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Novocontrol opens the avenue for dielectric measurements at nanometric length scales – *the Novocontrol NanoKit*

Introduction

Dielectric measurement techniques are distinguished by the fact that its sensitivity increases with decreasing thickness of a sample capacitor and hence decreasing amount of sample material. In order to benefit from this unique *principal* advantage the technological challenge has to be resolved how to apply an electric field to nanometric and - if so - submolecular layers of molecules in a capacitor-like arrangement. It is evident that the conventional approach to evaporate a metal counterelectrode on the molecules under study is no longer applicable because it would result immediately in electric shorts.

With the Novocontrol *NanoKit* a novel avenue is opened to study molecular relaxations and charge transport on nanometric length scales even down to layers of isolated molecules which might be anchored on a surface. For that nanostructured electrode arrangements are employed having highly insulating spacers made out of SiO₂ with heights down to 100 +/- 10 nm. As electrodes highly doped ($\rho \sim .002 \Omega\text{cm}$) Si-dices are used cut out of ultraflat wafers having a rms-roughness of ~ .5 nm. The molecules under study are either deposited by spincoating on the substrate or by Dip-Pen-Nanolithography (DPN). A sample capacitor is realized by covering the dice with the molecules under study by a similar dice being accomplished with nanostructured insulating spacers. Evidently preparations of this type require appropriate conditions like clean-rooms or clean-benches. Furthermore one has to realize that in nanometric samples the surface-to-volume ratio is extraordinarily high and thus effects caused by adsorption for instance of H₂O or organic pollutants from ambient air must be handled with great care. In the Novocontrol *NanoKit* the details of preparation are described thoroughly thus making measurements of this type a straightforward endeavour and – after a short training - easily possible. Eventual pitfalls in the preparation of thin molecular layers are discussed.

Installation requirements

It is evident that preparations of the capacitor having thicknesses down to 60 nm must be carried out under cleanroom conditions or at least in a flow box with filtered air. It is recommended to use filters of grade H14 which means that more than 99,995% of dust particles are separated. Commercial systems are offered for instance by spetec Ges. für Labor- und Reinraumtechnik mbH (www.spetec.de), Bleyemehl Reinraumtechnik GmbH (www.bleyemehl.com) or erlab D.F.S S.A.S (<http://captair.com>).



Fig.1: Content of the Novocontrol NanoKit



Fig.2: Sample cell

Preparation hints

To remove organic absorbents both, the plane and the nano-structured dice (which are protected with a photoresist layer) are rinsed in acetone (at least VLSI-grade) and ultra-sonicated for 2 minutes followed by drying in pure nitrogen. Despite the cleaning, organic pollutants might still remain at the surface of the plane and the nanostructured dice. In this case it is recommended to repeat the cleaning process and to employ a plasma cleaner and a CO₂ snow jet, if available. If an electric short is observed one should separate the plane and the nanostructured dice and bring them in contact at a slightly different position again. Both, the plane and the nanostructured dice can be reused after thorough purification.

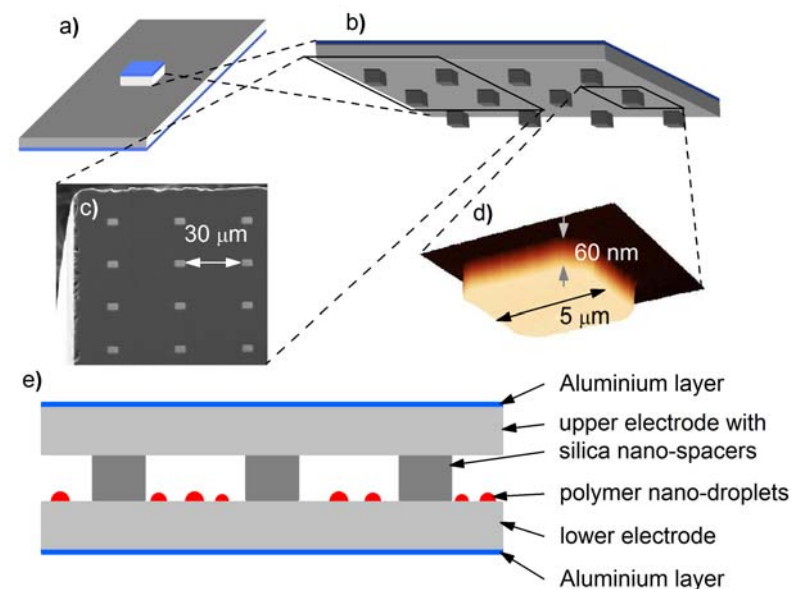


Fig.3:

a) Sketch of the 4×10 mm² large supporting electrode covered by the 1×1 mm² sized counter electrode. b) Schematic enlargement of the counter electrode tilted to show the spacer array which faces the sample on the bottom electrode. c) Scanning electron microscopy image of the regular array of nano-structures and d) 3D animation of an AFM height image of a single nano-structure. e) Scheme of the sample cross section (dimensions not to scale).

Preparation of nano-structured capacitor arrangements

Low molecular weight probes or polymers are deposited on the plane dice by spin-coating at for instance a rotation frequency of 50 rounds/second. In case DPN small numbers of molecules are transferred to the plane dice by use of an appropriate cantilever. In view of the fact that both techniques require to dilute the molecules of interest in a solvent it is necessary to anneal the sample at elevated temperatures for an extended period of time in an oil-free vacuum ($\sim 10^{-6}$ bar). Afterwards the two dices are attached to each other as indicated in fig.3a and mounted in the sample cell (fig 2). The latter fits directly into the usual Novocontrol sample holder.