Two- and three-dimensional micromachining of transparent polymers using femtosecond laser pulses

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Introduction

Focusing femtosecond pulses into transparent materials produces an intensity at the focus high enough to cause localized structural and chemical changes. This process allows precise micromachining of glasses, crystals, and polymers.

High intensity leads to energy deposition via nonlinear absorption

Tight focusing with microscope objectives and nonlinear nature of absorption confines structural alteration below diffraction limit

Short pulse duration minimizes energy necessary to cause nonlinear absorption, minimizing collateral damage.

Surface machining of polymers

Microcontact printing is used to produce micrometer-scale circuits using elastomeric stamps. Surface machining of stamps with femtosecond pulses eliminates photolithographic step.

Conventional microcontact printing

- Photoresist master made by photolithography
- PDMS cured over photoresist master
- PDMS removed from master to be used as a stamp for microcontact printing
- PDMS stamp coated with alkanethiol and placed in contact with gold surface
- Stamp removed and alkanethiol SAM attached to gold to serve as etch resist
- After etching, gold features are left on Si/SiO2 substrate

Laser surface machining of PDMS stamps

- Non-photolithographic technique has advantages over lithographic techniques.
  - Smaller features than transparency masks (for rapid-prototyping)
  - Equivalent feature size (1 µm) to chrome masks
  - Patterning of non-planar surfaces
  - Large-area pattern fabrication

Future directions

Doping polymer to increase conductivity of chemically-altered regions

Optimizing polymer to give more robust structures

Direct writing onto curved PDMS surfaces (e.g., for large-field IR detectors)

Fabrication of micrometer-scale device demonstrating mechanical and/or electrical capabilities (MEMS)

Investigation of new materials: application to sol-gels (colloidal silica suspensions) could induce localized glass formation

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