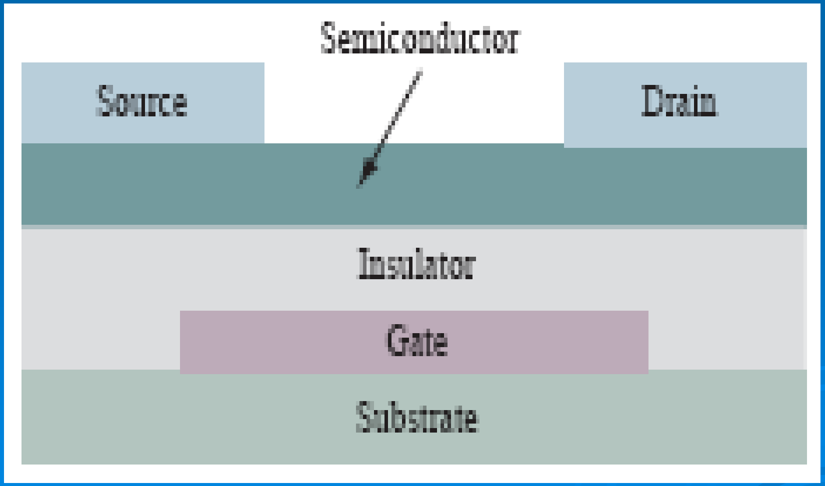
Dielectric materials for Organic Thin-Film Transistors



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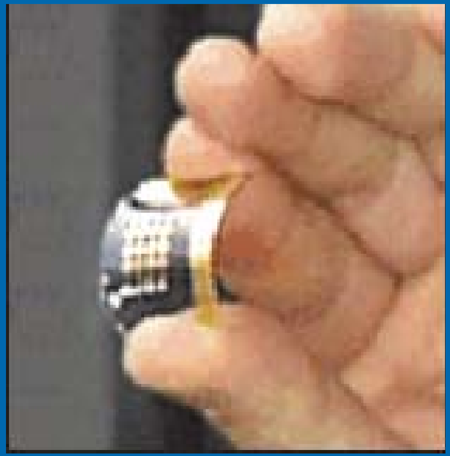
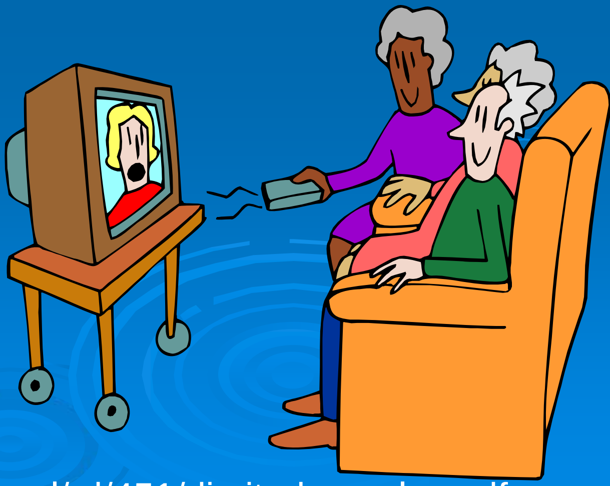
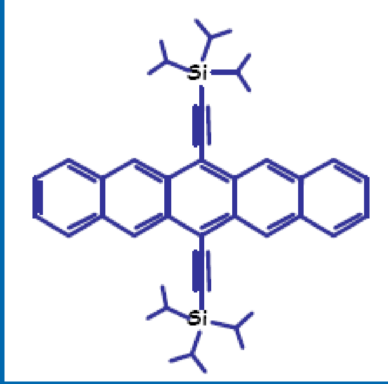
Why does it have to be organic?

- Fabrication is simple. Some methods used include: spin-coating, rod coating, and pad printing.
- It can be used on flexible substrates; for example, plastic
- It is cheaper compared to traditional methods using silicon or other metals
- Application: large area electronics; examples: flexible display, Radio Frequency Identification (RFID), sensors



