Unconventional bottom-up approach to nanofabrication of functional materials

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Contest of work

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Motivations and Aims

•Nanotechnologies **are not just a matter of downscaling**; instead, they provide overall flexibility and control on material response.

•The **growth method** determines the **properties** of organic thin films of functional materials.

•**Long-range molecular order** and a limited nucleation density of domain in organic thin films can lead to increase the charge mobility.

Aim

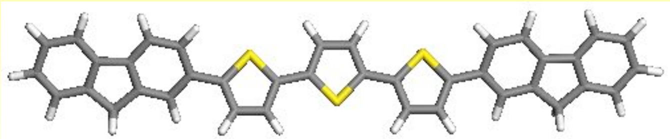
•Improvements of some physical properties **of functional materials thin film** (ex. charge mobility) by controlling the nanostructuration.

Strategy

The simplest strategy to achieve these results is to **exploit the self-organizing properties of materials by stamp assisted deposition (Bottom-Up approach).**

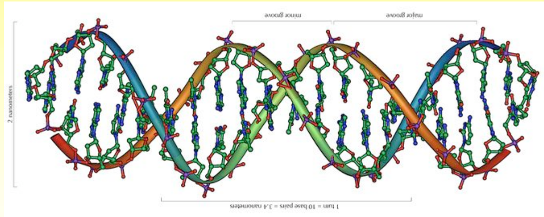
Materials of interest

Organic Semiconductors



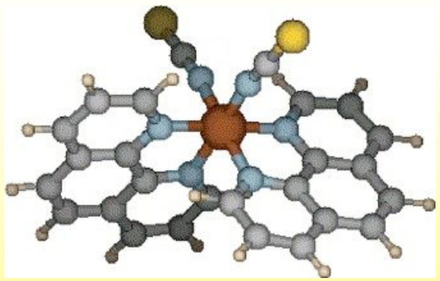
F-T3-F

Bio-Molecules



λ-DNA

Spin Crossover



$Fe\ (Phen)_2SCN_2$

Molecular Magnets

$Mn_{12}O_{12}(O_2CC_{12}H_9)_{16}(H_2O)_4$

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Lithographically controlled wetting*

