Nanometer Scale Patterning and Processing

Spring 2016

Lecture 37

Nanoimprint Lithography (NIL) – Resist for UV-NIL

- Section 6

RESIST FOR UV-NIL

Resist for UV-NIL

- UV-NIL resist has little in common with photo-resist, which resembles more thermal NIL resist.
- In principle, any material that is soft (thus can be imprinted) and becomes hard upon UV exposure, can be used as UV-NIL resist.
- For example, UV-glue for optical components and dental UV sealant, are UV-NIL resist.

Component of UV-NIL resist:

- Organic acrylates provide low viscosity.
- Organic cross-linker.
- Additives: silicon-containing acrylate monomer, flourinated compounds.
- Photoinitiator: cationic or free radical photoinitiator.

Photoinitiators:

- Cationic photoinitiator:

  Insensitive to oxygen, but low curing rates; and acids and heavy metals are harmful to semiconductors.
- Free radical photoinitiator:

  Great variety, high curing rates, but sensitive to oxygen, need vacuum or N_2 environment curing.

UV curing at 375nm: curing time

Typical curing time is a few seconds; oxygen is problem, need vacuum.

Results	Time (s) at 120 mW/cm²	Remarks
➢ Sealant: Helioseal	25	
	Time (s) at 30 mW/cm²	
➢ UV glue: NOA 61	20	
➢ UV NIL Polymers		
- Inoflex RP+	< 5	sensitive to oxygen
- PAK 01	< 5	sensitive to oxygen
- NIF 2	10	sensitive to oxygen
- NIF 1	10	sensitive to oxygen
- Z Resit	< 5	sensitive to oxygen

Increase in Power up to 120 mW/cm² possible → embrittlement

Note: those resists are just examples, none of them are popular – in fact currently there is no single UV-resist that gains enough popularity – each company/researcher has its own small market share.

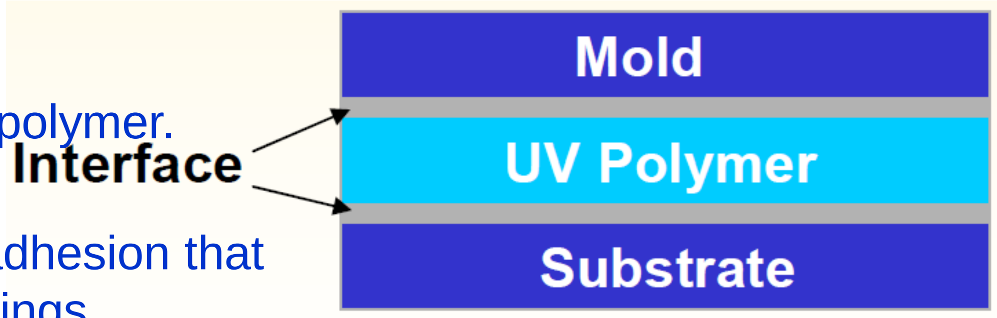
Holger Schmitt, Christoph Lehrer

Adhesion mold/UV polymer/substrate

Ideally:

No adhesion between mold/UV-polymer.

Strong adhesion between substrate/UV polymer.



Interface reaction:

Mechanical adhesion, wetting, specific adhesion that is mainly caused by inter-molecular bindings.

σ is surface tension (N/m), also called surface energy (energy/m^2=N/m)

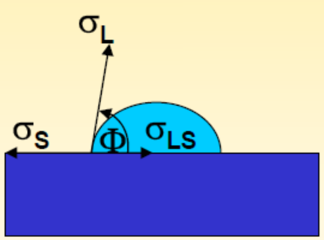
For substrate (Si, Si/HMDS, Si/ARC), low contact angle is better.

For mold, high is better.

Here, all resists still "wet" the mold (Φ<90^o)

Wetting:

Contact angle measurments



$$\sigma_S = \sigma_{LS} + \sigma_L{*}\cos\Phi$$

***ARC: Anti Reflective Coating**

****Mold: Quartz treated with FTCS**

	Contact angle (°)			
	Si	Si / HMDS	Si / ARC*	Mold**
NOA 61	23,7	41,8		68,3
Helioseal	15	26,7		66,2
Inoflex RP+	14,9	31,9	✓8	67,9
PAK 01	✓9,4	20,3	✓8,7	66,5
NIF 2	16,3	12,3	✓6,1	33,7
NIF 1	15,8	11,4	✓5,9	34,2
Z Resist	✓6,3	25,8	10,6	65,4

Residual layer thickness

For drop-dispensed resist (not spin coating)

