Printing Methods for Organic Electrode

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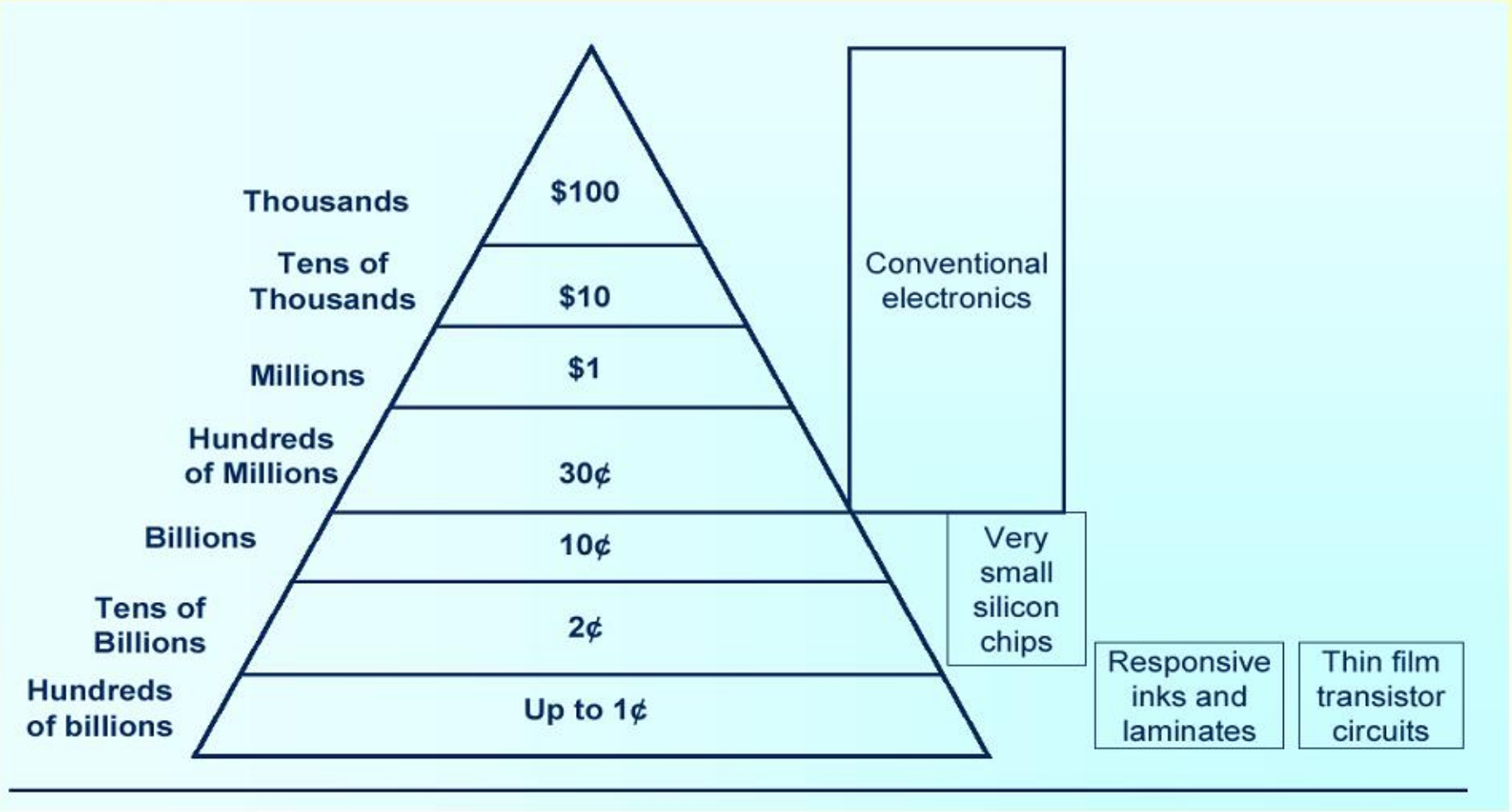
Smart Labels – Price Sensitivity of Markets



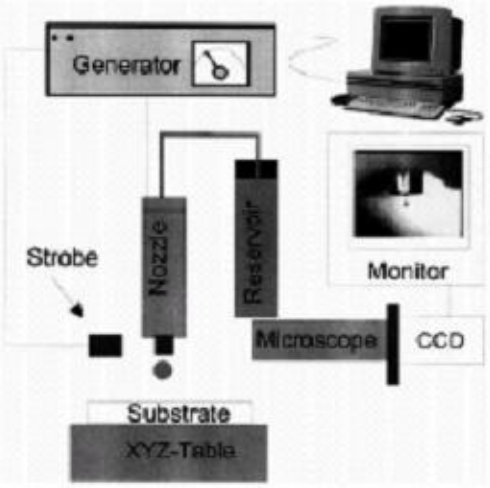
How do we learn to produce them cheaply
… or add value to high-volume products?