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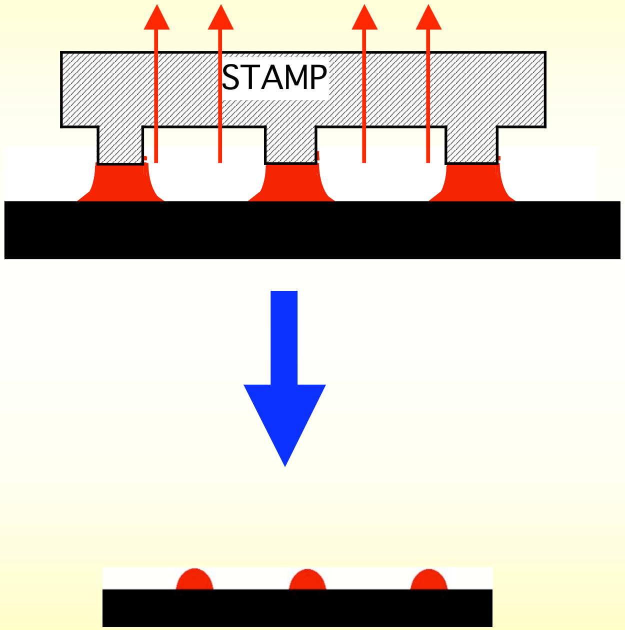
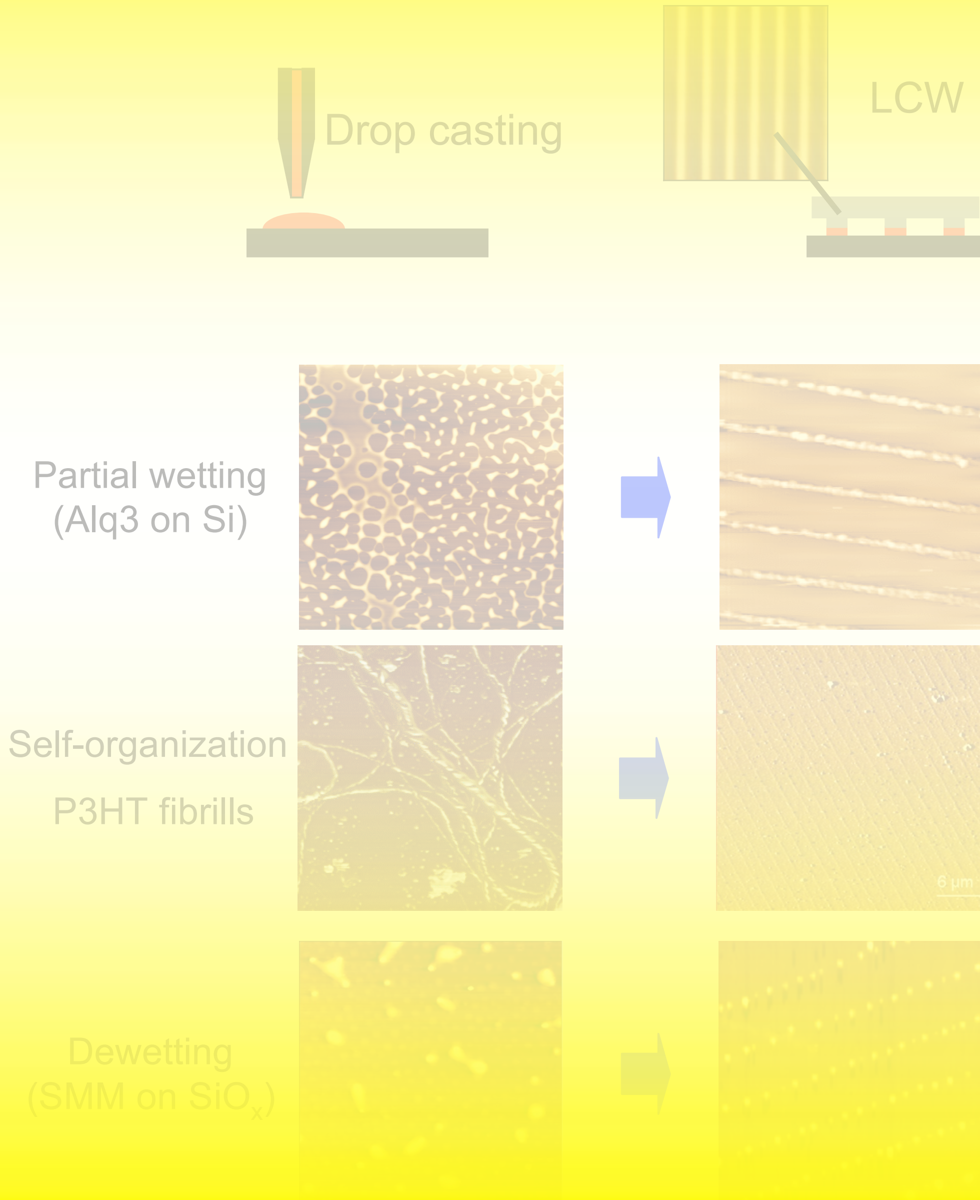
Stamp assisted self-organization



