Micro- and Nanoscale Tensile Testing Using FIB and Micromanipulator

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The current pace of miniaturization makes the development of mechanical tensile testing techniques and methodologies for micro- and nanoscale materials a challenging task. However, in comparison with other methods the interpretation of such data is relatively straightforward, but the technical hurdles are high. Mayor tasks are the handling of extremely small specimens as well as the fulfillment of the requirements of force/ displacement measurements. Conventional in-situ methods require that there is a certain displacement of the sample in order to obtain sufficient force resolution which is difficult to meet.

We have developed a novel method to overcome these limitations and challenges in an easy way. Figure 1 shows a schematic of our tensile testing setup. A specimen is fixed between the AFM tip and the probe of the micromanipulator by ion-induced Pt deposition. By moving the probe away from the tip, a force is applied. The micromanipulator is used to handle the specimens as well. By attaching fine tapered probes, tiny specimens can be manipulated and harvested with no to minimal damage. It also offers large ranges of motion as actuator. AFM cantilevers are sensitive load sensors as they are very flexible and so provide high force resolution. This point has been exploited in AFM. By changing the different AFM cantilevers, large ranges of measurement force can be achieved. In our experiment the loading was applied continuously and the SEM image was recorded in real-time using the movie tool. Three snapshots are shown in Figure 2. By analyzing the sequential snapshot images from the movie, the stress - strain curve can be drawn.

An example of a copper wire testing is shown in Figure 3. All the components and instruments are commercially available and the set-up is extremely easy to build. In contrast to a similar method [1], our method not only has all of the merits such as in-situ and irregular cross-section specimens but also make significant improvements e.g. it can perform several tests in one experiment by putting several cantilevers into the FIB chamber. The testing specimen is fixed on the tip of the cantilever so that the torsion of the cantilever can be avoided. The method can be easily applied to vast ranges of materials from normal metals to bio-materials such as feathers and hairs etc.

1. S. Orso et al., Adv. Mater. **18**, (2006) p874.

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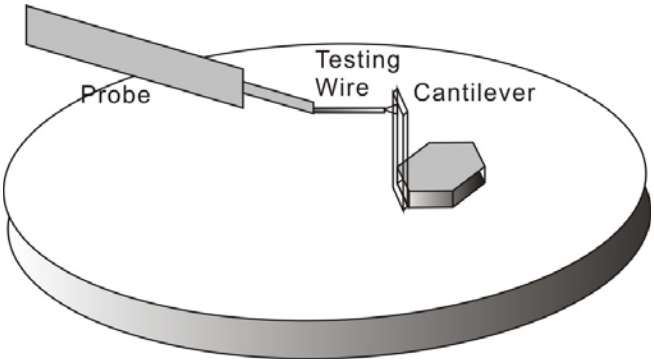

Figure 1. The schematic of tensile testing set-up.

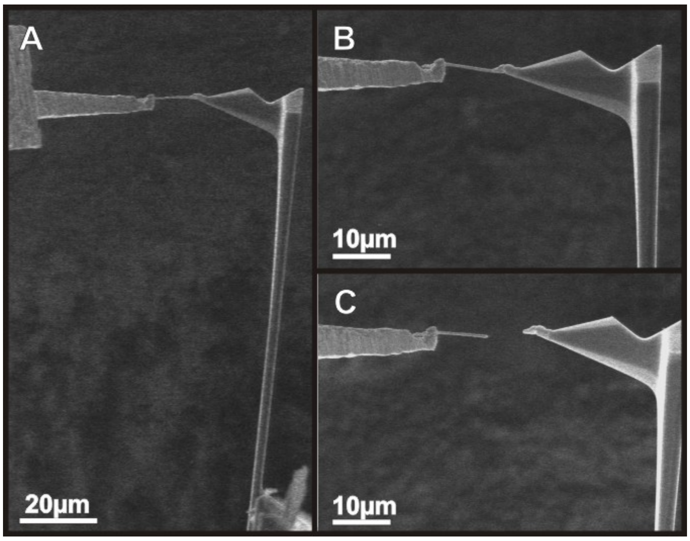

Figure 2. The tensile test of a copper wire. Before loading(A), during loading (B), and after failure(C).

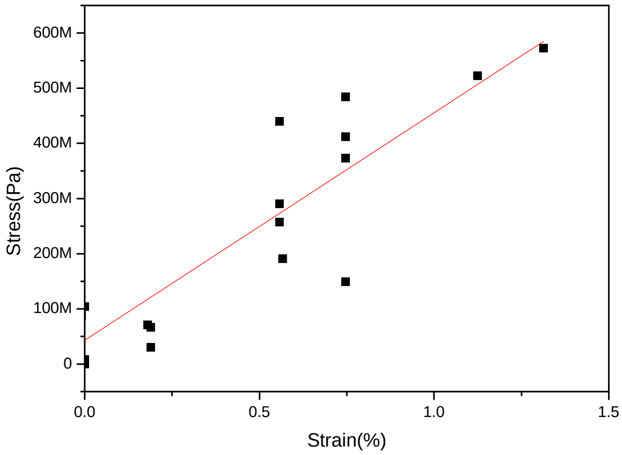

Figure 3. The stress and strain curve of copper wire.