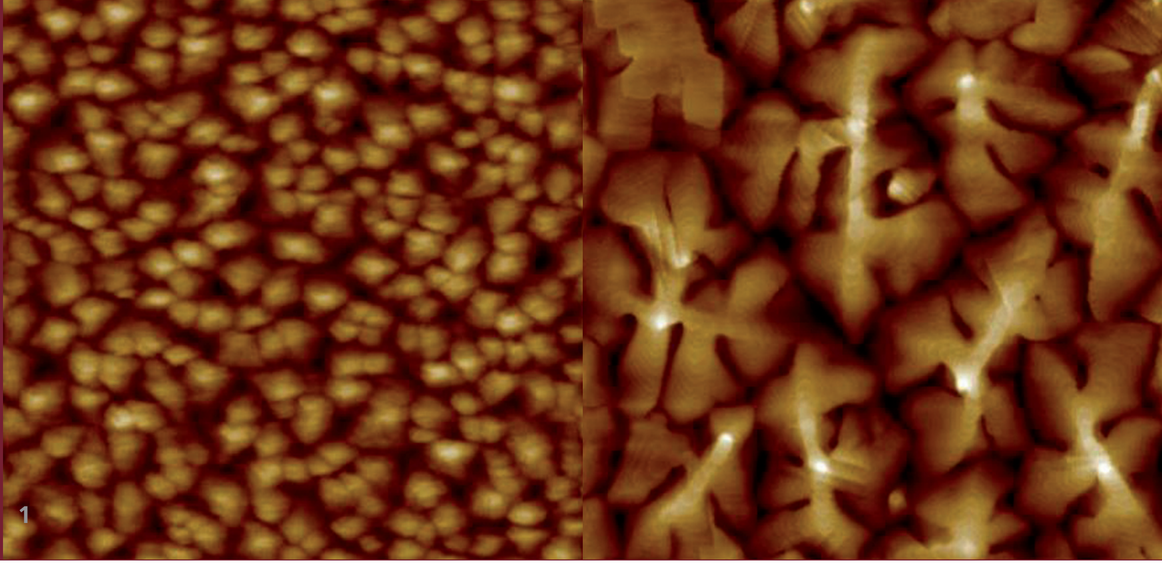
Based on more than 2400 starting products which differ in their organic functionality but are similar in the attached reactive inorganic functions, nano-sized inorganic oxide units can be formed by sol-gel chemistry

Fraunhofer-Institut für Silicatforschung ISC
Neunerplatz 2
97082 Würzburg, Germany

Contact
Competence Team Hybrid Materials for Microsystems and Micromedicine

Gerhard Domann
Phone +49 931 4100-551
gerhard.domann@isc.fraunhofer.de

www.isc.fraunhofer.de



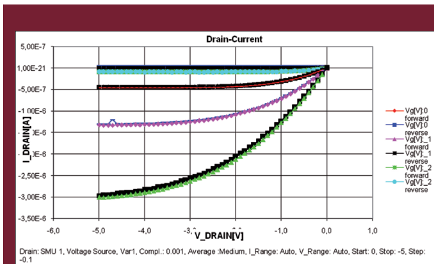
at low cost. These so called oligomers will later ensure the mechanical and thermal stability. In a second step upon their application (all techniques can be used) on substrate, semiconductor or other surfaces as resin or lacquer, these inorganic units will be crosslinked organically by UV- or thermal initiation of their organic reactive functions. Forming an inorganic-organic network at molecular scale, the resulting material offers unique properties and is easily tunable towards technology and application.

Processability

The processibility properties of ORMOCER® materials can be adjusted in two different ways: The ORMOCER® material itself can be modified by changing the ratio between organic and inorganic parts, or by introducing certain chemical moieties, such as e.g. aromatic, aliphatic groups etc. Besides, due to the fact that the ORMOCER® material is – in contrast to many purely organic polymers – a resin and not a solid, it offers more possibilities to solve the material in a wide range of diluters, and to add supplemental monomers and additives. Thus, the material is easy to formulate. Therefore, ORMOCER®s can be applied by a lot of printing techniques (e.g. ink-jet printing, screen-printing). When applied as a non-patterned film, spray- and dip coating methods can be used amongst others. In this case, a subsequent patterning can be realised by UV lithography, nanoimprint lithography or ablation techniques. Due to the fact that the materials can be cured by UV-light it is not necessary to carry out high-temperature processes. Therefore, the material is suited to be processed on PET foils which have a thermal stability of ~ 125 °C. These properties combined with the high chemical stability and the ability to act as a barrier for water vapour and oxygen renders it an ideal material for the passivation of printed devices.

Interface design

During the last decade it has turned out that certain chemical moieties may be beneficial / detrimental for the electronic states on the interface between organic semiconductor and dielectric. The presence of –OH groups, for example, may lead to a trapping of electrons which increases the mobility of p-type semiconductors such as pentacene. Moreover, regarding pentacene based devices, the ORMOCER® material can be tuned to be a proper substrate for an adequate growth of pentacene crystallites. Additionally, due to the chemical structure of ORMOCER® oligomers, most ORMOCER®s provide a very planar surface with a rms roughness below 1 nm.



Characteristics of Pentacene bottom-gate transistor using a 100 nm thick ORMOCER® dielectric; V_{on} = 1 V; μ = 0.25 cm²/Vs; σ_{rms} = 0.36 nm

Device built-up

Depending on the semiconductor used and the favoured process technique, different types of device built-ups are required. Thus, bottom-gate and top-gate transistors are designed with different dimensions regarding the source / drain contacts (ratio between channel width and length). Each built-up causes different requirements on the dielectric such as the use of "orthogonal" solvents as diluter in order to avoid damaging of the underlying organic semiconductor, or a vacuum stability when subsequent material applications takes place in vacuum-in line machines.

Further features of the material

The fact that the material is transparent in the VIS regime makes it usable also for optical devices such as displays etc. Additionally, the limits of the material can be further extended when incorporating purely inorganic particles. In this case, the ORMOCER® material can be used as a matrix for high-k materials, for instance.

1 *Improvement of growth of pentacene grains by changing the chemical composition of the ORMOCER® dielectric surface measured by AFM. The lateral length is equal to 5 µm*