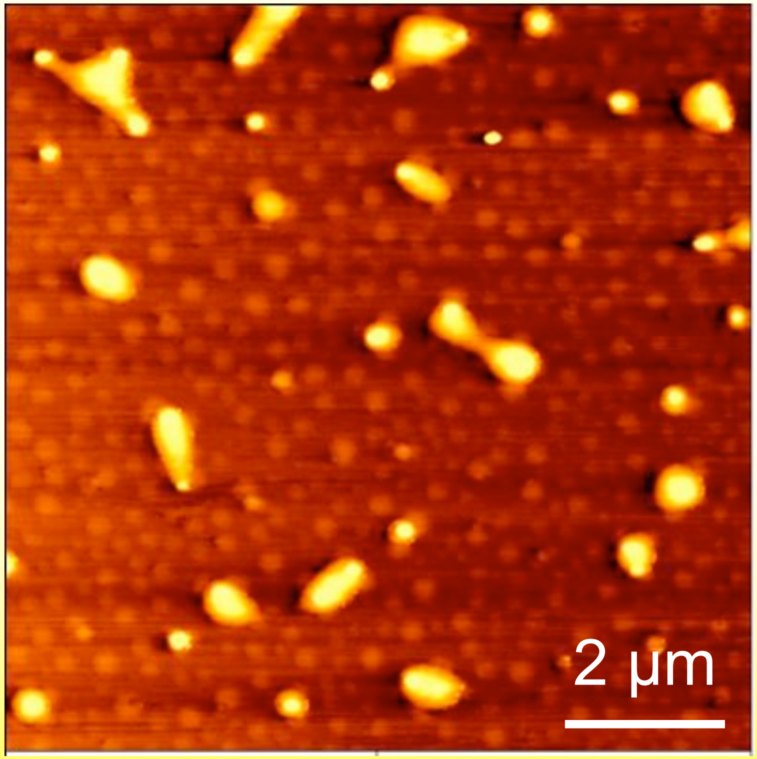
Self-Assembly
Crystallization
Dewetting



* EU Patent PCT: EP03/10242 16/9/2003 and
M.Cavallini, F.Biscarini *Nano Letters* **3,** *1269 (2003).*

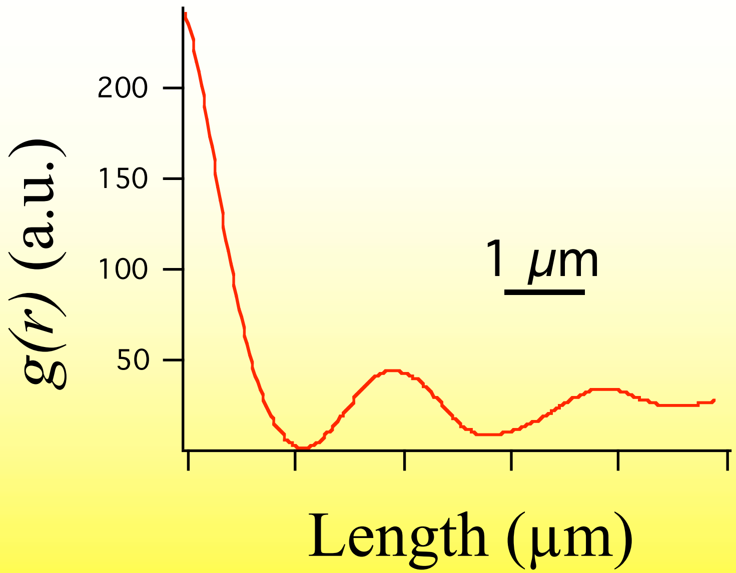
Dewetting of Mn12 SMM on Si/SiO_x (native)

The features generated by dewetting can have complex distribution but often **they are NOT randomly distributed!**



Z scale: 25 nm

2D height-height correlation function *g(r)* (radial distribution)