Application Dependent Targets

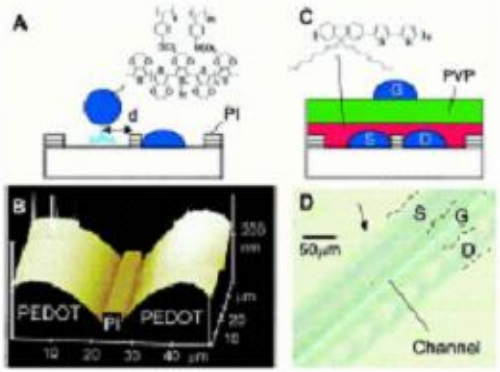
Critical Device Parameters	AM-OLED	E-Book	Unknown	
Field-effect mobility μ_{FE}	>1	>.01		cm^2/V-sec
On-off current ratio	$>10^6$	$>10^5$		
Operational lifetime	$>10^4$	$>10^4$		hr
Magnitude of mean threshold voltage	<5	<20		V
Minimum line spacing	5	5		μm
Minimum line width	10	10		μm
Alignment tolerance	10	10		μm
Gate dielectric capacitance	>35	>0.3		nF/cm^2
Subthreshold voltage excursion	<5	<10		V
Gate dielectric breakdown voltage	>30	>100		V
Conductor 1 sheet resistance R_S	<40	<100		Ω/square
Conductor 2 sheet resistance R_S	<10	<100		Ω/square

Ink jet printing

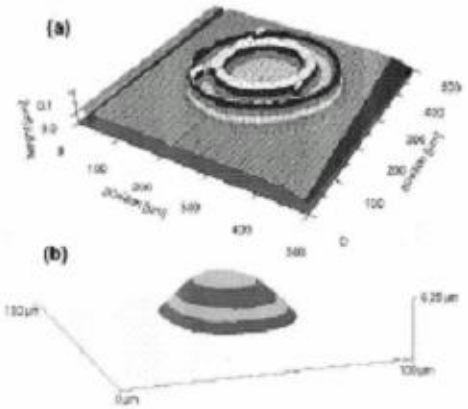
- **Inkjet printer** can be used to generate surface **pattern** with appropriate "**ink**" (resolution ~50 μm):
  - **resist**: by using a resist precursor as ink the mask can be printed directly
  - **electr. active materials:** "printing" of electronic devices, like thin film transistors (TFT)
  - **DNA**: generate DNA arrays for sequencing applications
  - **polymers**: printing of polymer precursors for rapid 3D prototyping (layer–by–layer)



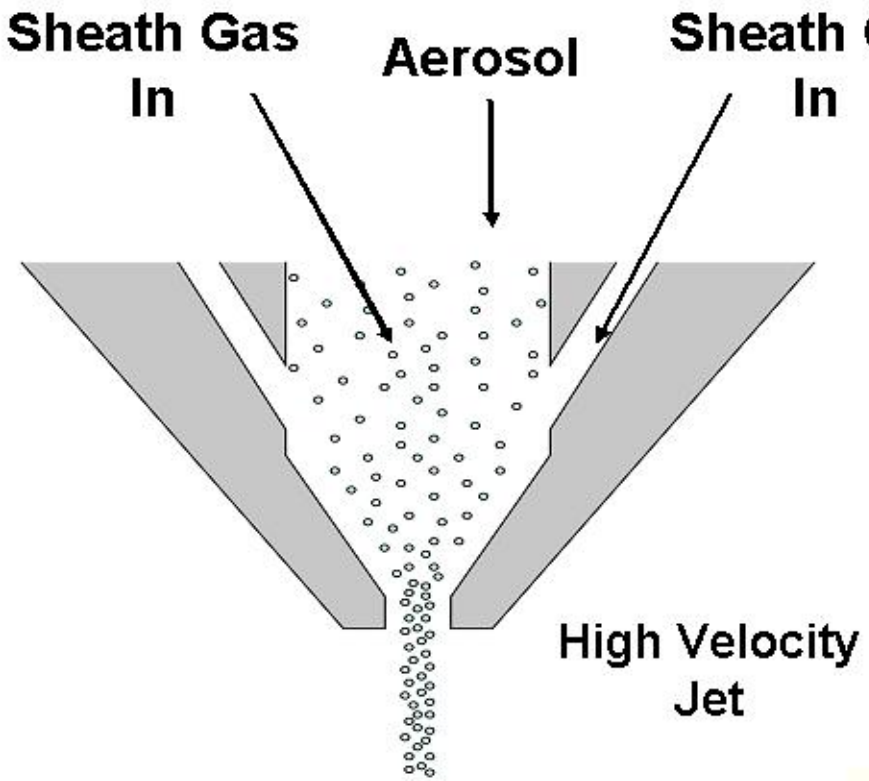
⇒ TFT printing:

