RESEARCH BRIEF

MEMS-BASED GRAYSCALE TECHNOLOGY

The potential

Scientists and researchers have long viewed micro-electro-mechanical systems technology with great hope towards its potential application.

However, common MEMS fabrication processes are limited to the production of vertical sidewalls through dry anisotropic etching; angled sidewalls dependent on the crystallographic orientation of the substrate through wet anisotropic etching; or undercut profiles through wet/dry isotropic etching.

Conversely, there is an ever-increasing interest in a batch fabrication technique that can realize gradient height profiles in silicon.

Although key production factors have slowed progress, ISR researchers, led by Dr. Reza Ghodssi, have found a solution. A technique called gray-scale lithography, typically used in diffractive optics, has recently been found to produce good results when used in the construction of miniature parts for MEMS.

Arbitrary 3D silicon structures that better emulate their macroscopic counterparts have become a reality with the development of small-scale silicon compressors and turbines for use in micro-engines and contoured x-ray Fresnel lenses for increasing lens efficiency.

The challenge

Various 3D fabrication techniques have been demonstrated in forming gradient height structures in MEMS devices. The inherent problems of these techniques are that they either require unconventional process equipment, or are not reproducible as a batch process. For a technology to be a realistic option for the fabrication of micro-components, a method of production that permits intricate design and robust construction in lightweight materials is necessary.

The research

Gray-scale lithography, a process previously used in the fabrication of diffractive optical elements, has proven to be a useful batch process for creating gradient height structures. This one-level lithography process enables the development of gradient height profiles in a photoresist-masking layer. Once this unique height profile is obtained in the photoresist layer, deep anisotropic etching of silicon (through either reactive ion etching [RIE] or deep reactive ion etching [DRIE]) is used to transfer the photoresist shape into the final desired 3D silicon structure.

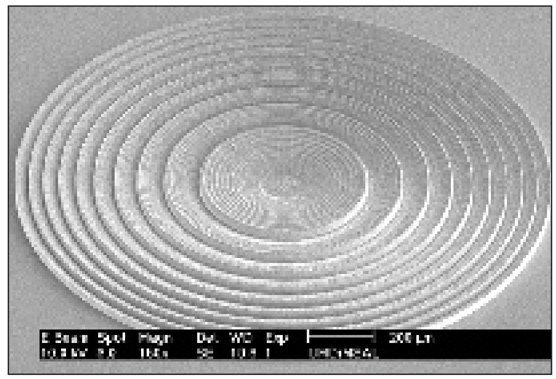

Figure of a silicon X-ray Fresnel Lens fabricated using gray-scale technology that incorporates a gradient height profile designed to increase lens efficiency. ©IEEE 2004

Key components of gray-scale lithography include the design of the optical mask and the use of a photolithography stepper system. Together, these components are used locally to modulate the intensity of ultraviolet light hitting a photoresist layer, which exposes the photoresist to a specified depth at each location. When the photoresist is 'developed' in a chemical solution, portions of the photoresist that have been exposed to the ultraviolet light are washed away. The gradient height profile left behind in photoresist then acts as a very technical 'stencil' that researchers can use in conjunction with deep anisotropic etching of silicon to achieve the desired 3D structure.

Awards

Army Research Laboratory Collaborative Technology Alliances (CTA): Power & Energy Program

Army Research Laboratory Power & Energy Electronics Research (PEER) Program

NASA Goddard Space Flight Center

ARCS (Achievement Rewards for College Scientists) Foundation

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Gray-scale technology project
www.ece.umd.edu/MEMS/projects_grayscaletech.html