LCW works at large area (mm^2) .....by dewetting

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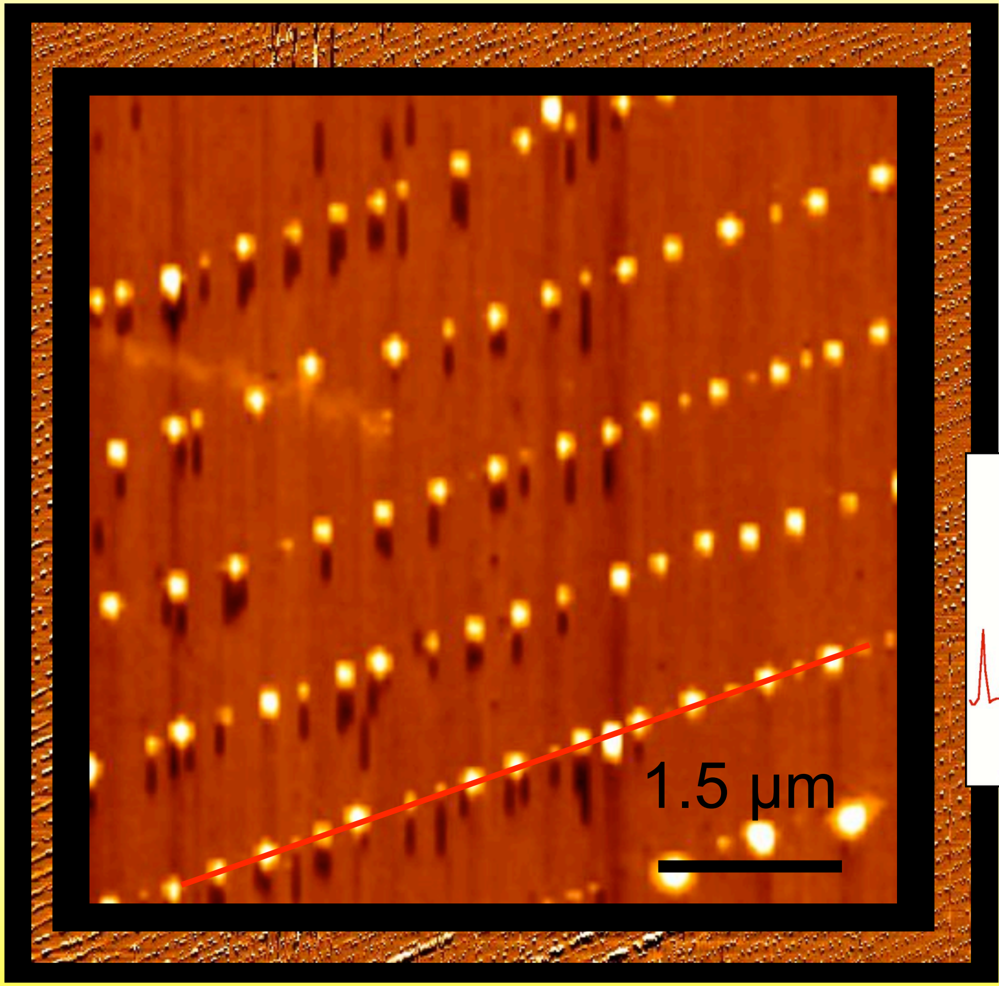
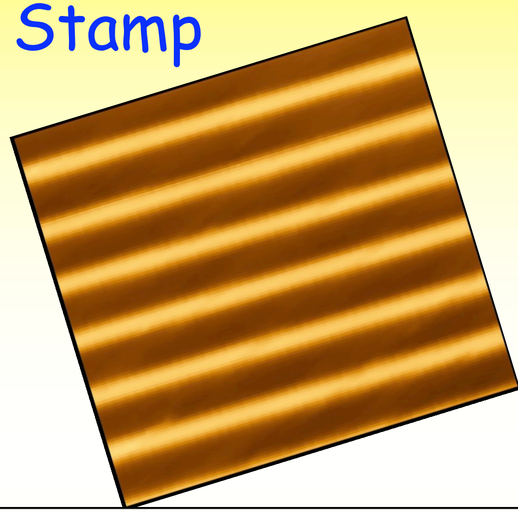


100 µm x 100 µm

Stamp



Diam. ≈ 200 nm

H ≈ 40 nm

*M.Cavallini et al.*Nano Letters* **3,** 1527 (2003))

