

Lecture - 14-15. Nano Imprint Lithography

10.1. In case there is slippage on the surface of the stamp which you are using for NIL will it have any influence on the process or on the patterns?

Ans: Existence of slippage at the surface of the stamp will in fact facilitate Nano Imprint Lithography. As there is finite slippage in that walls of the stamp, the velocity gradient will be lower, as compared to stamp which has no slippage. A reduced velocity gradient will lead to reduced level of residual stresses.

Also, with slippage detachment of the master after pattern replication becomes easier.

10.2. What is the compound-eye concept and where can it be used?

Ans: Compound eyes, which are commonly seen in insects consist of thousands of individual photoreceptor units. The image perceived is a combination of inputs from the numerous photoreceptor units (individual "eye units"), which are located on a convex surface, thus pointing in slightly different directions. Compared with simple eyes, compound eyes possess a very large view angle.

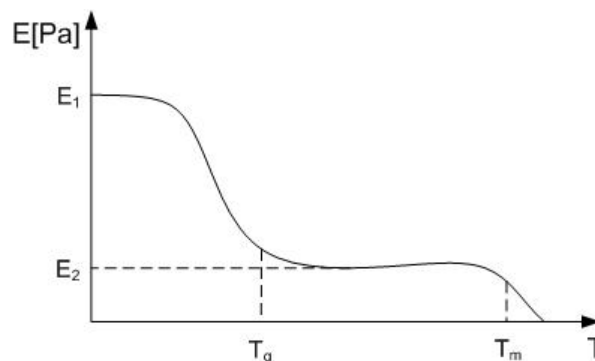
This concept can be used in Micro-lens array. In which, with an array of lens and one mask, multiple patterns can be created.

10.3. What is glass transition temperature for a polymer?

Ans: In [polymers](#) the glass transition temperature, T_g , is often expressed as the temperature at which the [Gibbs free energy](#) is such that the [activation energy](#) for the cooperative movement of 50 or so elements of the polymer is exceeded. This allows molecular chains to slide past each other when a force is applied.

The glass transition temperature is a function of chain flexibility. The glass transition occurs when there is enough vibration (thermal) energy in the system to create sufficient free-volume to permit sequences of 6-10 main-chain carbons to move together as a unit. At this point, the mechanical behavior of the polymer changes from rigid and brittle to tough and leathery

The stiffness of thermoplastics decreases due to this effect (see figure.) When the glass transition temperature has been reached, the stiffness stays the same for a while, i.e., at or near E_2 , until the temperature exceeds T_m , and the material melts. This region is called the rubber plateau.



10.4. Why is glass transition temperature important?

Ans: The importance can be explained by the means of an example, the [Space Shuttle Challenger](#) disaster was caused by rubber O-rings that were being used well below their glass transition temperature on an unusually cold Florida morning, and thus could not flex

adequately to form proper seals between sections of the two solid-fuel rocket boosters. The O-ring failure caused a breach in the SRB joint it sealed, allowing pressurized hot gas from within the solid rocket motor to reach the outside and impinge upon the adjacent SRB attachment hardware and external fuel tank. This led to the separation of the right-hand SRBs aft attachment and the structural failure of the external tank. Aerodynamic forces promptly broke up the orbiter.

10.5. What is Reactive-ion Etching and why is it used?

Ans: Reactive-ion etching (RIE) is an etching technology used in microfabrication. It uses chemically reactive plasma to remove material deposited on wafers. The plasma is generated under low pressure (vacuum) by an electromagnetic field. High-energy ions from the plasma attack the wafer surface and react with it. This is almost a compulsory step in Nano Imprint Lithography also, to remove the remnant layers on the surface, particularly at the valley locations of the substrate patterns.

10.6. Describe some problems associated with NIL?

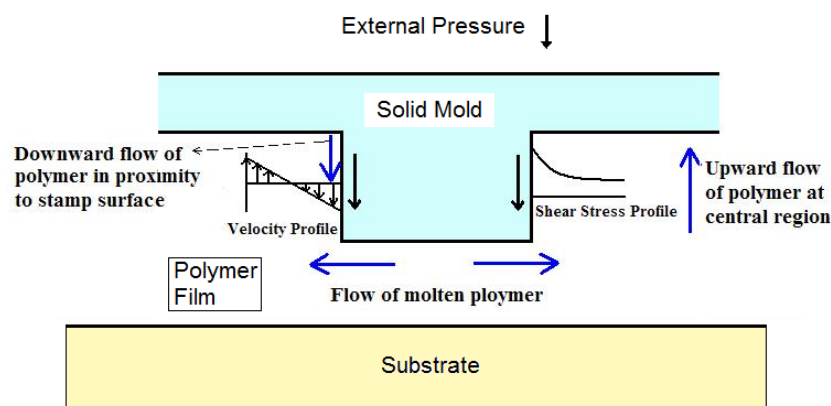
Ans: Nano Imprint Lithography (NIL) requires a rigid stamp. Thus, the first requirement is an absolutely parallel arrangement between the mold and the film is necessary. Else the structures will be wedge shaped and there will be variation in the feature height across the sample surface.

The second major aspect is detachment of the mold after the film has been cooled to room temperature and the pattern replication has taken place. The polymer tends to adhere to the mold intimately, making mold release difficult. To overcome this problem, often low surface energy mold release agents are coated on the mold surface. This facilitates easy detachment.

The use of a rigid stamp limits the use of NIL in patterning a non planar or curved surface.

10.7. Qualitatively draw and discuss the flow profile and pattern replication mechanism in Nano Imprint Lithography (NIL).

Ans: The accompanying figure shows the qualitative velocity profile and the shear stress profile during NIL.



It is important to note that the flow adjacent to the mold surface is similar to Couette flow, as the stamp is gradually being pressed in the film and due to no slip condition, the adajant liquid is flowing downwards. However, at the central part, the polymer liquid meniscus flows upwards. This leads to an inversion in the direction of flow within the film.

This leads to increased velocity gradient and consequently high shear stress. This stress remains within the patterned film as residual stress.