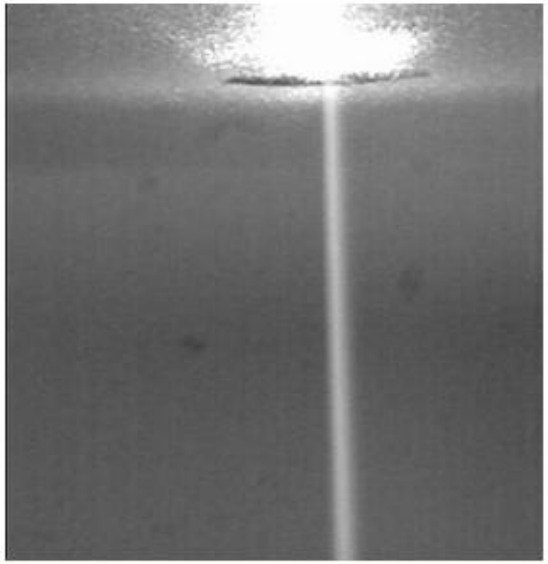


⇒ microlense printing:



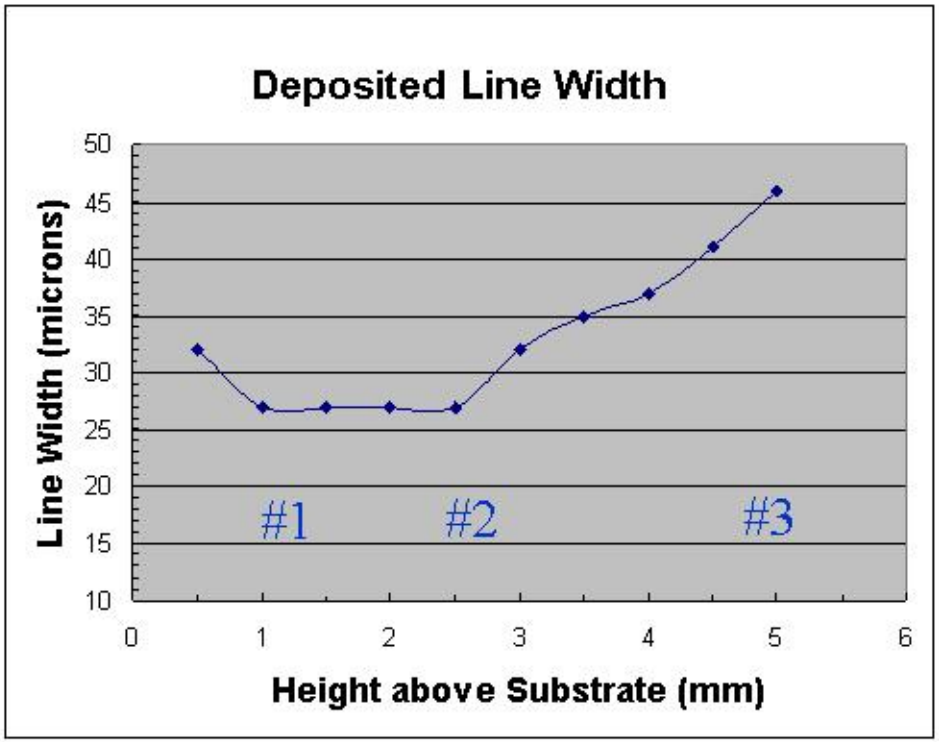
Aerosol Jetting

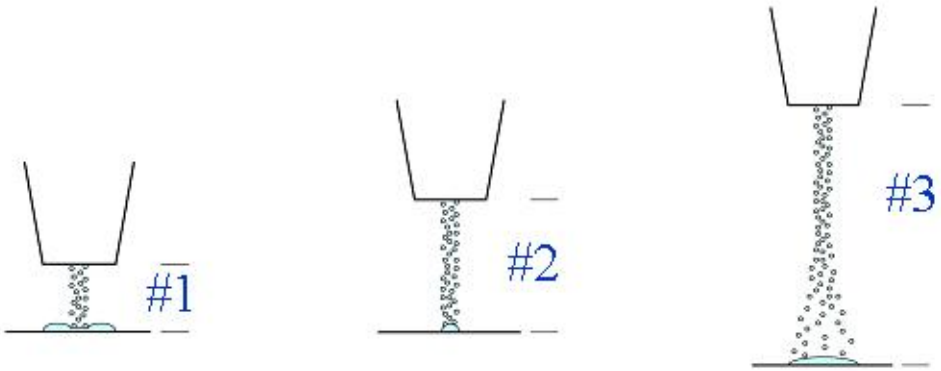




