Deposition and Characterization of Magnetic Permalloy for Future Endomicroscope Actuators

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Introduction:

When nickel and iron are combined in an 80% to 20% ratio, respectively, the resulting material is called permalloy. Permalloy expresses strong magnetic properties and as such, is a prime candidate for future actuator applications. The biomedical community has taken recent interest in the development of permalloy structures. One potential application in that field is as an alternative to comparatively large piezoelectric actuators currently used in novel prototype endomicroscopes. The use of permalloy will be attempted in order to produce smaller actuators that will instead apply a magnetic field to control lens movement. This project aimed to characterize the different permalloy films that were plated when variables such as current density, plating duration, and pulse timing were varied in the electroplating process.

Oxide-coated wafers were deposited with a chrome-gold seed layer and a secondary oxide coating on the back provided insulation. Photoresist was developed on wafers after electroplating, and was removed in order to begin etching. Ferric chloride, gold etch, and CR-14 etchants were used to etch to the oxide; plasma etch machines etched the oxide and the silicon in order to create cantilevers. A magnetic field was finally applied to test the magnetic properties of these permalloy cantilevers.

Experimental Procedures:

A typical electroplating process requires that a wafer be coated with a conductive seed layer and patterned with photoresist prior to the plating. A seed layer consisting of 500Å of gold and 300Å of chrome was deposited onto the oxide wafers with an EnerJet Evaporator tool. Subsequently, KMPR photoresist was spun at 3000 rpm in order to produce a film 9-10 μm thick. Various different masks were initially used in order to characterize the plating rate and experiment with the current density. Wafers were inserted into a nickel-iron electroplating solution. A dummy was plated for ten minutes at a current density of 20 mA/cm^2 in order to prepare the ion flow in the solution. Wafers were then plated at several different current densities for varying amounts of time. The plating program for the electroplating process consisted of a forward current pulse 90 ms on and 10 ms off for a total pulse duration of 100 ms. After a primary energy dispersive x-ray spectroscopy (EDX) analysis with a scanning electron microscope, it was concluded that a lower current density provided a higher concentration of nickel. Once the permalloy was plated, the photoresist was stripped with acetone and Remover PG.

The permalloy structures were inspected with the Olympus BX-51 microscope and the LEXT Interferometer in order to measure surface roughness and determine if there was any remaining photoresist. A wet etch procedure was conducted with gold etch and CR-14 chrome etch in order to strip the seed layer; a 40 second gold etch produced a substantial undercut in the permalloy features, causing them to fall off.

A different approach was attempted in order to reduce the undercut and produce useful permalloy structures. Thus, permalloy was then plated directly onto the seed layer. Furthermore, the seed layer thickness was reduced to 75Å of chrome and 250Å of gold. Since the permalloy was being plated onto a bare surface, the resulting films were extremely stressed and were peeling at the edges of the wafer.

The plating program was gradually modified to include a reverse current and adjusted pulse timing, as seen in Figure 1. The reverse current allowed the ions to ease off the wafer before being plated, thus reducing the film stress and providing a smoother film.

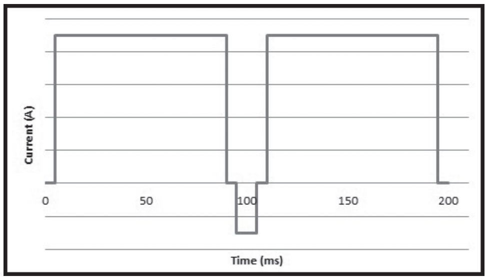

Figure 1: Final pulse timing.

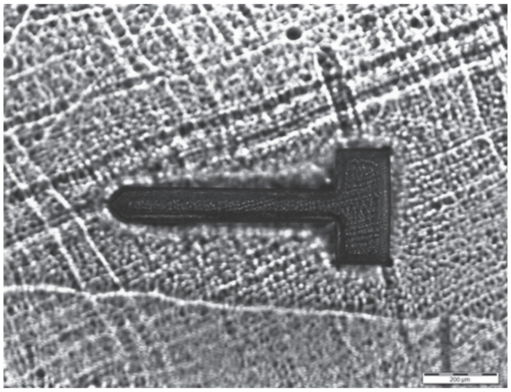

Figure 2: Completed cantilever.

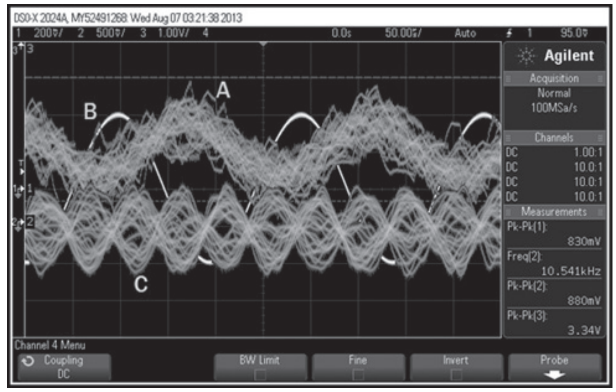

Figure 3: Oscilloscope readings.

The permalloy wafers were then spun with AZ-9260 photoresist. Exposure times for a permalloy base are not given, so we used the same exposure time as one would use for a gold base, in this case 90 seconds (s). The wet etch was attempted again, though this time the excess permalloy was etched with ferric chloride, an etchant typically used for copper. The permalloy structures still suffered from severe undercut, compromising the structural integrity of the cantilevers and rendering them unusable. The etching was characterized and it was determined that 43 seconds of ferric chloride, 18 s of gold etch and 7 s of CR-14 produced stable permalloy features.

Once the seed layer was stripped, the wafers went through a 30 minute plasma etch on the Plasmatherm 790 tool in order to remove the 8000Å oxide layer. The wafers were then subjected to an anisotropic xenon difluoride (XeF_2) etch in order to undercut the cantilever structures and release them from the wafer base. This process ran for a total of 230 cycles at 30 seconds each. Figure 2 shows a cantilever after all the etching has been completed.

Results and Future Work:

After the cantilevers were created, they were tested by applying a magnetic field generated from running a current through a coil. A Laser Doppler vibrometer was placed over the cantilevers in order to measure the vibration of the cantilevers. Frequency sweeps were conducted in an attempt to find the resonant frequency, but most of the input frequencies produced no noticeable patterns from the cantilevers. As seen in Figure 3, wave C shows that a certain frequency did produce some kind of pattern on the cantilevers. Though the LDV did measure a pattern, this was enough to prove the strength of the permalloy films. It is also possible that the LDV was picking up a different motion. More accurate testing must be done in order to confirm that permalloy is indeed a viable alternative to the lead zirconate titanate (PZT) material that is currently used in endomicroscope actuators.

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