Parallel Fabrication of Three-dimensional Nanostructures Utilizing Two-Photon Polymerization

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Impetus

We want top-down fabrication techniques for producing arbitrary three-dimensional nanostructures.

Method

- Photopolymers are materials that harden (polymerize) upon exposure to UV light
- Using a focused laser, we can selectively solidify a structure
- Afterwards, we wash away the unpolymerized resin
- Resulting structure is non-conductive, to make conductive we use an electroless plating process
- Specially polymers optimized for electroless plating or for biocompatibility are possible, expanding applications

What about the Diffraction Limit?

- Normally feature size is limited by the diffraction of light, the smallest focal area is almost the same as the wavelength
- By utilizing non-linear properties of two-photon absorption, polymerization occurs only at the focal point in an area smaller than the diffraction limit
- This allows features smaller than 120 nm

What is Parallel?

- For thousands of structures, fabricating one by one takes too long
- Solution: Split the laser beam into many beams using an array of tiny lenses (a microlens array or MLA)
- Each beam has its own focal point, so the process works the same, except now with many simultaneous fabrication points

Process

- The fabrication is done using an optics table to prepare the beam and a microscope with a computer controlled stage to perform the fabrication.
- Steps of process:
  1. Place drop of photopolymer on a glass slide
  2. Pulse laser to control polymerization
  3. Use mechanical stage to move focal points in xyz-axes to “draw” arbitrary three-dimensional structures

Applications

- Without Plating:
  a. Biology: for example, creating scaffolding for growing cells
  b. Mechanical components: proof of concept = a resin spring that follows Hooke’s law

- With Plating:
  a. Now we can create periodic, conductive nanostructures
  b. With conductivity, can build nanoscale electromagnetically resonating structures for use in meta-materials

Conclusions

With the addition of special resins for biology, the electroless plating process, and a microlens array, two photon polymerization is a flexible but powerful technique for nanoscale fabrication of structures.

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