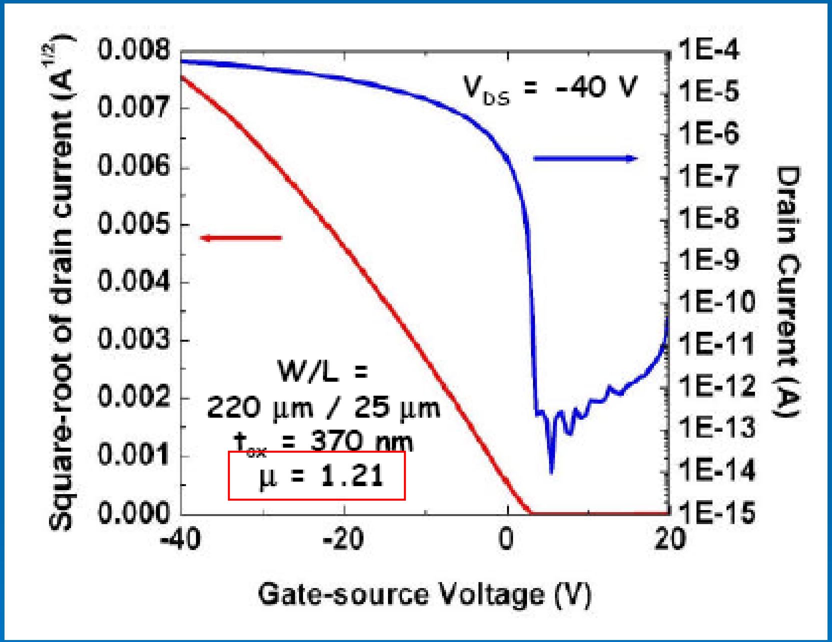


http://researchweb.watson.ibm.com/journal/rd/451/dimitrakopoulos.pdf

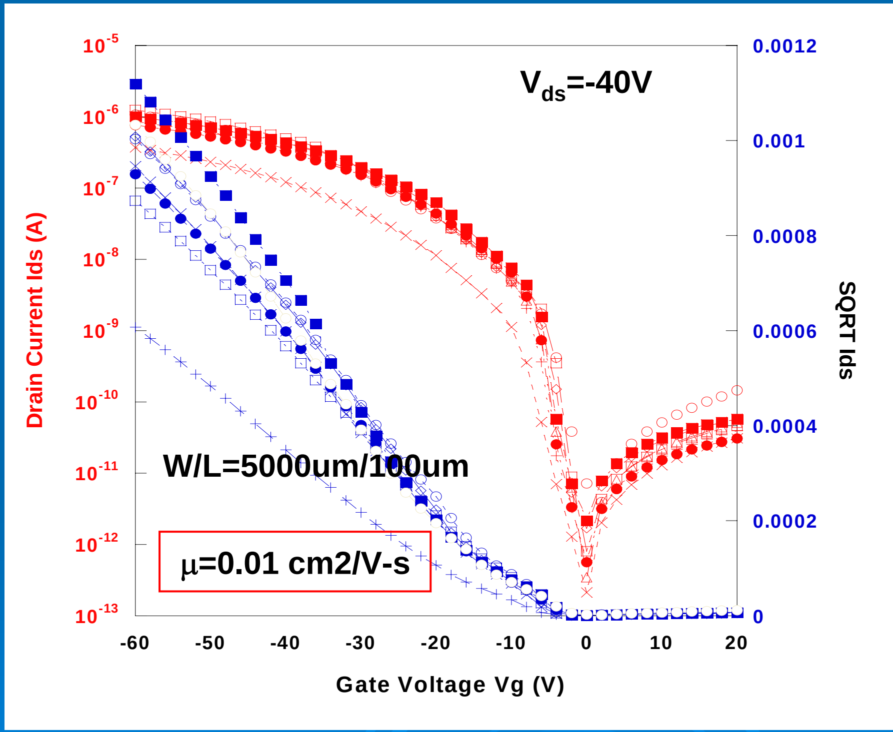


Organic Semiconductor

bis(triisopropylsilylethynyl)pentacene (TIPS-pentacene)



Result from Penn State Univ.



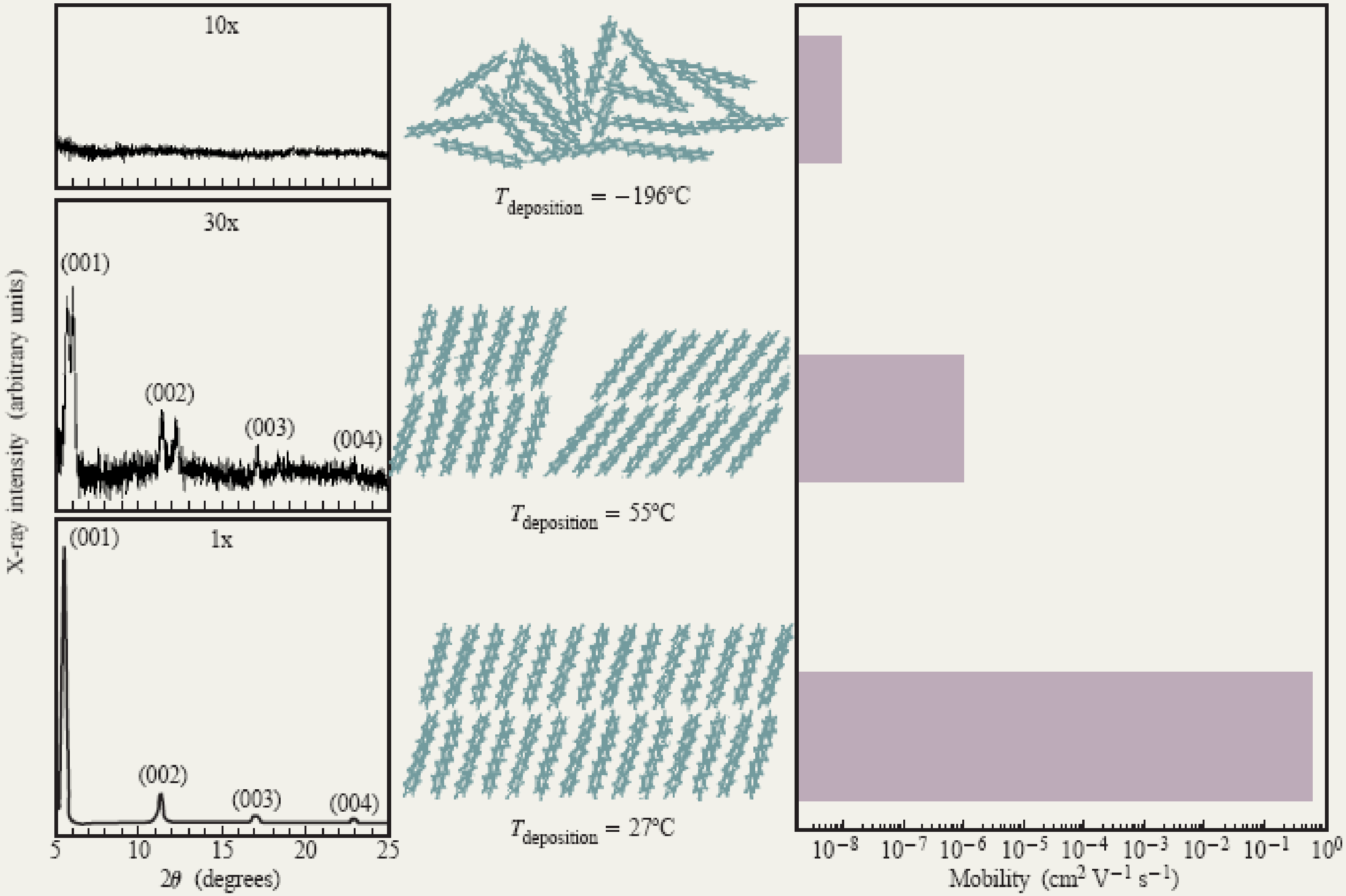
Performance on Si wafer with SiO_2 as gate dielectric

