Nanolithography by Combined Self-Assembly and Directed-Assembly

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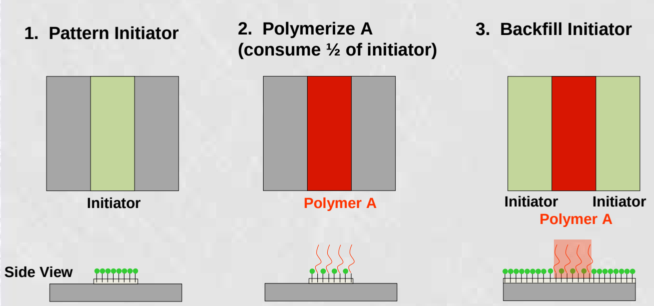
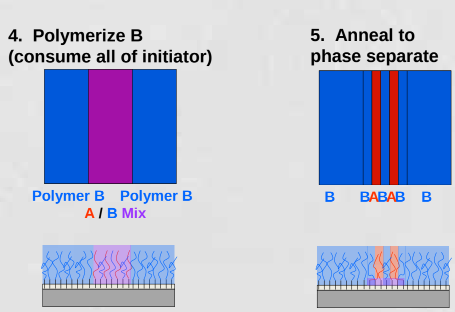
Problem

- There is a shortage of methods to produce controlled, directionally-aligned nanoscopic features on surfaces.
- The current method of choice is electron beam lithography, an extremely expensive, time-consuming technique that can only be used on a limited range of materials.
- In contrast, self-assembly approaches are fast and relatively easy ways to make nanopatterns, but they typically lack directional control.
- Micron-scale lithography is similarly routine, provides control of directionality and structure, but does not provide nanoscale features.
- A method that combines the structural control of photolithography with the size-scale and ease of use self-assembly would be highly desirable.

Approach

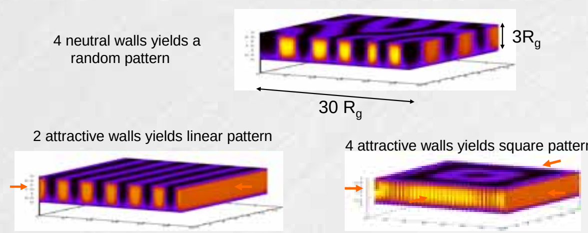
- Use micron-scale directed assembly to drive nanoscale self-assembly.
- This unique approach allows us to form directionally aligned nanopatterns.
- The process is compatible with standard lithographic procedures.
- Parallel process can produce materials in large quantities, unlike serial processes like electron beam lithography.



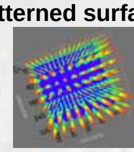


Results

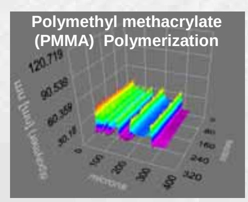
Simulation — Definitively shows that boundaries determine ordering in phase separation

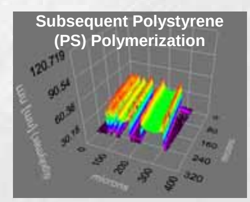


Experiment — Guided by simulation, numerous nano-patterned surfaces can be formed

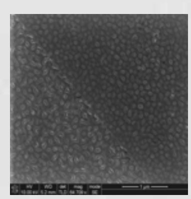


- Lithography creates surface features that may be selectively functionalized with free radical initiators.
- Surface initiated polymerization from these features grows polymer tens of nanometers in thickness from the surface.





- Ellipsometry quantitatively measures the growth of polymer.
- Mixed polymer brushes are created by sequentially exposing initiator functionalized surfaces to various monomer solutions.



- Mixed polymer brushes of PMMA and PS phase separate forming self-assembled structures.
- Polymer proportions and annealing conditions drive self-assembly.
- Lithographic templating creates a discrete boundary in the brush (e.g. mixed brush → single component brush).

Significance

- This approach allows us to create repeating nanostructures in defined architectures.
- Polymers can be selectively removed — this directly produces nanochannels or can be metallized to form nanowires.
- Self-assembly approaches have been of great interest to the microelectronics industry, but no practical systems had been found.
- This work represents an exciting new way of forming nanomaterials for basic nanoscience research, as well as potentially valuable intellectual property for the American electronics industry.
- Potential commercial applications include: Microchips, magnetic and optical information storage, and on-chip nanofluidics.

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