Overview
June 2002
PLASMA ETCH USERS GROUP Meeting

Topic: **Plasma Etching Related To MEMS/MOEMS Fabrication**

Chair: **Jim McVittie**, Stanford NanoFabrication Facility
Stanford University (mcvittie@stanford.edu)

Description of Meeting

For the last few years, we have been having a session in the May/June period devoted to plasma etching issues related to the fabrication MicroElectroMechanical Systems (MEMS). This year we are continuing the tradition but have added talks on MicroOptoElectroMechanical System (MOEMS). The first talk focuses on the development of a tapered trench etch process in silicon. The second talk uses the etching of high aspect ratio holes to fabricate an enhanced X-ray detector. In the third talk, we move to MOEMS in the form of a scanning micromirror system. This talk will also discuss the general plasma etch needs of MOEMS. The final MOEMS talk discusses a high resolution microscopy system bases on the fabrication of micromachined lenses and optical antennas.

Talks

Fabrication of Deep, Large Angle Tapered Trenches for Microelectromechanical (MEMS) Applications
Mike Rattner – AKT/Applied Materials

Optimization of deep hole etching in silicon for 3-D x-ray detectors
Eric Perozziello – U of Hawaii/Stanford U

Plasma Etching for Optical MEMS: Scanning Micromirrors Based on Self-Aligned Vertical Combdrive Actuators
Stefan Zappe – Stanford Microphotonics Laboratory/Sanford U

Scanning Nearfield Optical Microscopy with Micromachined Lenses and Optical Antennas
Ken Crozier – Ginzton Laboratory/Stanford University

Fabrication of Deep, Large Angle Tapered Trenches for Microelectromechanical (MEMS) Applications

M. Rattner, R. Guenther, B. Cooper, J.D. Chinn -- MEMS Division of AKT / Applied Materials, Jeff_Chinn@amat.com

Abstract: Many advanced MEMS device designs require smooth positive taper angle sidewalls. Examples include fluid channels and plastic micromolding dies. Results from experiments used to determine the process parameters that affect the sidewall taper angle of a cyclic C4F8-SF6 deposition and etch process are presented. The sidewall profile is determined by the interactions of the etch and deposition steps. The etch pressure is particularly important, as a high etch pressure along with an aggressive etch allows for a unique undercut process. Another important factor is theetch bias power which is used to control the anisotropy of the etch. The choice of etch power must balance factors such as etch taper angel, etch rate, sidewall roughness and scalloping. In addition, a final etch step is explored to decrease sidewall roughness and scalloping.

Optimization of Deep Hole Etching in Silicon for 3-D X-ray Detectors

Eric Perozziello, Sherwood Parker -- University of Hawaii/Stanford University eap@gloworm.Stanford.ED, sher@SLAC.Stanford.EDU

Abstract: Silicon radiation detectors originally developed for high energy physics are now being fabricated to serve as x-ray detectors for Protein Crystallography. They use an array of p-i-n diodes to detect the electron- hole pairs caused by an incident x-ray. For good X-ray sensitivity,thick detectors are needed. To make them both thick and with no significant dead regions along their edges, their electrodes penetrate through the three dimensional volume of the silicon and line the edges, rather than being confined to planes on the top and bottom surfaces as has been done with all detectors made previously.

The first step in fabricating such electrodes is to etch deep, narrow vias. Ideally, the vias should penetrate the wafer (500 micron deep) and have a diameter that consumes an insignificant portion of the detector area. Current work has been aimed at optimizing the etch process (Bosch process) in an older STS system at Stanford. In this endeavor, our effective aspect ratio (depth/average diameter) of small (~10 micron diameter) holes has doubled from tuning of the Bosch process with a maximum of 25:1 achieved so far. This talk presents a background of the project, and the optimization of the etch process.

Plasma Etching for Optical MEMS: Scanning Micromirrors Based on Self-Aligned Vertical Combdrive Actuators

Stefan Zappe, Uma Krisnamoorthy, Daesung Lee and Olav Solgaard
Stanford Microphotonics Laboratory, Stanford University
zappe@stanford.edu

Abstract -- There is great demand for high-speed, high-resolution micromirrors in a variety of optical applications including optical scanning, optical switching and spectroscopy. For many of these applications, electrostatic combdrives are the preferred actuation mechanism, because combdrives
provide high speed and relatively high force, and they can be made using standard materials. We present design, fabrication and characterization of micromirrors that are driven by self-aligned, vertical combdrives based on Deep Reactive Ion Etching (DRIE) of Silicon-On-Insulator (SOI) wafers.

Combdrives produce large deflections at relatively low voltages with continuous stable control over the full range of motion. In vertical combdrives the two sets of comb teeth of a conventional comb drive are staggered in the vertical direction. A voltage applied between the movable
top comb array and the static bottom comb array produces a vertical electrostatic force that can be applied to create torsional or piston-like motion of micromirrors. (next page)

Plasma Etching for Optical MEMS: Scanning Micromirrors Based on Self-Aligned Vertical Combdrive Actuators

Abstract continued -- A critical aspect of combdrive design is the spacing between adjacent comb teeth, because the generated force is inversely proportional to this gap size. Combdrives with small gaps are, however, more susceptible to misalignment between the top and bottom comb arrays. For the actuator to be operational, the misalignment tolerance level between the top and bottom teeth should be an order of magnitude smaller than the gap width.

We have developed a simple fabrication process based on plasma etching that produces self-aligned vertical combdrives. Self-alignment makes it possible to fabricate reliable narrow-gap, high-force actuators with excellent yield. A resonance frequency for 300 mm x 100 mm mirrors around 5.5 kHz has been achieved.

After a first part covering the above described specific application of plasma etching, the needs concerning plasma etching for optical MEMS components will be discussed in a broader context.

Scanning Nearfield Optical Microscopy with Micromachined Lenses and Optical Antennas

Ken Crozier Stanford University, kcrozier@leland.stanford.edu

Abstract -- We discuss two methods for improving optical resolution beyond the optical diffraction limit in air based on micromachined lenses and optical antennas.

The first method, the Solid Immersion Lens (SIL), improves optical resolution by focussing light in a high refractive index lens held close to the sample. We present experimental results with a scanning optical microscope (at a wavelength of 400nm) based on a micromachined silicon nitride SIL integrated with an atomic force microscope cantilever. The spot size of the SIL-based microscope is measured to be ~130nm, which is ~1.9 times better than the spot size without the SIL (256nm). We discuss the surface micromachining method used to make these lenses.

The second method for improving resolution is based on antennas that operate at optical wavelengths. When illuminated with light, intense and spatially localized optical fields result at the ends of the antenna. We present a numerical study at visible and infrared wavelengths based on the finite difference time domain (FDTD) technique. We also present experimental results at infrared wavelengths with optical antennas fabricated by electron-beam lithography.