# Design, Fabrication, and Testing of Piezoresistive Pressure Sensors Using Carbon Nanotubes

SNF Researcher: John Liu, Computer Engineering, University of California at Irvine (2002 SNF REU)
Principal Investigator: Dr. Hongjie Dai, Department of Chemistry
Collaborator: Randy Grow, Applied Physics, Stanford University

Traditional silicon piezoresistive pressure sensors are highly temperature-dependent. One alternative material that has also been shown to exhibit the piezoresistive effect is the singled-walled carbon nanotube (SWNT), which is a single graphene sheet rolled into a cylinder. We grew SWNTs on suspended polysilicon membranes. Air pressure was applied uniformly to press down on the membranes, causing the tightly attached SWNTs to deform. The current passing through the SWNTs was measured with respect to continuous time.

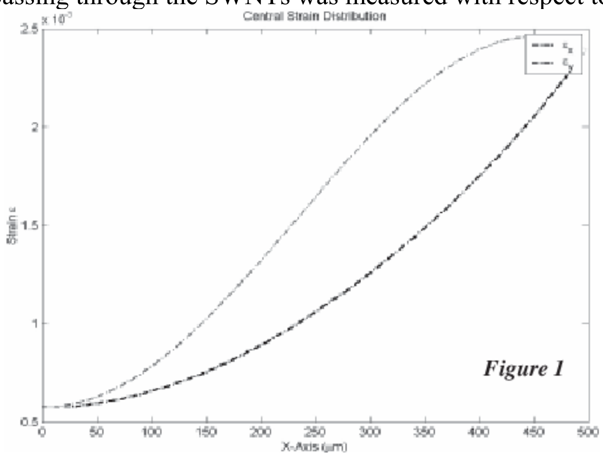


*Figure 1*

MATLAB simulations, using Timoshenko's equations, were used for the design of the membrane. Fig. 1 shows the results for a 1000um by 1000um membrane, with the strain peaking at the midpoints on the edges.

Double-polished Si wafers were used as the substrates. A layer of 0.2 µm thick oxide, 2 µm thick polysilicon, and 0.2 µm thick nitride were deposited on both sides of a substrate, consecutively. The back side nitride was patterned by photolithography and etched. Next, the backside polysilicon was plasma etched. The backside oxide was etched using HF. A layer of Mo was then deposited on the front side of the substrate, followed by its patterning and lift-off to form the metal electrodes. The catalyst was deposited over the metal electrodes, patterned and etched, creating catalyst islands from which the SWNTs would grow. Backside etching was performed on the silicon substrate using KOH, creating a trapezoidal cavity as the vertical etching rate is much greater than the lateral etching rate. After removing the front side oxide, a suspended square polysilicon membrane was created. Figure 2 shows the front side of our design at this point. Each individual device was separated for growth of SWNTs. Wire bonding was done after the growth.

Probing each device was performed between each pair of metal electrodes. The SWNT could be either metal or semiconductor, or there could be no connection at all. The devices that showed semiconductor behavior were examined by AFM (atomic force microscopy). Figure 3 shows the AFM image of a SWNT connection between two metal electrodes. Each working device was properly set up in a sealed gas chamber with an internal breadboard and external cable connections to a multi-scope to measure current. Air was pumped into the chamber and pressure was applied to the membrane.

Figure 2

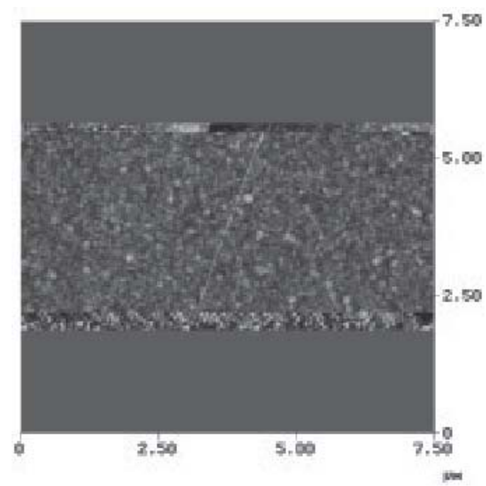


Figure 3

When air pressure deformed the SWNTs, a decrease in current was observed, indicating an increase in resistance. Moreover, when the gas was pumped out and the membrane was restored its original condition, the current rose back to the same level. This showed that the process is reversible. Further investigations on the potential of SWNTs as piezoresistive pressure sensors can be carried out with our designs.