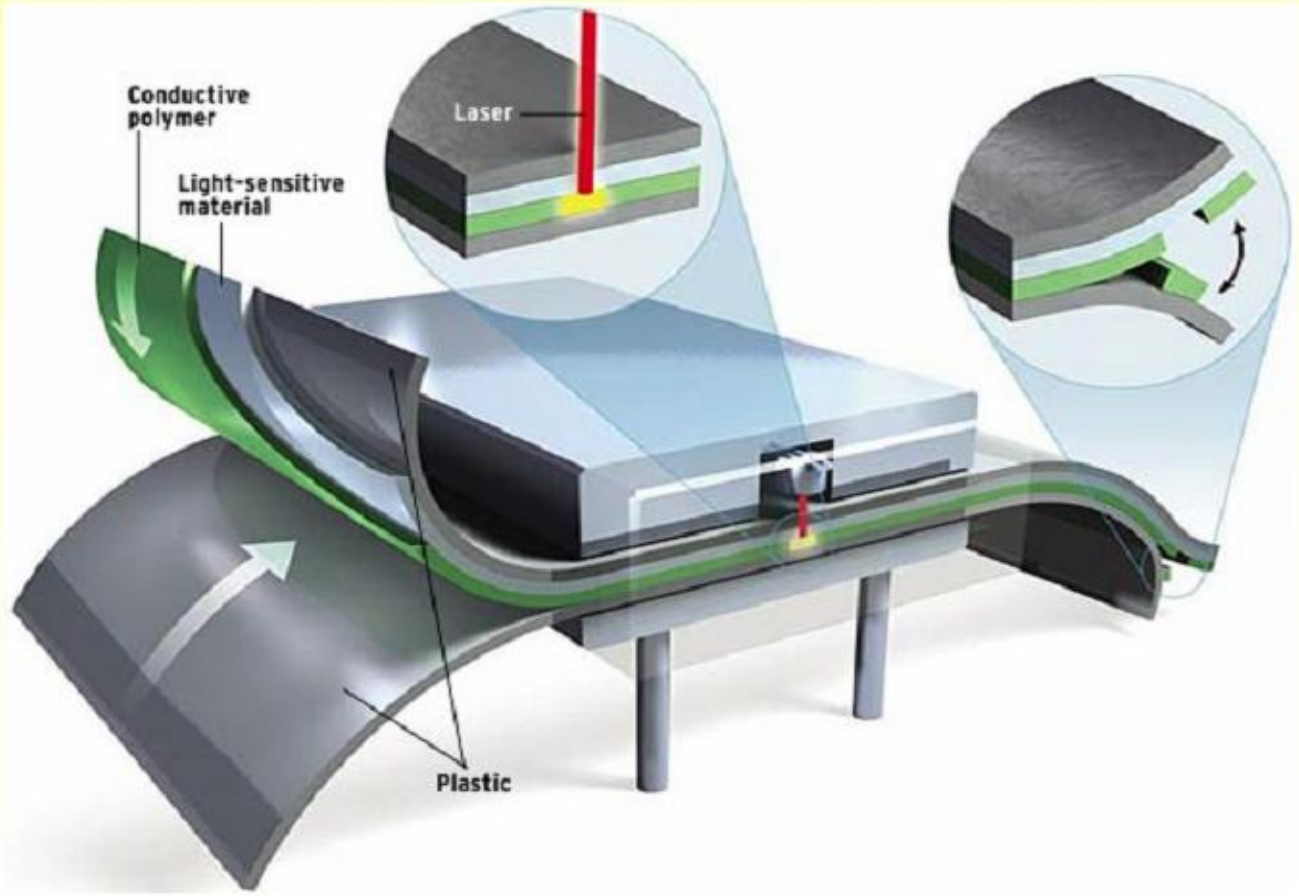
- *M3D Deposition Rate: Aqueous Material, Ultrasonic Atomization*
  → *0.25 mm^3/s*
- *Typical inkjet: 40 µm diameter droplets @ 4 kHz*
  → *0.1 mm^3/s*

