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Computationally inexpensive simulation and modeling for future lithography processes

Nanoimprint lithography (NIL) offers sub-10 nm patterning resolution with lower capital costs than competing technologies such as extreme ultraviolet lithography (EUV). To be adopted widely in data storage and semiconductor manufacturing, NIL's throughput needs to increase and its defect rate needs to fall. One way of improving NIL's throughput and yield is to develop comprehensive models of the process that can guide its optimization.

Over the last seven years we have developed a computationally inexpensive simulation technique for NIL. The technique captures the deformation behavior of an imprinted polymeric film using its mechanical impulse response, and describes elastic deformations of the imprinting stamp via a point-load response. We have developed the technique to simulate chip-scale patterns containing many millions of features, and to model the imprinting of both thermoplastic resists and ultraviolet-curing resins. I will describe the simulation technique and how we have applied it to: (*i*) optimize process parameters, (*ii*) select materials for the stamp, and (*iii*) guide the design of the imprinted pattern itself.

We have extended the model for roller-based imprinting on continuous substrates, capturing substrate-speed and roller-load dependencies. By considering viscoelasticity of the imprinted material, we argue that there is an optimal substrate speed that maximizes the fidelity of imprinted patterns.

Finally, I will describe a new holographic lithography process that has the potential for forming multi-layer microstructures in photosensitive hydrogels and resins, in principle over unlimited areas. This and hybrid mechanical/optical lithography techniques could be instrumental in offering high spatial resolution over progressively larger areas.