Traditional growth vs. LCW

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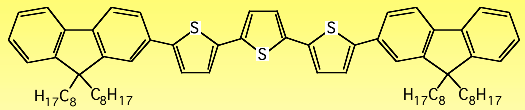
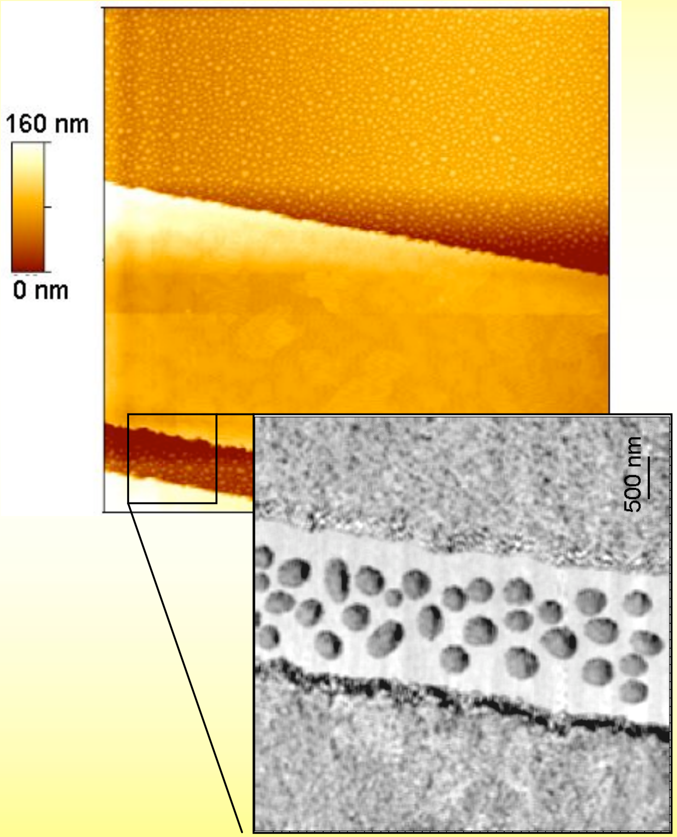
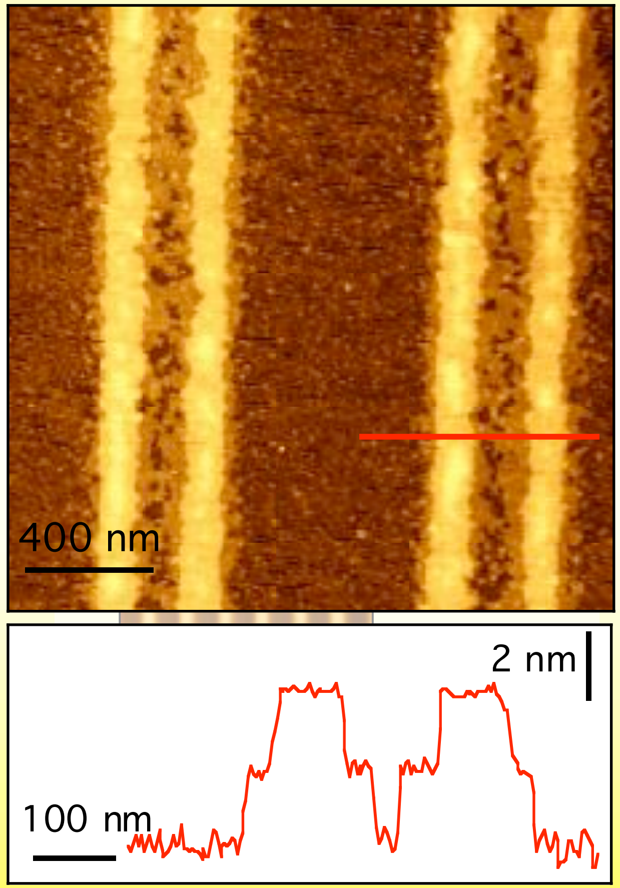
The nature of the substrate strongly influence the morphology of thin film (layered growth vs. droplets)







Thin film does not work in FET!

Thick films (>250 nm) FET works

μ=1.4x10^{-6}cm^2/Vs

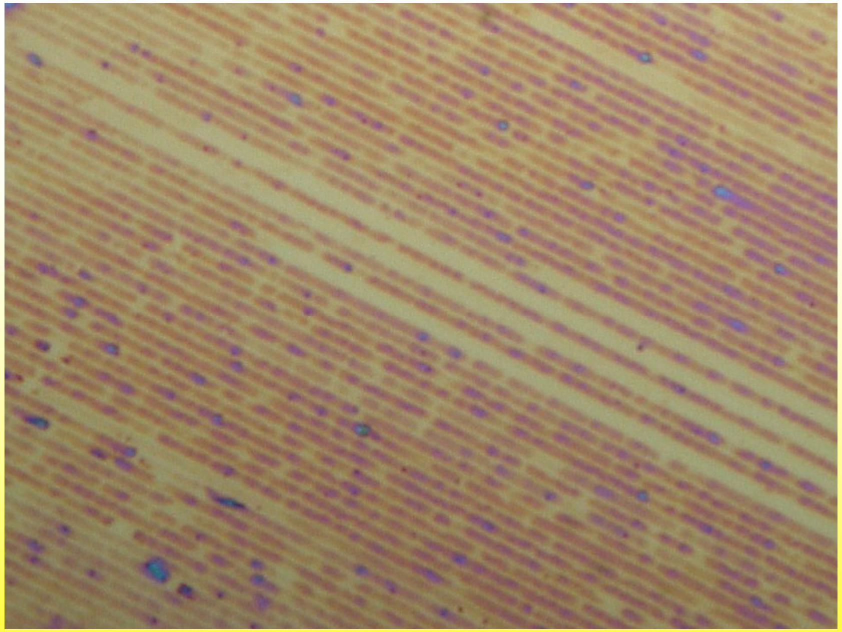
*M.Cavallini *Nano Letters* **5,** 2422 (2005)