Aerosol Jet Characteristics





Patterning Technology: Thermal Multi-Layer



NIST ATP ADVANCED TECHNOLOGY PROGRAM

DUPONT

Lucent Technologies
Bell Labs Innovations

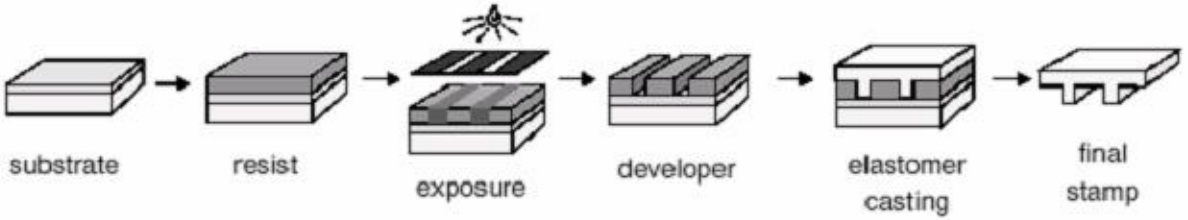
SARNOFF Corporation

Microcontact printing

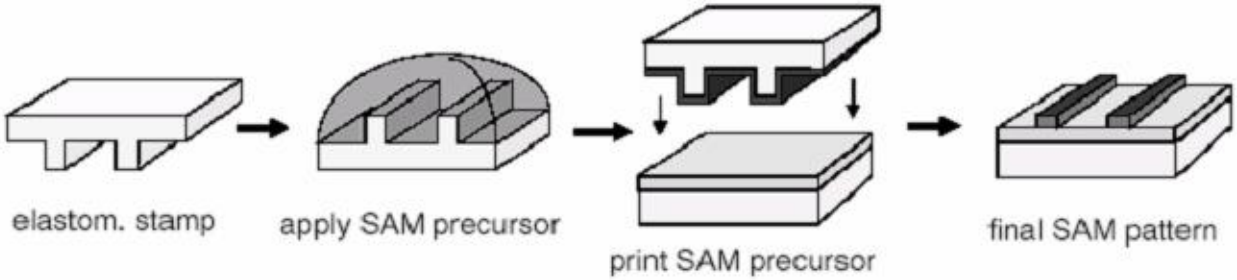
- **Transfer** of **SAM precursor** with elastomeric **stamp** onto substrate:

  ⇒ **master** generation by **photolithography** and similar techniques:

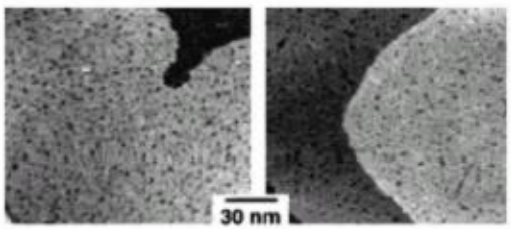
  – stamp is obtained by **casting** of **elastomer** (PDMS, e.g.) over **master**

