STUDY OF ORGANIC FIELD-EFFECT TRANSISTORS FROM POLY-3-OCTYLTHIOPHENE SOLUTIONS ON DIFFERENT GATE DIELECTRICS

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One promising field of application of organic transistors is electronics on flexible substrates. In order to achieve this, the thermal SiO_2 dielectrics often used for research purposes has to be replaced by a gate dielectric that can be deposited at low temperatures.
On one hand side, this dielectrics should be processable from solution in oder to ease the process, to enable printing technologies, and to end up with a fully organic low-cost transistor. On the other side the gate capacitance should be as high as possible in order to allow low gate voltages for current control. This calls for thin dielectrics with high permittivity and high ultimate field strengths. Unfortunately, common soluble polymer dielectrics do not show high permittivity, and common anorganic thin film dielectrics have to be vacuum deposited to keep their good electrical properties.
We developed and studied organic thin film transistors using comercially available poly-3-octylthiophene (P3OT, Aldrich) as semiconductor on different gate dielectrics from different processes on rigid substrates of $Si/SiO_2/Al$ and Si, respectively: Benzocylobutene (BCB, Dow) has been spun on from solution, Al_2O_3 has been anodically grown on aluminum gate from tartaric acid based electrolyte solution, Ta_2O_5 has been reactively sputtered, and thermally grown SiO_2 for comparison. S/D-electrodes have been evaporated and lift-off patterned for devices of 20 - 50 µm channel length and 1 - 3 mm channel width. P3OT has mainly been spun on from chloroforme solution, additionally we tried ink-jet printing from chlorobenzene solution in oder to reduce gate leakage and to take account of patterned gate dielectrics. Fig. 1 display the transistor design schematically.
At first we compared the electrical behaviour of the insulators by investigating metal-insulator-metal- (MIM) structures. Table I gives the extracted data. Because of its high permittivity together with excellent break down characteristics Ta_2O_5 turned out to be best for gate insulator application. The rather improper performance of BCB is further decreased by the fact, that we did not succeed in keeping the moderate ultimate field strength at films thinner than approx. 500 nm, whereas the inorganic insulators were introduced at 100 nm thickness. The major advantage of anodic Al_2O_3 is, that it can be grown into holes within photoresist masks, and by this additively patterned already during deposition (fig. 2).
Blanked films of P3OT did not yield strong differences in morphology on the substrates under investigation and we succeed in preparing transistors on all underlayers (fig. 3). Nevertheless, we obtained field-effect mobilities of only $1 \cdot 10^{-4}$ Vs/cm² on BCB, but of up to $2 \cdot 10^{-3}$ cm²/Vs on the inorganics.
Although Ta_2O_5 is working best among our candidates for gate dielectrics because of highest possible gate charge we suggest anodic Al_2O_3 for further application because ease of patterning.

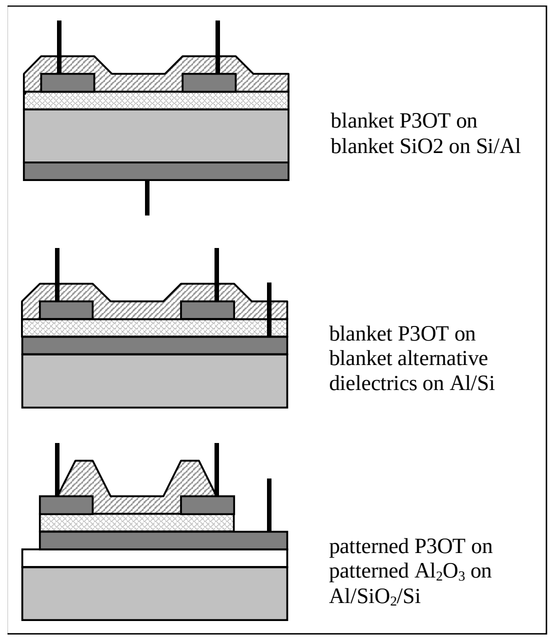

Fig. 1: Transistor design and tips

Dielectric	rel. permittivity ε_r	ultim. field strength E_{bd} [MV/cm]	max. gate charge (avg.) (@ U_T=0) Q'_{max} [10^{-6} As/cm^2]
therm. SiO_2	3.9	5 - 7.5	2.2
BCB	3.0 - 3.4	1 - 3	0.6
anodic Al_2O_3	7 - 10.5	2.5 - 5	2.9
Ta_2O_5	20 .. 26	4.5 - 5.5	10.2

Table I: Electrical insulator properties

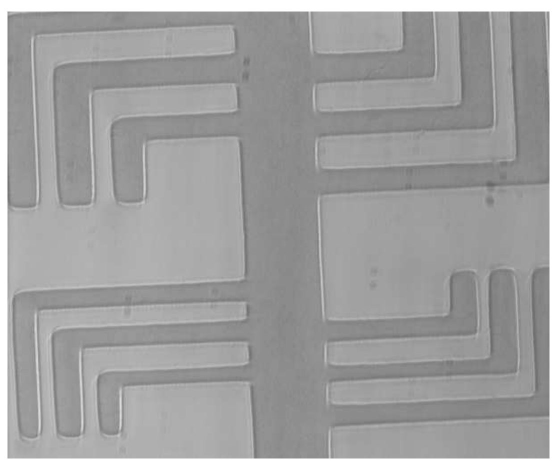

Fig. 2 Additively Patterned anodic Al_2O_3

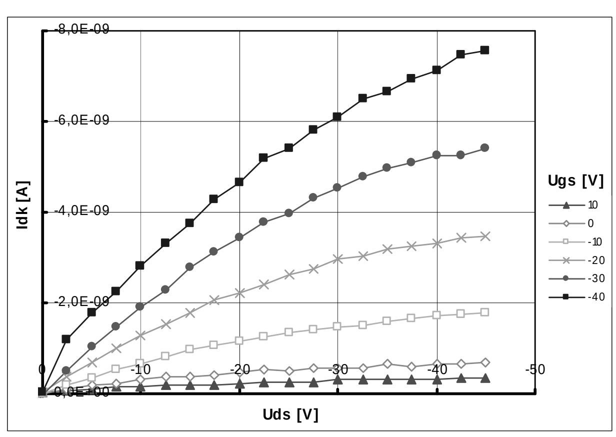

Fig. 3: Outut characteristics of ink-jetted P3OT-oFET on BCB (35x1000µm² channel)