Result from Motorola

Performance on Poly Ethylene Terephthalate with polymer as gate dielectric

•Performance is 100x less on polymer dielectric

Importance of Crystal Structure on Mobility



Result from IBM

Study Outline

- Understand dielectric interface vs. organic transistor electrical performance
  - Benchmark SiO_2 surface treatment technology
  - Determine functional groups at the interface that promote semiconductor crystal formation

Experimental Process – Silicon Dioxide(SiO_2) Growth

- $Si + O_2 \longrightarrow SiO_2$

- Growth time was estimated using Deal Grove Model:

  $$t = x_o^2/B + x_o/(B/A)$$

  where: B and A = constants, x_0 = desired thickness

- We grow the silicon dioxide by putting silicon wafers in an oven at about 1000 °C for a certain amount of time.

  - Pressure = 1atm
  - Oxygen flow rate = 3.5 l/min

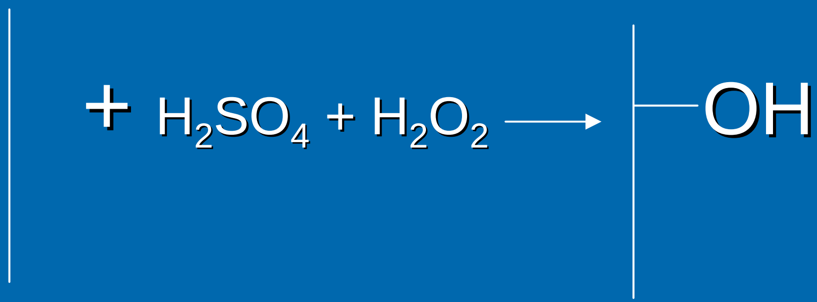
  - Thickness = 60 nm, 100 nm, greater than 100 nm; after 30 min, 1 hr, 2 hr, respectively

Surface Modification of Silicon Substrate with Hexamethylsilazane (HMDS)

1. 100 nm thick silicon dioxide (SiO_2) is grown on clean silicon substrate for 1 hr.
   - Conditions: 1000 °C, 1 atm, 3.5 l/min flow of oxygen
2. reacted with piranha solution (sulfuric acid and peroxide) for 20 min
   - Conditions: 80 °C, 1 atm
3. reacted with the HMDS for 1 hr
   - Conditions: 120 °C, 1 atm; rinsed with acetone to remove excess

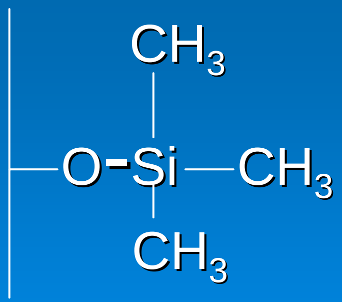
Process of adding HMDS

1.