Optical microscopy on sub-micrometric stripes

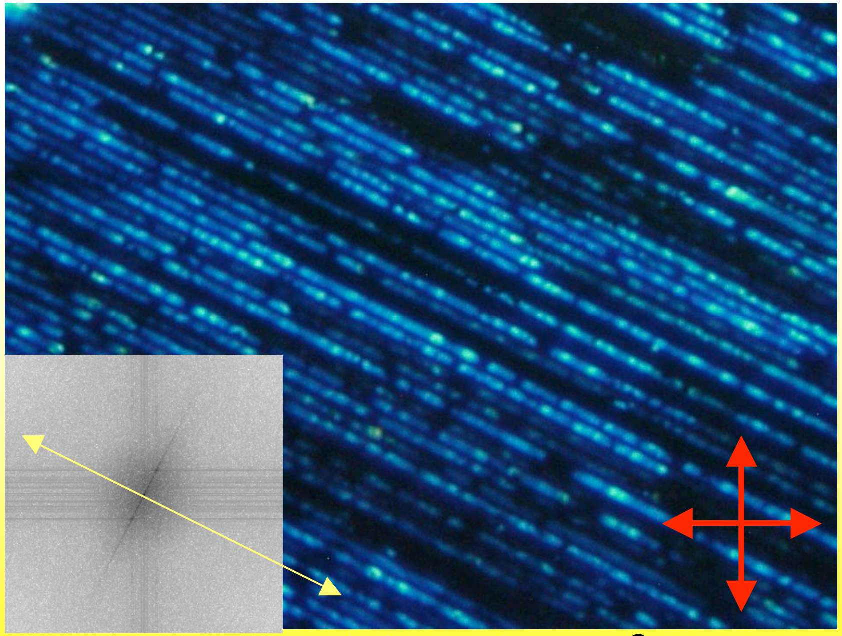
Optical micrographs of a thin deposit of nanostructured F-T3-F on a SiO_x Stripes thicker than 25 nm (pich> 1μm) are visible by optical microscope. These aligned stripes are made of crystallites of F-T3-F which are birefringent under crossed polars.

Under natural light

Mean size of domains:
6.1±1.0 μm



60x90 μm^2



60x90 μm^2

Grazing incidence x-ray diffraction of the stripes

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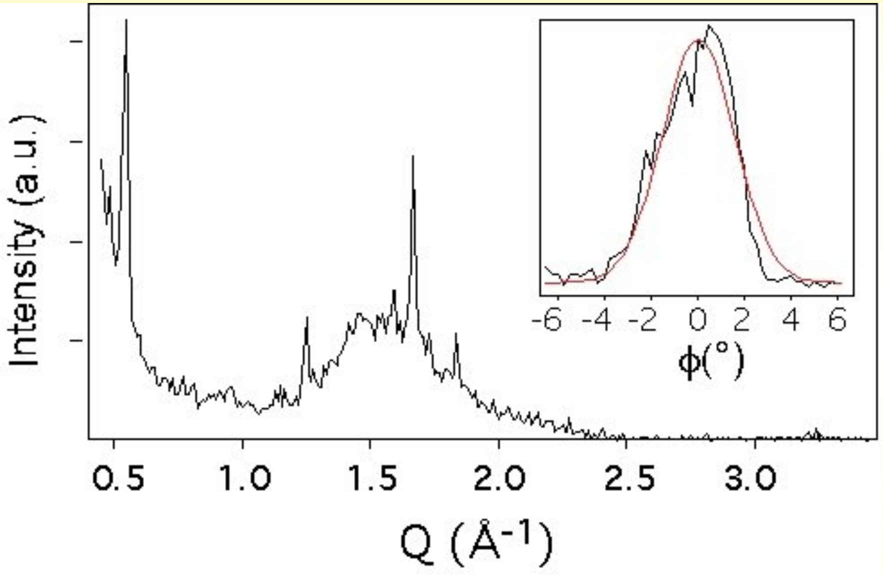
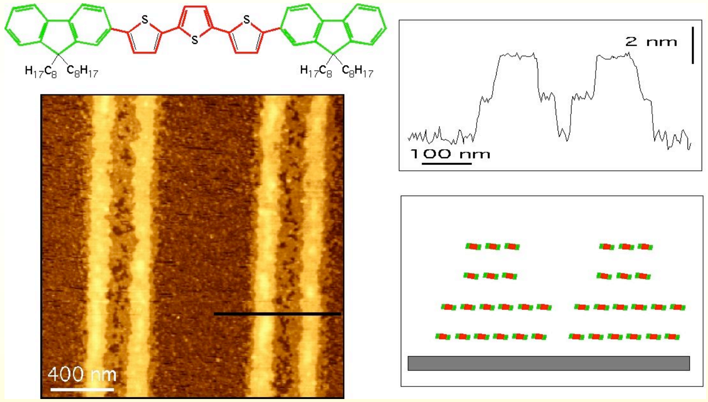
Sharply defined reflection was observed at Q=1.51 Å^{-1}, along the direction of F-T3-F stripes.



