Cryoelectronic Characterization of Organic Molecules

Matthew Kiok
Chemistry, Tulane University

NNIN iREU Site: Institut Für Bio- Und Nanosysteme (IBN), Forschungszentrum, Jülich, Germany
NNIN iREU Principal Investigator: Professor Doctor Roger Wördenweber, Peter Grünberg Institut 8
NNIN iREU Mentor: Tino Ehlig, Peter Grünberg Institut 8
Contact: mkiok@tulane.edu, r.woerdenweber@fz-juelich.de, t.ehlig@fz-juelich.de

Abstract:

The temperature dependence of electronic properties of conducting and semi-conducting materials is a well-studied phenomenon, with many interesting effects in low temperature ranges. This project sought to develop a method by which the temperature dependence of capacitance of gold on glass or sapphire inter-digitated capacitors could be characterized, in addition to their inherent frequency dependence. The purpose of this was to establish a reference capacitance for each substrate, such that the capacitance of subsequently deposited or grown organic monolayers could be calculated independently of inherent capacitance via subtraction of the coated samples' values from the reference values. This is especially pertinent in the lower temperature ranges (sub 100K) as unusual effects have been observed previously, especially with ferroelectric materials. The capacitors were first fabricated via photolithography, gold deposition, and liftoff processes in the cleanroom. Afterwards, their capacitance was measured across a wide range of temperature and frequency, from 50K to 300K and 20 Hz to 2 MHz respectively.

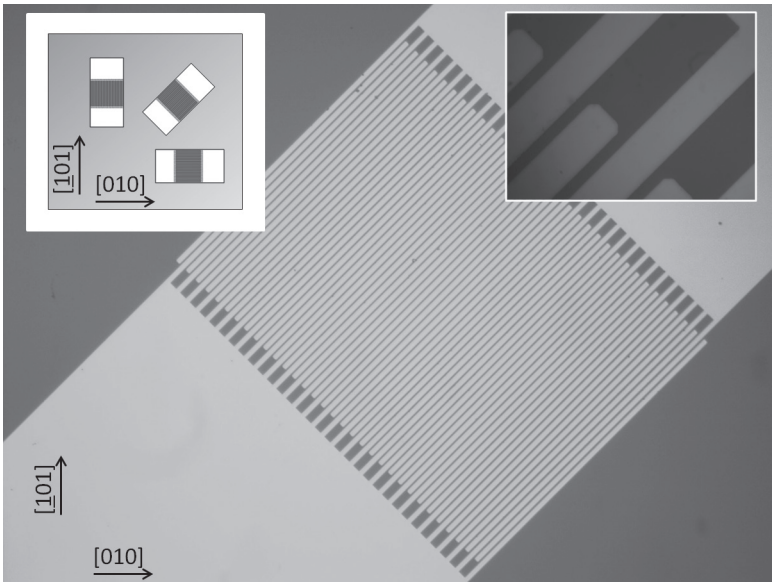

Figure 1: Structure of the interdigitated capacitors and the three orientations.

With referencing complete, the samples underwent oxygen plasma cleaning, followed by silinization in an inert atmosphere with octyltrichlorosilane under various pressures and concentrations of the reagent to yield organic monolayers on the substrate surface. The presence of monolayers was verified via contact angle measurements. Finally, the capacitances of the newly coated substrates were measured in the same fashion as the references and their results compared. For octyltrichlorosilane, no noticeable difference in capacitance was measured.

Experimental Procedure:

Interdigitated capacitors of three orientations made of gold were initially fabricated in the cleanroom. The capacitors were patterned onto glass and sapphire substrates and exposed by contact lithography for 4.7 seconds. The metal was then sputtered onto the samples under reduced pressure. The purpose of the three orientations was to determine the best position for perpendicular deposition. Liftoff was performed outside the cleanroom in acetone under sonication. Each "finger" of the capacitor was approximately 10 μm wide and separated by 5 μm. Afterwards, one orientation of the capacitor was bonded to a probe and the capacitance was measured under varying temperature and frequency; 50K-300K and 20 Hz to 2 MHz. This was repeated for the other two orientations.

After a reference capacitance had been established for the capacitors, they underwent oxygen plasma cleaning in order to provide a clean surface for subsequent silinization. The silinization process entailed leaving the substrate in an enclosed system with liquid octyltrichlorosilane under reduced pressure for one hour. Contact angle measurements were performed before and after silinization to verify deposition on the substrate surface. Measured values before silinization were approximately 0 to 5°, and post silinization values ranged from 90 to 110°, suggesting deposition of mono and bi layers. The capacitance for the newly silinized samples was measured in the same manner as the reference samples.

The results were compared and no noticeable difference was observed between the silinized and reference sample.

Results and Discussion:

As stated previously, this project sought to develop a process by which the electrical properties, the dielectric constant specifically, of various organic molecules could be measured and calculated. Several issues had to be addressed in order to optimize the process, namely fabrication defects, short circuits, and adhesion problems. Despite the relatively large scale of the structures, the samples demonstrated extraordinary sensitivity to fabrication parameters such as exposure and development times. Even the best samples were still prone to developing defects during the liftoff stage, where a small amount of residual gold could result in a short circuit in the capacitor. Finally, bonding certain samples to the probe was problematic due to the poor adhesion between the bonding wire and the metal. This issue was resolved through creative positioning of the bonding wire and the use of conducting paint as a glue to assist bonding. The final remaining issue is whether or not this process is sensitive enough to detect differences between reference and silinized samples. Due to time limitations, only octyltrichlorosilane was measured, and more alkylated silane derivatives need to be tested before a conclusive result can be obtained.

Acknowledgements:

The author would like to thank Professor Roger Wördenweber, Tino Ehlig, Thomas Grellmann, Eugen Hollmann, and Kirill Greben for their assistance and kindness both in and out of lab. Additionally, this project would not have been possible without the National Nanotechnology Infrastructure Network International Research Experience for Undergraduates (NNIN iREU) Program and the generosity of the National Science Foundation.