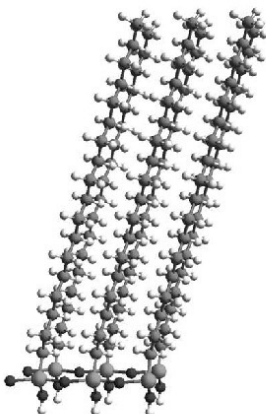




Martin Rittner (Autor)
**Elektronische Bauelemente auf der Basis
selbstorganisierter molekularer Monolagen**

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Abstract

This work is dedicated to the investigation of organic materials with respect to their electrical transport properties and their possible use in transistor devices. The results are presented in three essential parts. The first part describes the electrical properties of isolating dielectrics which are manufactured by plasma enhanced deposition techniques. The second part describes the field-effect-characteristics of vacuumsublimated oligothiophenes and the third part describes the electrical characteristics of self-assembly-monolayers.

First siliconoxide and siliconnitride layers are characterized and also their quality properties are determined. Thereby of particular interest is the maximization of their electrical isolation in dependence on the deposition parameters. To perform this the method of orthogonal process design is applied. The current-voltage-characteristics of the dielectrics show the typical charge carrier transport mechanisms. For siliconoxide the Fowler-Nordheim tunnel process is observed as the dominant mechanism under high electric field strengths. For the siliconnitride Frenkel-Poole excitation is observable under high electric field strengths, although there is a relatively large leakage current appearing in the low field region. The dielectric breakdown field strengths were determined for the oxide to about 8,5 MV/cm and for the nitride to about 7,2 MV/cm. Nevertheless the rather good results for the oxide, the layers were not sufficient to built up

high performance gate isolations in organic-field-effect-transistor (OFET) structures. Therefore these devices are realized on a thermally grown oxide. The first part will be finished with the results of the fourier-transform-infrared-spectroscopy (FTIR). These measurements were performed to confirm that siliconoxide and siliconnitride were actually deposited. All vibrational modes of the oxide could be detected in the observable range of wavenumbers. The position of one mode in the spectra showed that the oxide layers are deposited under stress but can be annealed under a rapid thermal annealing procedure. Although the molecular oxygen carrier component is N_2O no nitride modes are detected. This will be related to the high argon concentration which acts as a carrier gas for the silan. In the deposited nitride layers the typical vibrational modes are observed.

Second the properties of organic-field-effect-transistor devices are described which were manufactured by vacuumsublimated oligothiophenes. The measurements were performed on quater-, quinque-, sexi- and octithiophenes. All devices show accumulation mode characteristics under negative gate bias, which is related to positively charged mobile polarons and negatively charged immobile polarons. The determination of the charge carrier field effect mobilities in dependence on thiophene chain length was possible, whereby the calculation procedure for the field-effect-mobility has been primarily performed from the drain-current-characteristics in the saturated regime of the device. The results showed that the polycrystalline structure of the deposited organics depends on the oligomere chain length, too. All oligothiophenes are doped from the oxygen of the ambient atmosphere less or more fast. A leakage current through the gate is observed. This is related to the evaporation of the active organic semiconductor over the whole sample area. The determined values varied between $3,2 \cdot 10^{-5} \text{ cm}^2/\text{Vs}$ for the quaterthiophene, $4,8 \cdot 10^{-3} \text{ cm}^2/\text{Vs}$ for the quinquethiophene, $1,0 \cdot 10^{-3} \text{ cm}^2/\text{Vs}$ for the sextithiophene and $3,9 \cdot 10^{-5} \text{ cm}^2/\text{Vs}$ for the octithiophene. These results show

that the macroscopic mobility is not only depending on the chain length but on the structural properties of the deposited layers too.

Third the electrical characteristics of self-assembly-monolayers (SAM) are investigated. The SAM consist of an anchor-group which must be related to the chosen substrate, an alkyl-chain skeleton which perform the layer built up through its van-der-Waals-interaction and a chain termination which is variable with specials groups. Such SAM were prepared on two silicon-wafer-systems. Depending on the anchor-group of the SAM one system was chosen as hydroxilated (100)-Si and the other as oxidefree (111)-Si. On the hydroxilated System DC current-voltage-characteristics were performed on sandwich structures. Degenerated n^{++} - and non-degenerated p^- -Wafers were therefore used as substrates, the SAM as insulating layer in between and a gold or aluminium metallization as counter electrodes. In these measurements the current densities depend in quantity of the chosen terminating group, which is also related to the total thickness of the monolayer and in quality of the chosen counter electrode metallization. These properties point to the tunnel mechanism as the dominant charge carrier transport mechanism along the chain. Therefore this sandwich structures can be denoted to metal-insulator-semiconductor tunneldiodes. Also we assume that no metal should penetrated the SAM or diffused between the SAM molecules. Further results were gained by performing AC measurements. The applicability of these is shown by the determination of the doping concentrations of the silicon wafers and the determination of the relativ dielectric constant. Later has to be assisted by x-ray reflectivity measurements which aimed on the determination of the monolayer thickness. The doping concentration values which were found are in good agreement with the specifications of the manufacturers. The determined typical values of the dielectric constants lie in the range of $\epsilon_r \approx 1,8$. Furthermore pretty high dielectric breakdown voltages are observed. Depending on the investigated

termination and the chosen metallization typical values has been found in the range of 9 to 15 MV/cm. The biphenyl-termination with aluminium counter electrode even showed values up to 20 MV/cm.

On the oxidefree system DC current-voltage-characteristics were also performed on sandwich structures with non-degenerated p⁻-Wafers. Dependencies on chain-length and chosen contact metallization are also observed in this system.

Further characterizations aimed to the lateral conductivities of the terminations. Most favourably with respect to conductivity appeared the biphenyl system, the termination with the largest π -electron-system in this work. This SAM was built up on high insulating quartz substrate. But no conductivity through the terminating group can be found for the undoped SAM. From the two possible dopants, FeCl₃ and I₂, the FeCl₃ doping shows a rise in conductivity which is related to parasitic currents. But the iodine doping finally leads to a detectable rise in conductivity without any parasitic effects.

Because of their easy modification and their regular structure SAM seem to be ideal candidates to perform OFET-structures. At the end the resulting experiences and knowledges about vertical and lateral conductivity are fused to built up an organic-field-effect-transistor based on a SAM system. Unfortunately the bad ratio between the maximum lateral current and the vertical leakage tunnel current made any detection of field-effect impossible.