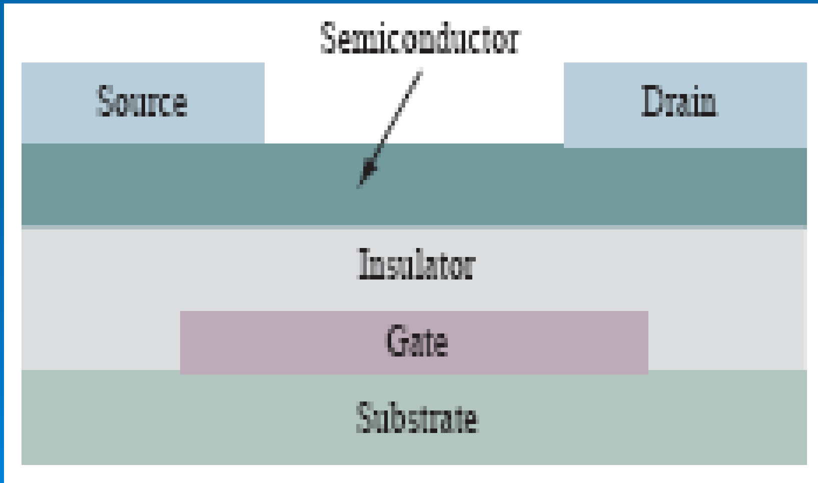
2.

3.



After Modification- Making the Transistor

- Spin-coat surface with semiconductor material – pentacene derivative in toluene
- Pad-print source and drain using carbon suspension
- Cure in oven for 15 min at 110 °C



Top Contact Deposition Method

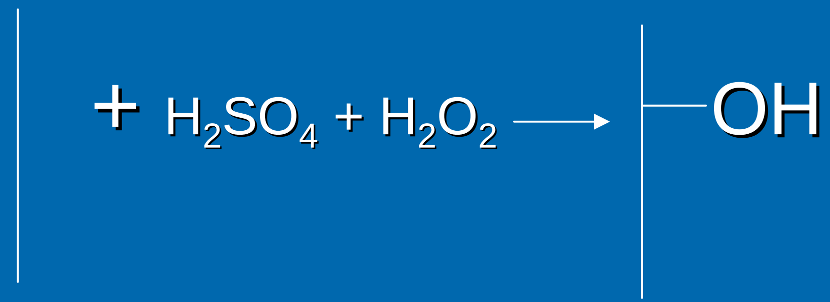
http://researchweb.watson.ibm.com/journal/rd/451/dimitrakopoulos.pdf

Surface Modification of Silicon Substrate with Octyltriethoxylsilane (OTS)

1. 60 nm and greater than 100 nm-thick Silicon dioxide(SiO_2) is grown on clean silicon substrate for 30 min, 2 hr respectively.
   - Conditions: 1000 °C, 1 atm, 3.5 L/min flow of oxygen
2. treat with piranha solution for 20 min
   - Conditions: 80 °C, 1 atm
3. place wafer in OTS solution
   - Conditions: 70 °C ,30 min ; evaporated at 120 °C, 15 min; and then rinsed with acetone

Process of Adding OTS

1.



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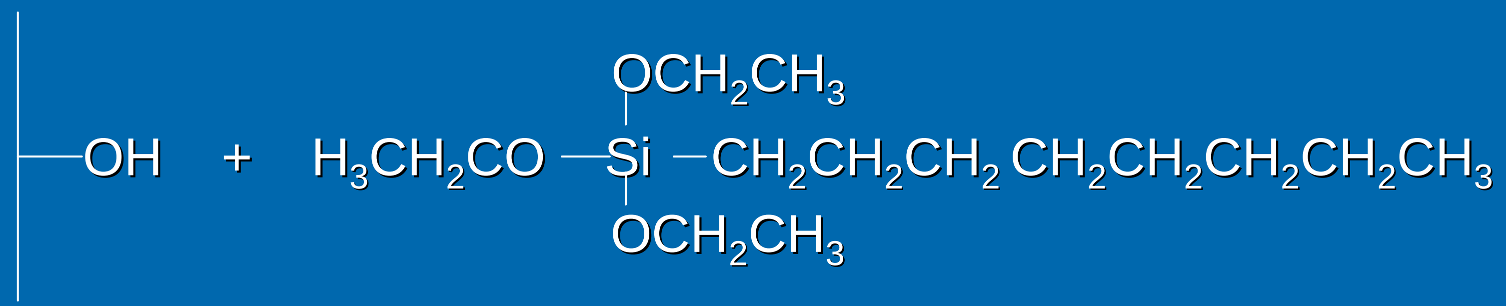
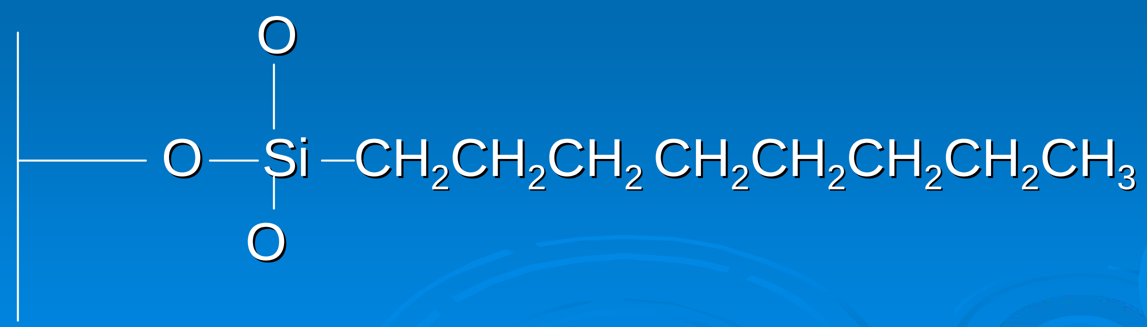
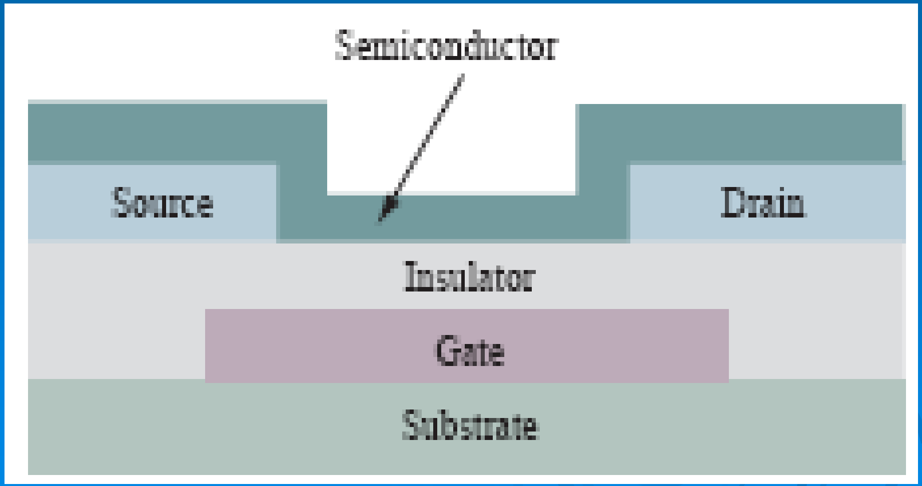


