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 (poylmerize) upon exposure to UV light

✓Using a focused laser, we can selectively solidifiy a structure

✓Afterwards, we wash away the unpolymerized resin

✓Resulting structure is non-conductive, to make conductive we use an electroless plating process

✓Specialty 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)

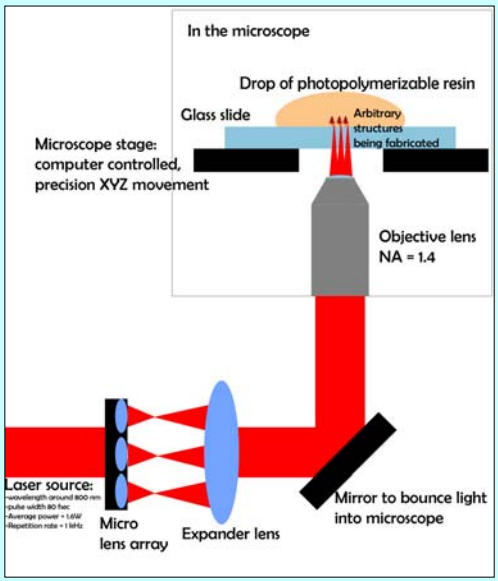
✓Each beam has its own focal point, so the process works the same, except now with many simultaneous fabrication points

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



Diagram

4. Wash away photopolymer, leaving behind only polymerized parts
5. Immerse resulting resin structure in an electroless plating solution to coat it with silver particles

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

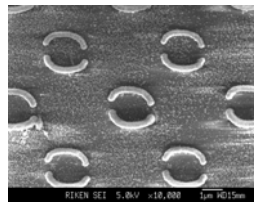
Cardiomycytes growing on a polymerized scaffold (scale 10 μm)

Mechanical spring with attached resin ball (scale 2 μm)

✓**With Plating:**

a. Now we can create periodic, conductive nanostructures

b. With conductivity, can build nanoscale electromagnetically resonating structures for use in meta-materials



Array of nanoscale, conductive split rings. Potential for use as resonators

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.

Acknowledgements

My research in the electroless plating process was made possible by a grant from the National Science Foundation. The main nanofabrication research is funded by the RIKEN (The Institute of Physical and Chemical Research) Nanoscience and Technology Program and the Extreme Photonics Program.