Mechanical Property Evaluation of Nanospring Using Scanning Electron Microscopy with Micromanipulator

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An expansion from two-dimensional (2D) to 3D will offer further functionalization to conventional nanodevices. Therefore, 3D nanocomponents are required to develop high performance nanoapplications. In particular, spring structures will be very suitable for applications such as actuators and electromagnets, and thereby are essential elements for the establishment of the 3D nanodevices. To form the 3D nanostructures, we have proposed the use of focused-ion-beam chemical vapor deposition (FIB-CVD). FIB-CVD promises 3D nanostructure fabrication in arbitrary locations through the *in-situ* alignment. In our previous experiments, diamond-like carbon (DLC) nanosprings were successfully fabricated by FIB-CVD. The nanospring showed the unique property of expanding and contracting as flexibly as macro-scale springs. The spring constants were measured using optical microscopy[1].

However, there is a limitation that the measurement system previously developed cannot accurately measure spring constants of nanosprings with a diameter approximately below 1 μm, because the resolution in the optical microscopy is not sufficient. To overcome the above problem, a new system allowing accurate measuring of the spring constants has been developed, which uses scanning electron microscopy (SEM) with a micromanipulator.

Figure 1 shows SEM micrographs of a mechanical motion of a 10-turn DLC nanospring fabricated on an Au-coated glass capillary set on the micromanipulator. The nanospring has 480-nm diameter, 100-nm spring-section diameter and 4.7-μm height. The tip of the nanospring was fixed to the tip of the Si cantilever by deposition of DLC. Figure 1(a) shows the initial condition. In Fig. 1(e), the nanospring was extended 1.5 μm longer than its initial state. Finally, as shown in Fig 1(f), the nanospring was transferred to the tip of the Si cantilever without any deformation, indicating a high elasticity of the nanospring. Figure 2 shows the relationship of displacements of the nanospring and the Si cantilever. We found a linear relationship between these displacements in the four plots. The spring constant estimated from conventional Hooke’s low was 1.6 N/m.

A dependence of spring constants on a spring diameter within a range below 500 nm will be presented at the conference.

[1] K. Nakamatsu and S. Matsui. et al, J. Vac. Sci.Technol., B **23**, 2801 (2005).

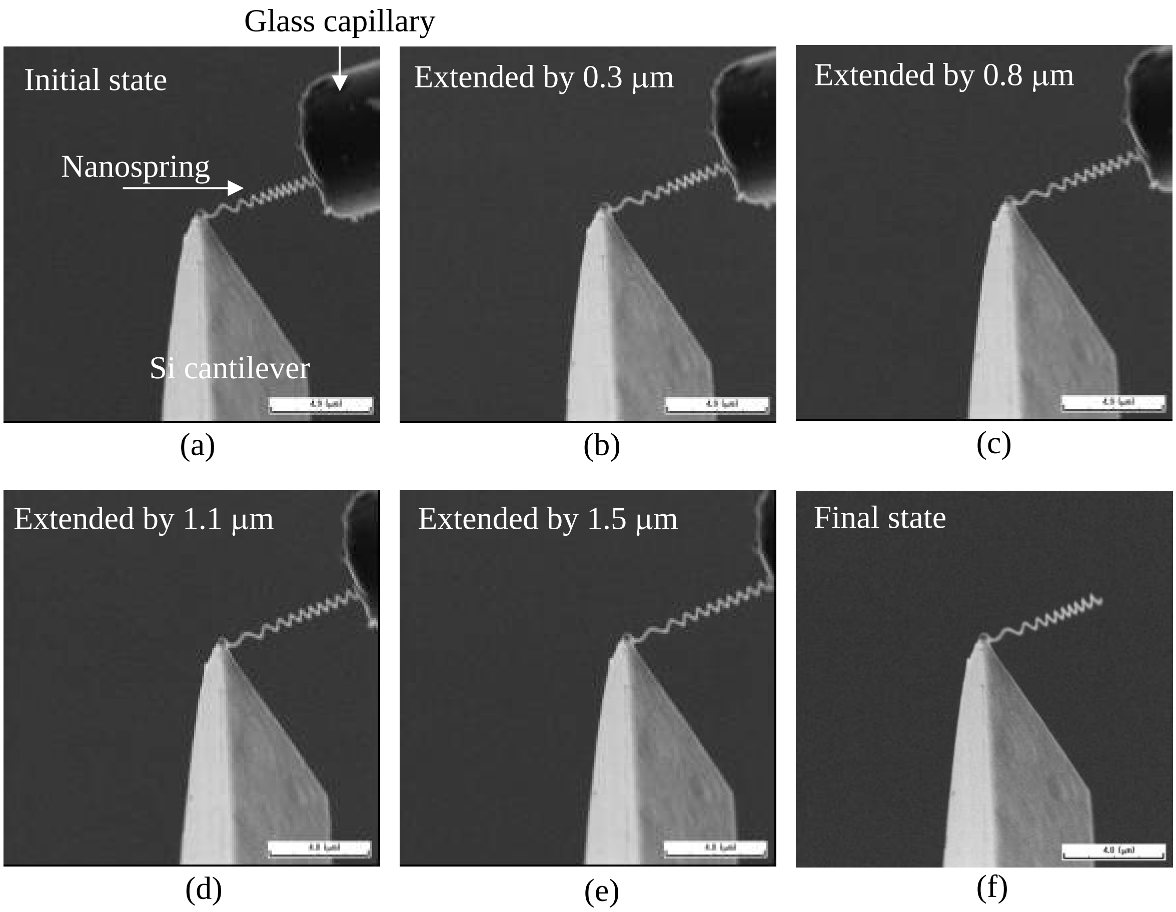

Figure 1. Mechanical motion of FIB-DLC nanospring with 480-nm diameter and 100-nm coil-section diameter.

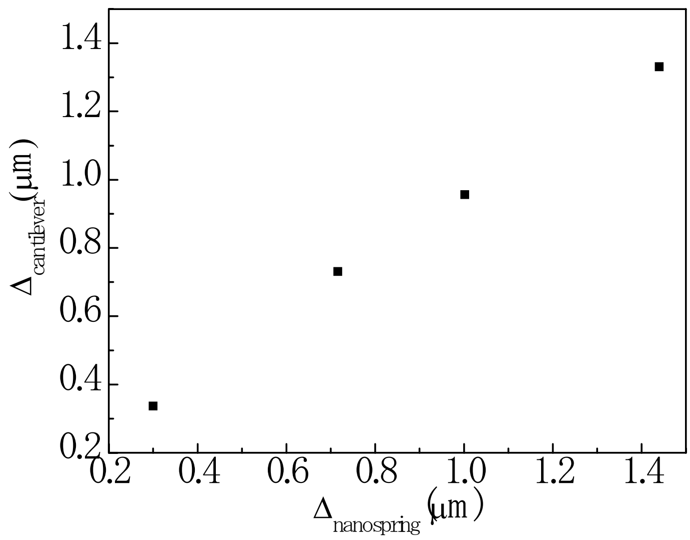

Figure 2. Relationship of displacements of nanospring and Si cantilever.