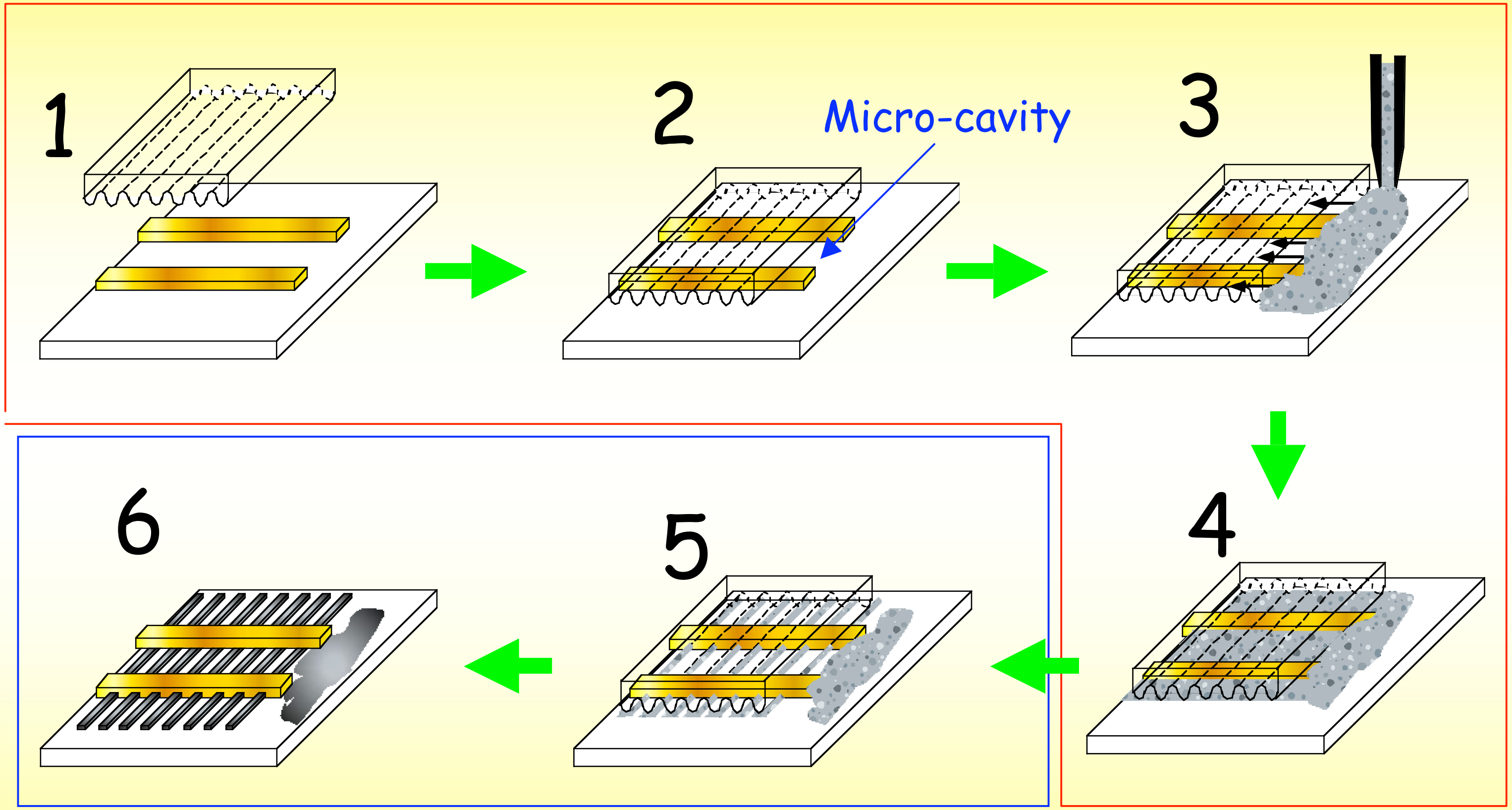
Q scan along the stripes direction, inset displays the in-plane rocking scan at Q=1.51 Å^{-1}. Φ=0 corresponds to the direction of the stripes.



