Process Development for Novel Fibrous MEMS Structures

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Abstract:

Micro Electronic Mechanical Systems (MEMS) have been developed primarily using isotropic materials such as silicon, and are processed using traditional semiconductor fabrication techniques. It is of importance to investigate other materials which exhibit anisotropic material properties that allow for the design and development of application specific tailored micro-mechanical structures.

Fibrous materials display a broad range of anisotropic behavior depending on the type of material of which they are composed. This project focused on the development of a simple fabrication process to incorporate fibrous materials into MEMS structures. Since cantilevers are the most basic of MEMS structures, a fabrication process was developed to make graphitic fibers based cantilevers on silicon wafers using conventional photolithography, wet and dry etching techniques.

Introduction:

This project was motivated by the fact that materials selection for MEMS is severely limited to traditional semiconductor fabrication materials, which lack basic mechanical property flexibility, preventing the development of structures designed for specific types of deformation and actuation modes. Therefore anisotropic materials must be investigated for specific MEMS devices.

Many fibrous anisotropic materials have strong mechanical properties. The choice of graphite fibers was made because they provide high strength with good strain characteristics and their deposition process is well characterized. Graphite fibers were used to fabricate aluminum tipped cantilever beams. The aluminum tip would act as a mirror to reflect light from a laser that could be gathered and processed to develop a position verses time characterization data plot.

The goal of the project was to develop a fabrication process for aluminum tipped graphite fiber cantilever beams and begin elementary testing and characterization of the graphite cantilever beam.

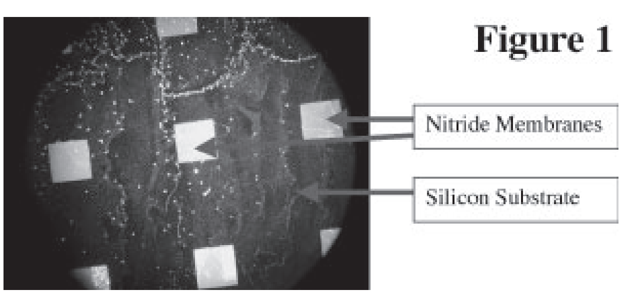


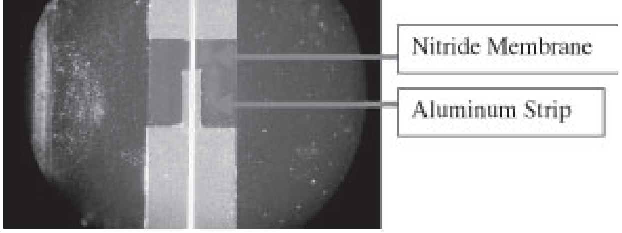
Figure 1

Method:

The process consisted of starting with a four inch silicon wafer. Low stress silicon nitride was grown onto the wafer using a Low Pressure Chemical Vapor Deposition (LPCVD). The silicon nitride thickness was in the range of 500-750 Å. Then the back side of the wafer was coated with 1 µm of Shipley 1813 photolithography resist. The wafer was exposed to ultra violet light with a backside mask made of 1 mm squares. Next the wafer was developed using MIF 300. The backside of the wafer was left with photo resist covering all but 1 mm squares. The exposed silicon nitride squares were etched using a Plasma Thermal 72 (PT72) etcher. The gas used to etch the silicon nitride was CF_4 which etched the nitride at about 300-350 Å/min. The wafer was left with silicon exposed squares. Then the wafer was dipped in KOH and the silicon squares were etched all the way thru the silicon wafer. KOH does not react with silicon nitride, and once all the silicon was removed, only silicon nitride membranes covering the square aperture were left. (See Figure 1.)

Then the front side of the wafer was patterned, exposed and developed using photolithography. This step patterned the nitride membranes for an aluminum deposition. 1000 Å of aluminum was deposited using a thermal evaporator under vacuum. The wafer was set into acetone and lift off was induced. The lift off procedure only left aluminum where the resist had

Figure 2

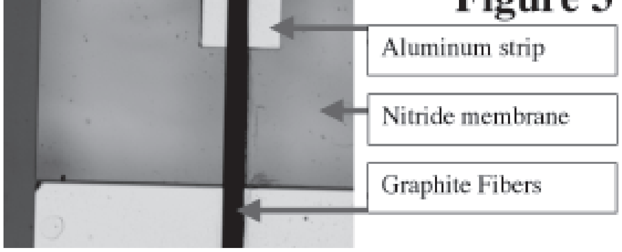


been exposed. The wafer had an aluminum strip on each of the silicon nitride membranes. (See Figure 2.)

With the aluminum attached to the membrane, the graphite fibers were deposited onto the wafer. (See Figure 3.) To keep the fibers anchored to the wafer, Shipley 1075 photo resist was used. Shipley 1075 served as a glue to bond the fibers to the aluminum tips and also to hold the fiber onto the wafer. The silicon nitride membranes were etched away using the PT72. The photo resist held the aluminum to the bottom of the fiber beam. (See Figure 4.)

The last step of the cantilever beam fabrication process was releasing the beam. This step was accomplished by using a laser to cut the graphite fiber at a desired location. Depending on the location of the laser cut, different lengths of cantilevers could be tested for characterization. Once the cantilever was released, the wafer could be cut and the devices could be tested. The devices were tested by attaching the wafer chip to a piezoelectric material and providing an oscillating voltage. The piezoelectric material would create an oscillation force applied to the cantilever and this oscillation frequency of the cantilever was directly proportional to the applied voltage to the piezoelectric material.

Figure 3



Discussion and Conclusion:

Problems with the silicon nitride membranes stability arose at the beginning of the research. This was solved by making sure the low stress silicon nitride was grown with the right process conditions and with proper spacing of devices on the wafer. Another challenge that was faced happened to be with the aluminum strip not staying in place after the silicon nitride etch. The process was modified by laying the graphite fibers onto the aluminum and then securing the tip of the aluminum strip to the fibers using photo resist.

Elementary device characterization was very promising, with a natural frequency of around 25 kilohertz. However, further device and material characterization is needed to produce feasible devices for the application proposed.

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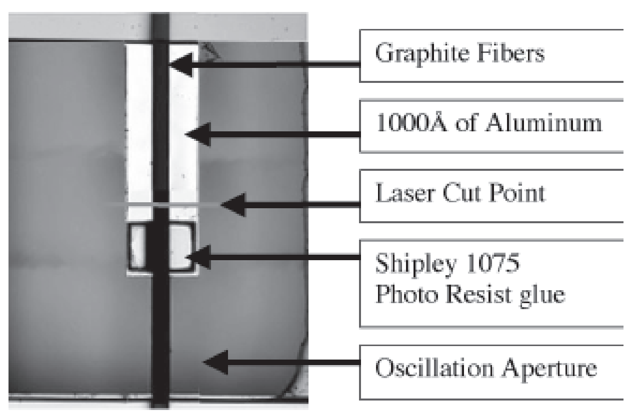

Figure 4