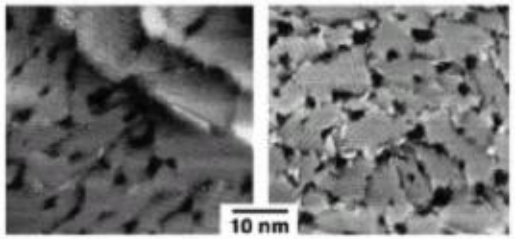


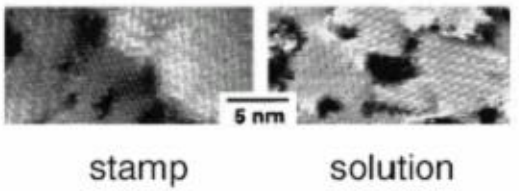
⇒ **pattern** generation by **stamping** of SAM precursor onto substrate:



⇒ **quality** of ***μ*CP** SAMs is **comparable** to films obtained by **adsorption** from solution

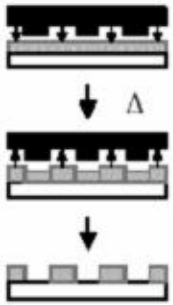


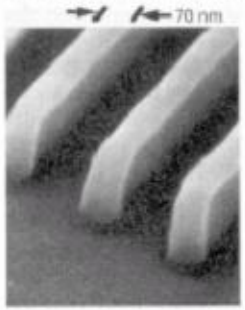




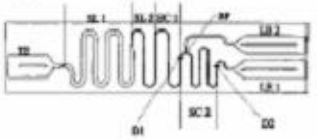
Embossing

- **Rigid master** (stamp, Ni or SiO_2, e.g.) is **pressed** into thermally **softened polymer** substrate (PMMA, polycarbonate → CD, e.g.) to transfer relief structure to polymer:

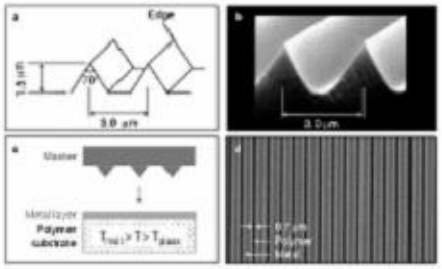




– application: microchip for isotachophoresis (electrophoretic separation technique for ionic compounds)



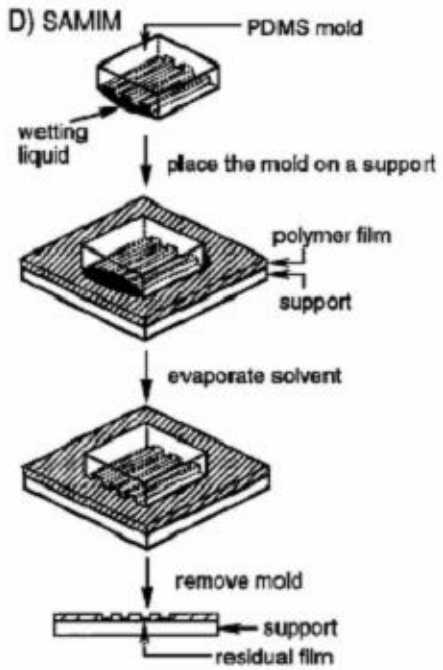
⇒ **Microcutting**: embossing of **metal-coated** polymer films creates metallic **micro-objects**

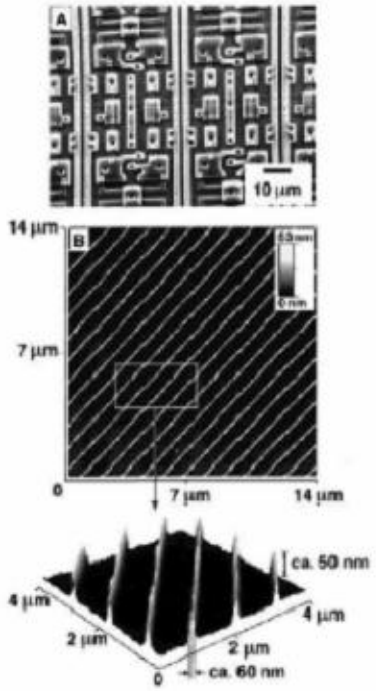


– application: IR-polarizer, polarization-dependent color filter (on the right)

Solvent Assist Micromolding(SAMIM)

