TWO-PHOTON LASER FABRICATION OF MICRO/NANO 3-D STRUCTURES

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Two-photon absorption allows for the confinement of photo chemical reactions in a volume on the order of the laser wavelength. Using two-photon absorption we have developed a two-photon photopolymerization technique for fabricating micro/nano structures. A mode-locked Ti:Sapphire laser (780 nm, 82 MHz, 80 fs) is focused into a photopolymerizable liquid resin and within the focal spot, where the photon flux is sufficiently high enough, two-photon absorption initiates a chemical reaction which polymerizes the resin into a solid. The resolution of this solid can be made less than the diffraction limit because only the exposure energy in the centre of the focal spot is great enough to fully polymerize the resin. By scanning the focal spot according to a pre-programmed pattern, three dimensional structures can be formed. The production of these micro/nano structures via two photon photopolymerization has established the femtosecond laser as a powerful fabrication tool. However, delicate structures are ruined by surface tension forces while trying to move them from liquid to air. Using supercritical fluids that have low surface tension, we are able to dry spring-shaped polymer nanowires that have been fabricated by two photon photopolymerization and test their physical characteristics with a laser trapping system.

Two-Photon Laser Fabrication of Micro/Nano 3-D Structures

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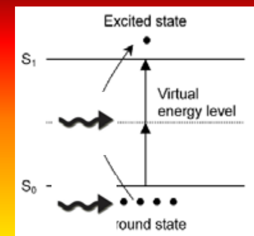
1. Abstract

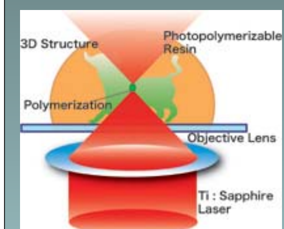
- Using two-photon absorption we have developed a two-photon photopolymerization technique for fabricating micro/nano structures
- A mode-locked Ti:Sapphire laser (780 nm, 82 MHz, 80 fs) is focused into a photopolymerizable liquid resin and within the focal spot, where the photon flux is sufficiently high enough, two-photon absorption initiates a chemical reaction which polymerizes the resin into a solid
- By scanning the focal spot according to a pre-programmed pattern, three dimensional structures are formed
- Delicate structures are ruined by surface tension forces while trying to move them from liquid to air. Using supercritical fluids that have low surface tension, we are able to dry delicate spring-shaped polymer nanowires that have been fabricated by two photon photopolymerization and test their physical characteristics with a laser trapping system

2. Two Photon Absorption



- Electron transitions from ground state to excited state by simultaneous absorption of two laser photons
- This process is used to initiate local photopolymerization from which micro/nano structures are created
- Femtosecond laser used because:
  1) Fast deposition of energy – no thermal effects
  2) Very high peak power – large photon flux sufficiently enables two photon absorption to modify the material for fabrication

3. Fabrication Process



Focus femtosecond laser into photo-polymerizable resin. 3D structures can be formed by scanning focal spot according to pre-programmed pattern

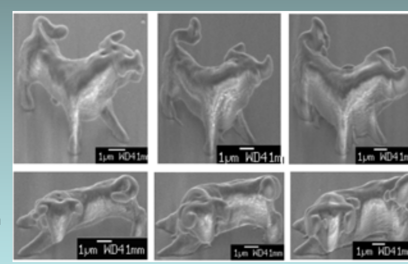
Wash away non-solidified resin with ethanol

When ethanol evaporates, structure remains

4. Spatial Resolution

Far field optical system is used for fabrication so spatial resolution is defined by diffraction limit and is on order of wavelength (780 nm)

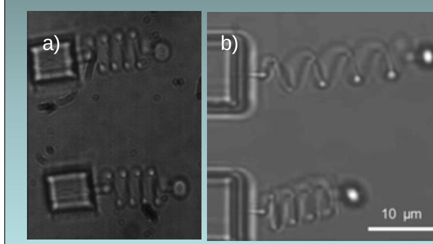
To achieve sub-diffraction resolution chemical threshold effect is used such that photon flux is only high enough in central portion of focal spot to initiate polymerization



Fabricating with an average laser power between 100 and 130mW gave me the best resolution. I achieved a spatial resolution of about 100 nm, much smaller than the incident wavelength

As the laser power decreased, the area in the focal spot that could initiate polymerization also decreased

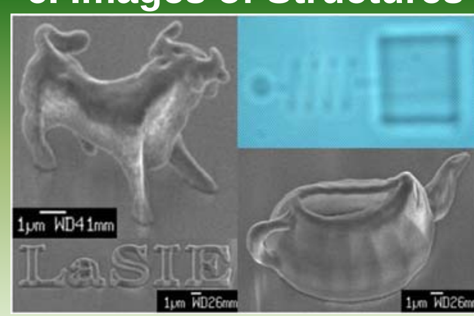
5. Laser Trapping



Optical microscope images of micro-springs

a) Springs are in relaxed state
b) Top spring is being extended using laser trapping and bottom spring remains relaxed

6. Images of Structures



7. Conclusions

- Consistent fabrication of micro/nano structures is possible with two-photon photopolymerization technology
- Sub-diffraction resolution can be achieved to fabricate better defined features
- Micro-springs can be extended and contracted using a laser trapping system. This is a step towards using this technology to develop microelectromechanical systems

8. Future Steps

- Fabricate micro springs with varying wire thickness
- Dry micro springs using supercritical fluids, which have low surface tension, as an intermediate between ethanol and air
- Find springs' physical properties using laser trapping system and SEM

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http://nanojapan.rice.edu

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