F-T3-F stripes results crystalline and highly oriented, the π-stacking direction being along the stripes.

Combined Micromolding in Capillaries and Lithographically Controlled Wetting

Micromolding in capillaries*



Lithographically Controlled Wetting**

Timing using DMF solution:
Steps 1→4: <5 s
Steps 4→6: ~12 hrs

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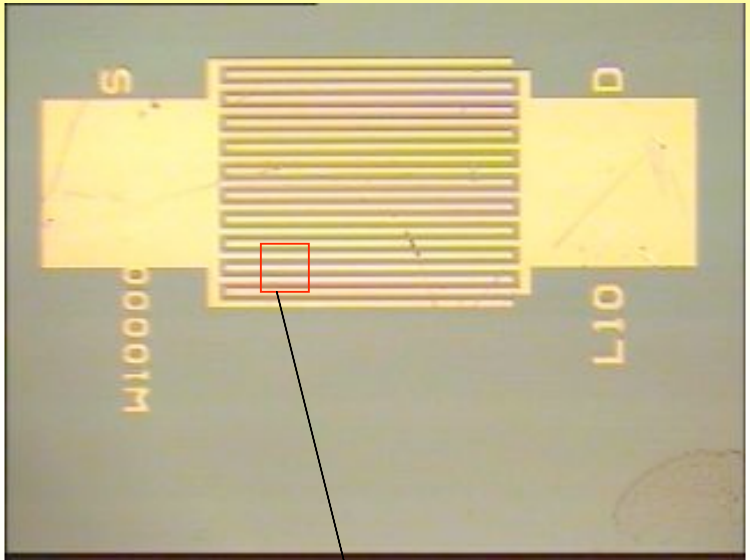
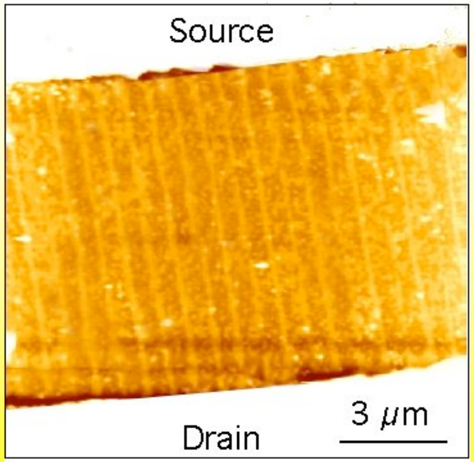
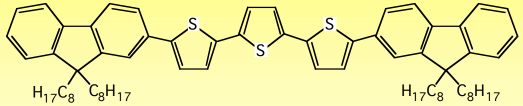
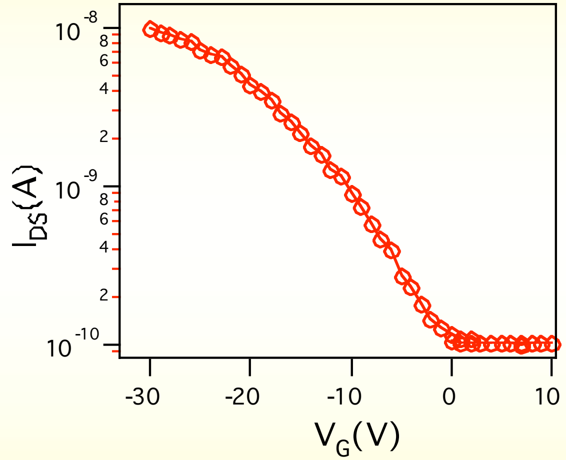
Application to Nanoelectronics*: Nano-stripes based FET







Transfer characteristics



FET based on nanostripes work!

$\mu = 0.5 \times 10^{-4} cm^2/Vs$

Vacuum sublimated films (>250 nm) FET mobility

$\mu = 1.4 \times 10^{-6} cm^2/Vs$

*M.Cavallini *Nano Letters* **5**, 2422 (2005)

Summary and conclusions

- LCW exploits spontaneous properties of materials.
- It allows the **fabrication of layered nanostripes or nanopattern** of functional materials.
- It can induce oriented crystallization of nanostructures at large area.
- **The FET based on nanostripes works!**
- **FETs based on nanostripes** exhibit **charge mobility** (measured along nano stripes) **two orders of magnitude larger** than vacuum-sublimed thin films.

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