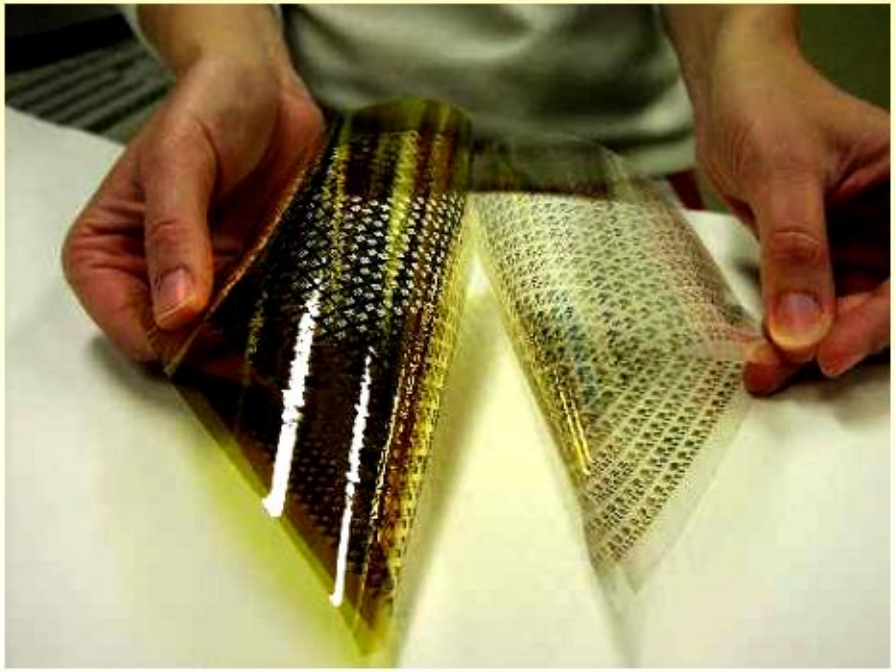
- **Quasi-3D microstructure** formation in **polymeric substrates** by **solvent** etching in microcapillaries:





polymer film:
photoresist,
solvent:
ethanol

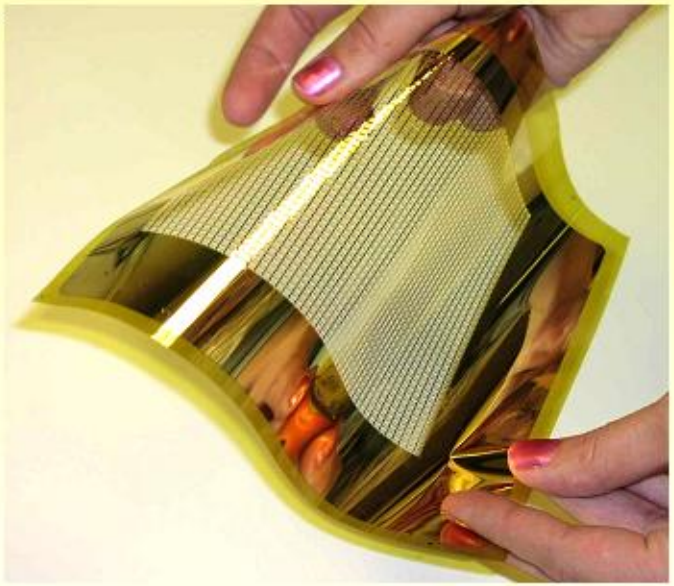
Shadow-Mask Patterned Microelectronics at 3M

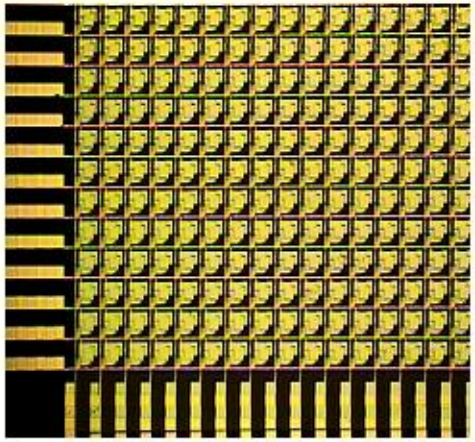


Steven Theiss, Paul Baude, Dave Ender, Chris Gerlach, Michael Haase, Tommie Kelley, T.C. Lee, Dawn Muyres, Dennis Vogel

Why polymeric shadow masking?