3.



Making the Transistor

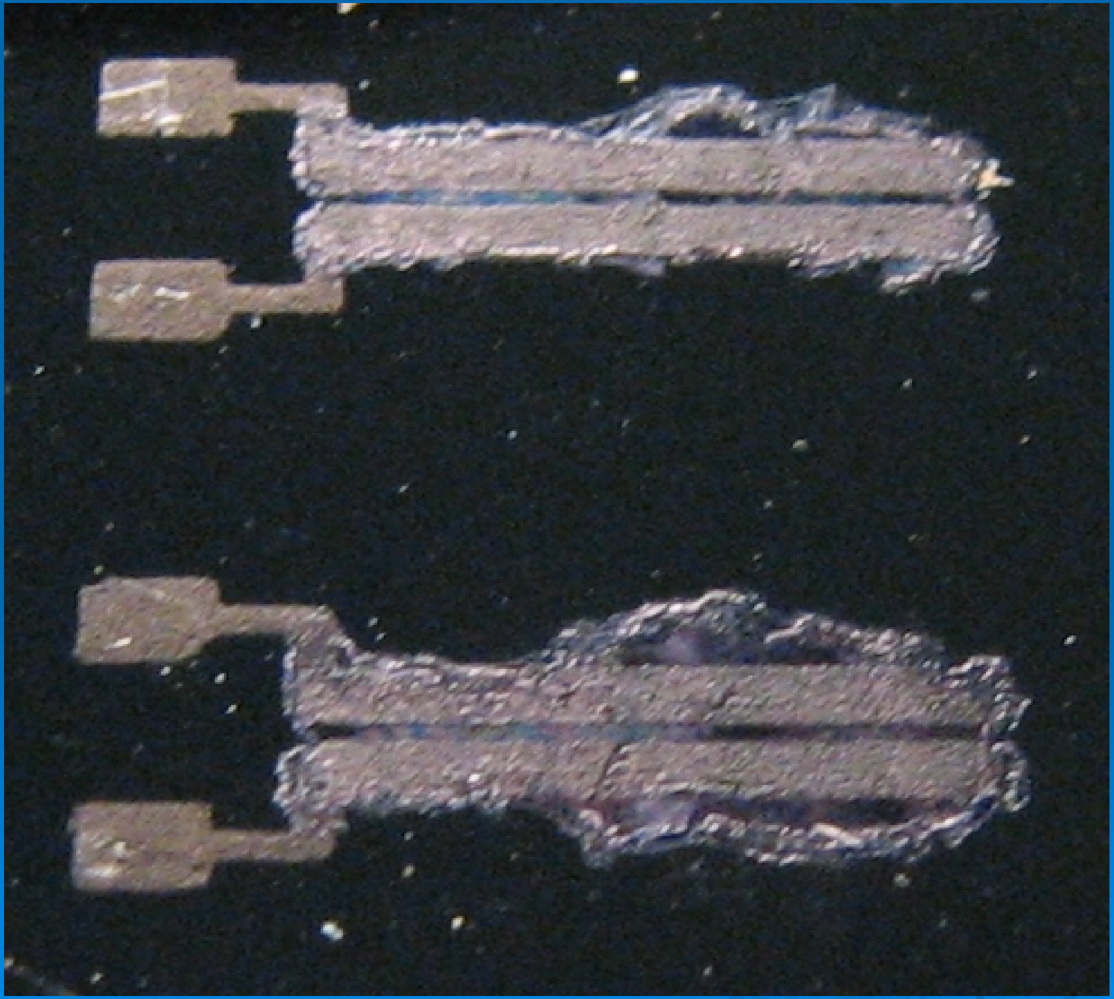
- Pad-print source and drain using carbon suspension
- Cure in oven for 15 min at 110 °C
- Deposit semiconductor between the source and drain channel using pipette