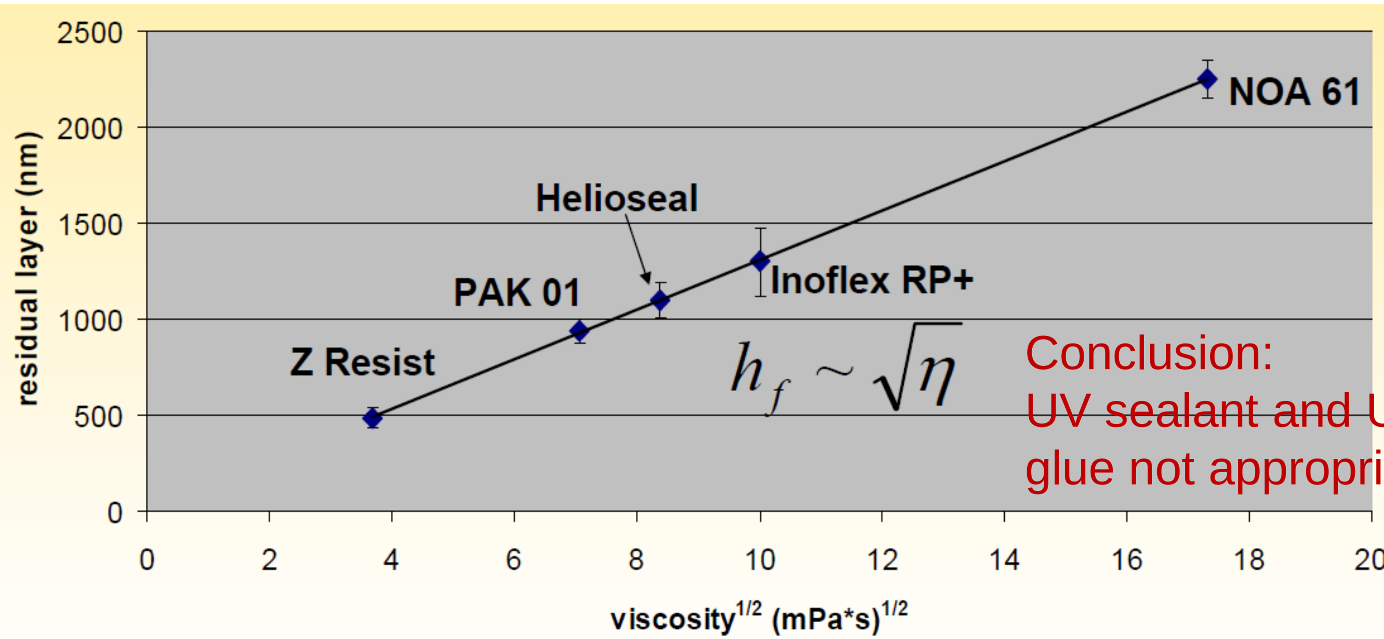
$$if \quad h_f << h_0$$

$$h_f = \sqrt{\frac{s^2 \cdot t_f}{2p}} \cdot \sqrt{\eta}$$

$$\Rightarrow h_f \sim \sqrt{\eta}$$

h_f: final thickness
h_o: initial thickness
s: distance
t_f: imprint time
p: pressure
η: viscosity

Thin (<<100nm) residual layer leads to less dimensional accuracy loss, so low viscosity (high flow rate) is desired.



Conclusion:
UV sealant and UV glue not appropriate.

Certainly, residual layer thickness also depends on initial dispensed drop volume.

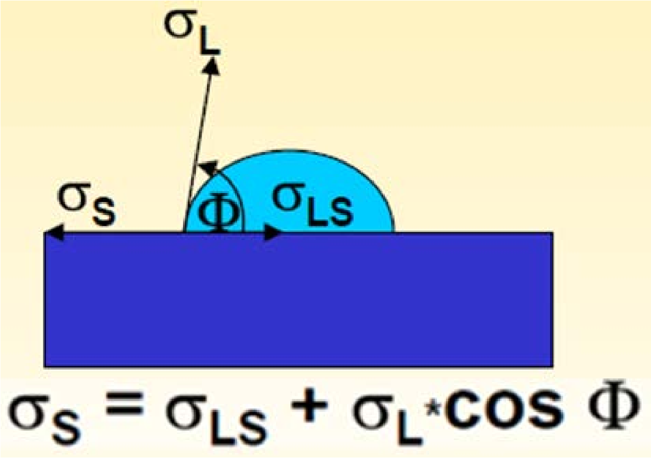
Summary for resist

Curing chemistry: ideally it should be compatible with oxygen, so no need of vacuum.

Curing speed: higher is better for faster imprint, typically few seconds curing time.

Viscosity: lower is better, to fill large features faster, to have thinner residual layer.

Surface energy: Since the resist has to "wet" the mold (contact angle <90 degree) for imprint using low pressure, both the mold and the resist have to have low surface energy for easy separation. Low surface energy resist may not adhere (wet) the Si substrate, making spin coating difficult or leading to resist peel off upon separation. One strategy is to coat an under-layer (PMMA, PMGI, ARC…) that binds well with the resist having low surface energy.



If mold is coated with mold release agent (very low surface energy), the resist may still "wet" the mold if it also has low surface energy. (i.e. all the σ in the equation is small, one can still have $\Phi<90^o$)