- Cheap/ reusable
- Compatible with roll-to-roll
- Flexible
- Non-damaging

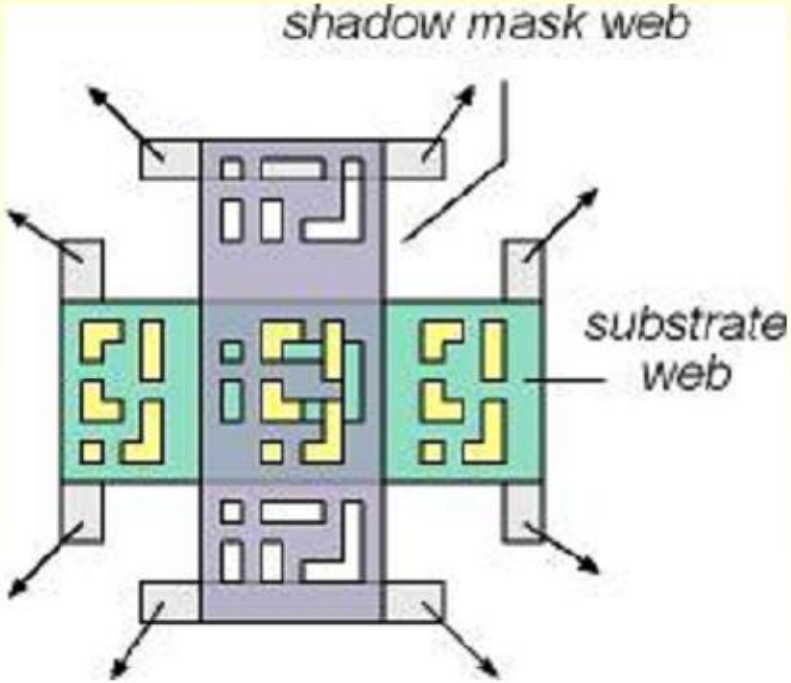




- Large area
- Enables top contact devices
- All additive

Web coating – alignment

- Registration with 20-30 μm accuracy is the challenge
- 3M pending I.P. for laser ablated shadow masks for integrated circuits
- Align shadow mask cross-web with substrate, active alignment
- Step-and-repeat manufacturing process



R2R Deposition and etching

- Moving from photovoltaics to flexible electronics
  - R2R reactive ion etching
  - Deposition of silicon nitride and intrinsic micro-crystalline silicon
- Device results

Imprint Lithography

- Basics of imprint lithography
- Comparison with R2R patterning alternatives
- R2R implementation of imprint lithography
- Self-Aligned Imprint Lithography (SAIL)

IOWA THIN FILM TECHNOLOGIES

HEWLETT PACKARD

Benefits and Drawbacks of Roll-to-Roll Processing

- Benefits
  - High throughput --- expected lower costs
  - Steady state operation in deposition and etching systems
    - amenable to in line monitoring
  - Substrate loads 1000 ft^2 at a time
- Drawbacks
  - Distortion of web increases difficulty in lithography
  - No "prior generation" production equipment available for R&D work
  - Each added step leads to a new design and build development program
    - New material deposition or etches require new machines
    - Variation of order in processing steps require modifications of internal structure on existing machines

IOWA THIN FILM TECHNOLOGIES

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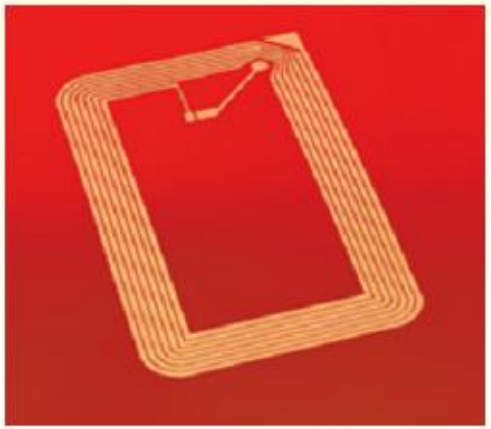
Metal printing



Applications of electrode patterning

•Achievable minimum line widths are a function of droplet size and wetting properties

•Demonstrated resolution and line width of 100 microns

•Emerging print head technologies with smaller droplet sizes will enable lines down to 50 microns

•Combined with other patented technologies, track and gap down to 10 microns have been demonstrated

- •RFID tags
- •Plastic electronics
- •Batteries and fuel cells
- •**Printed circuitry**
- •RF shielding
- •EL disposable displays
- •Sensors

- •Rapid prototyping
- •Decoration – high metallic lustre
- •Aerials and antennas
- •Solar panels
- •Windscreen heaters
- •**Display**