Bottom Contact Deposition Method

http://researchweb.watson.ibm.com/journal/rd/451/dimitrakopoulos.pdf

Top View Image of Transistor – Source and Drain on Octyltriethoxylsilane(OTS) Modified SiO_2 Surface



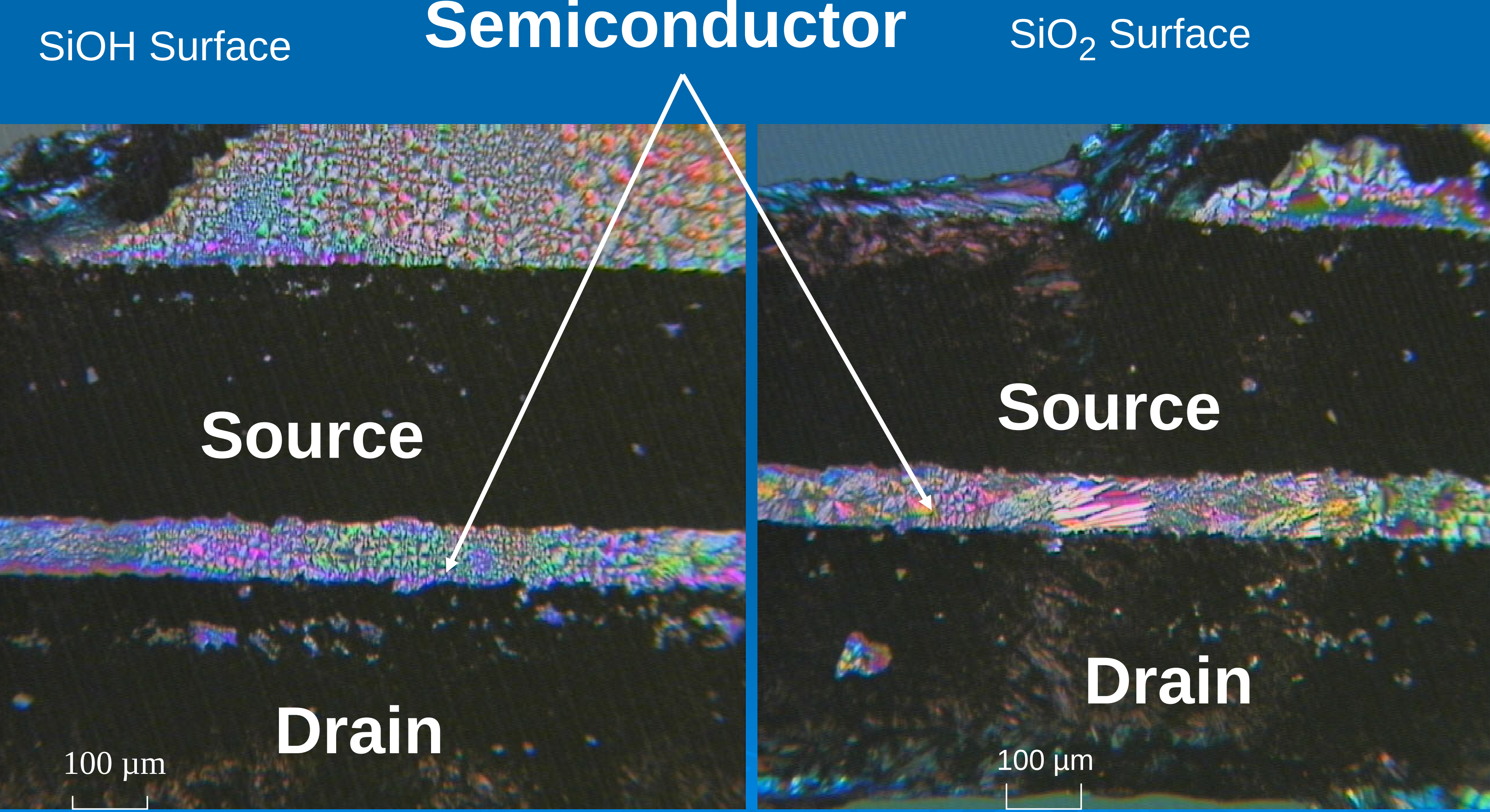
Dimensions

Channel length: 5000 µm

Channel width: 100 µm

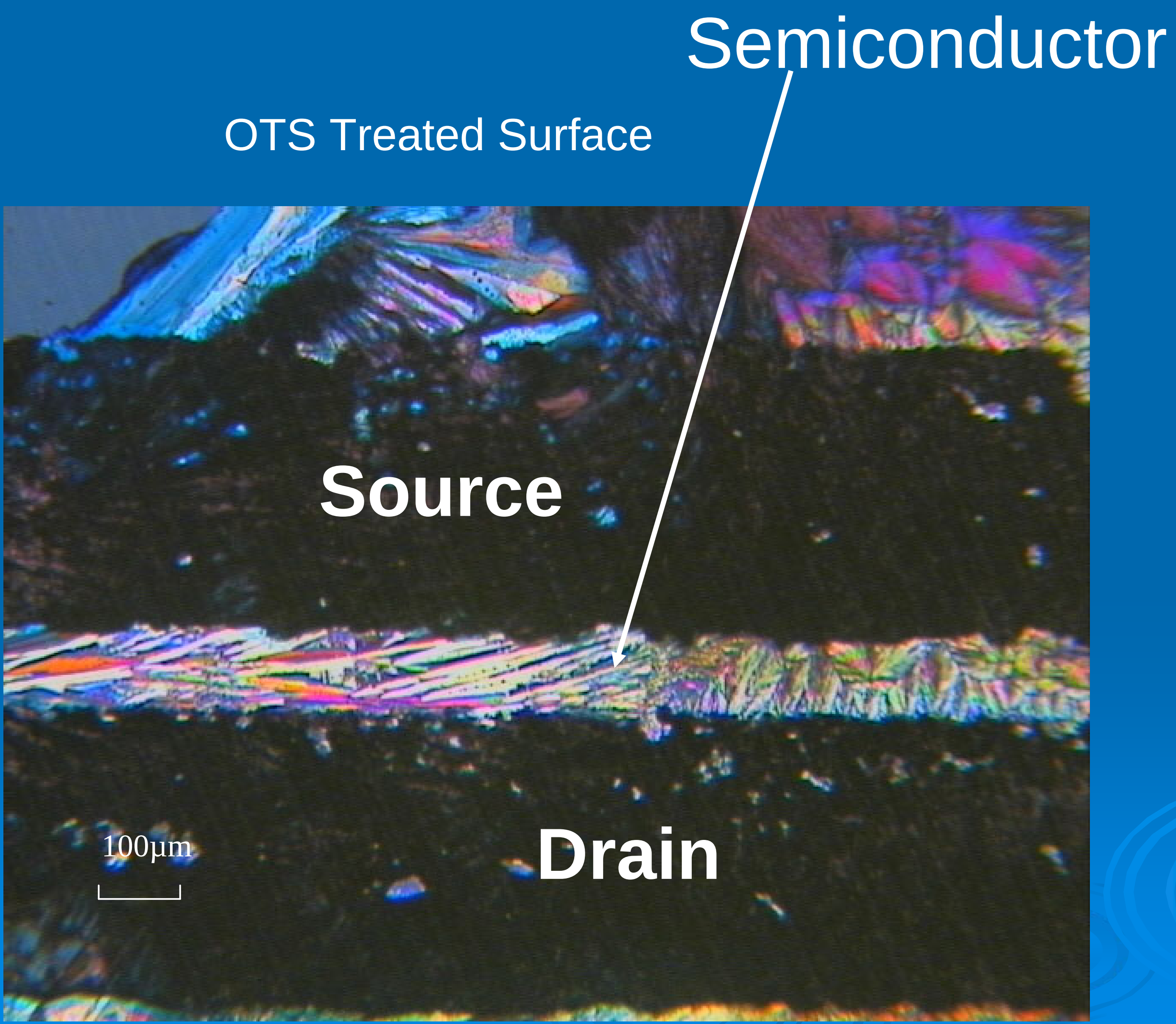
Source and Drain width: 500 µm

Crystal Structure of Semiconductor after Deposition: Top View of Transistor

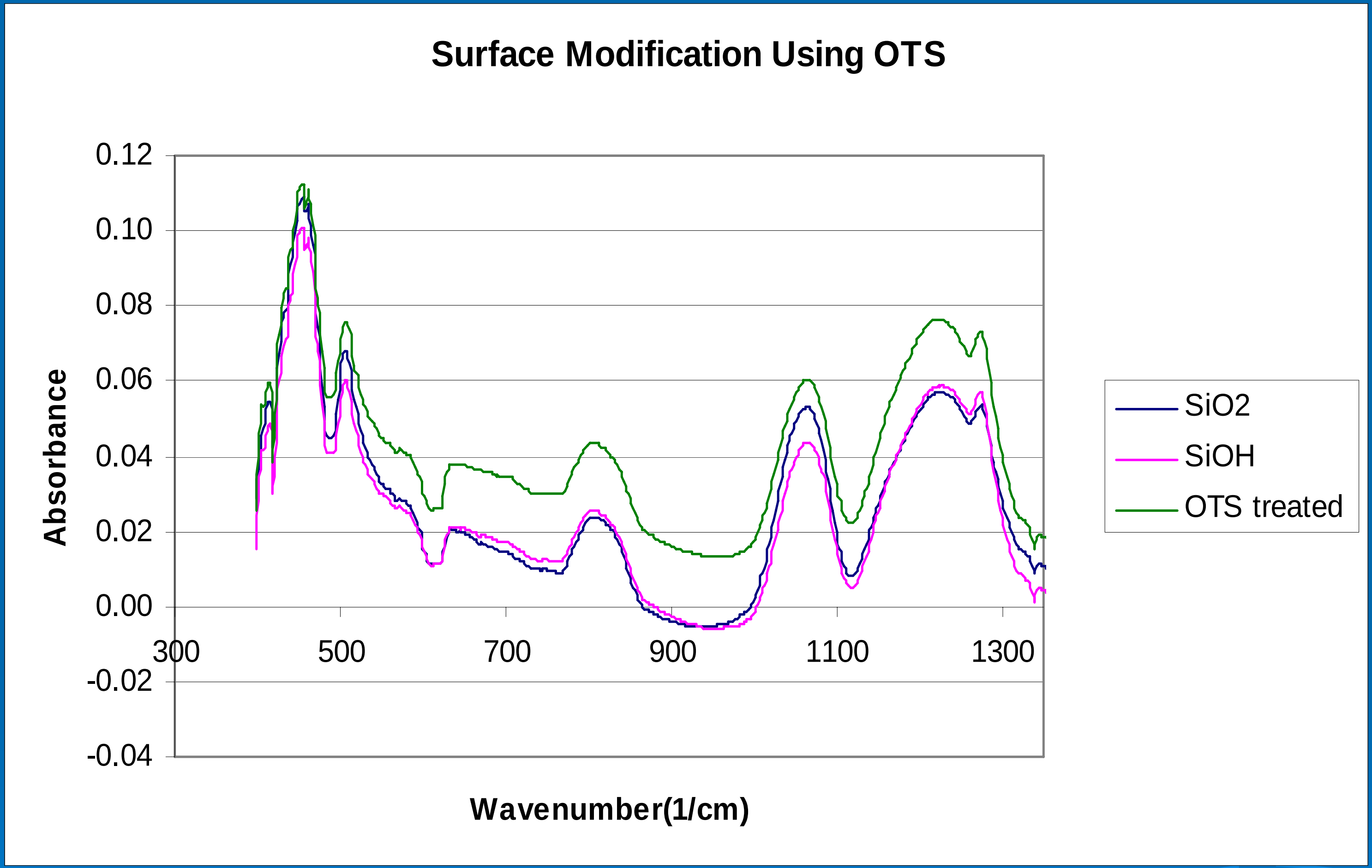


Instrument: OLYMPUS PMG3

Crystal Structure of semiconductor after deposition



FTIR Results

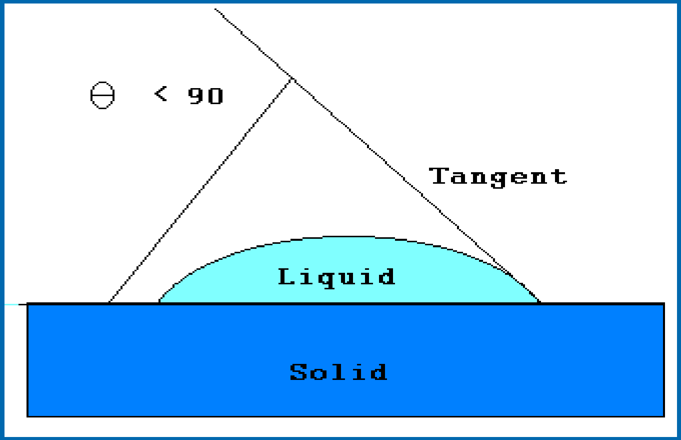


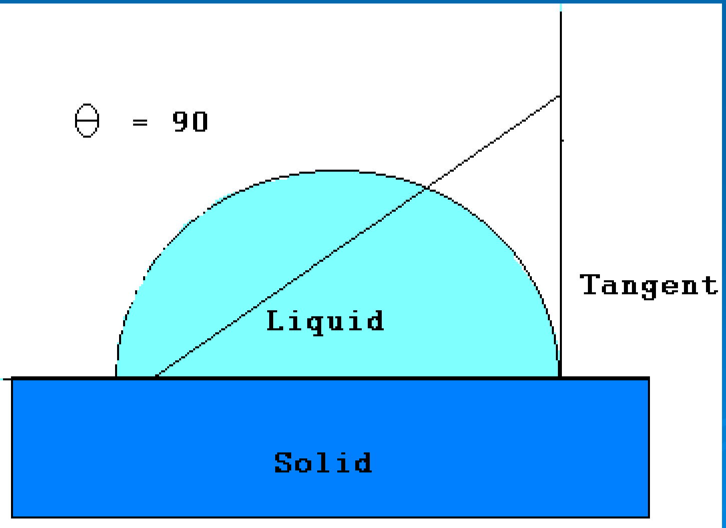
Virtually no change in result after each step:

Could be due to the formation of a monolayer of SiOH and OTS that could not be detected by using FTIR spectroscopy

Contact Angle Measurements

- Liquid used : water





Surface	Approximate contact angle (°)
SiO_2	30
SiOH	30
OTS	90
HMDS	70

http://www.ksvinc.com/contact_angle.htm

Conclusions

- Using silane derivative we have been able to get bigger crystals and better ordered crystal structure

- FTIR results do not show any surface changes but using the contact angle we can tell that OTS and HMDS have bonded

Acknowledgements

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- Dr. Jie Zhang
- Dr. Christos Takoudis
- AMReL Lab Members

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- Thanks!

- Questions?