Evaluating mechanical characteristics of various shape nanosprings fabricated by Focused-ion-beam chemical vapor deposition

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Focused-ion-beam chemical vapor deposition (FIB-CVD) technique is a promising method of fabricating the three dimensional (3D) nanostructures. Evaluating characteristics of nanospring is important because these can be applied to wide application such as actuators, magnetic coils and others. So far, the mechanical characteristics of circle-shape nanosprings fabricated by FIB-CVD have been reported [1)]. In this study, we fabricated various shape nanosprings and evaluated those mechanical characteristics.

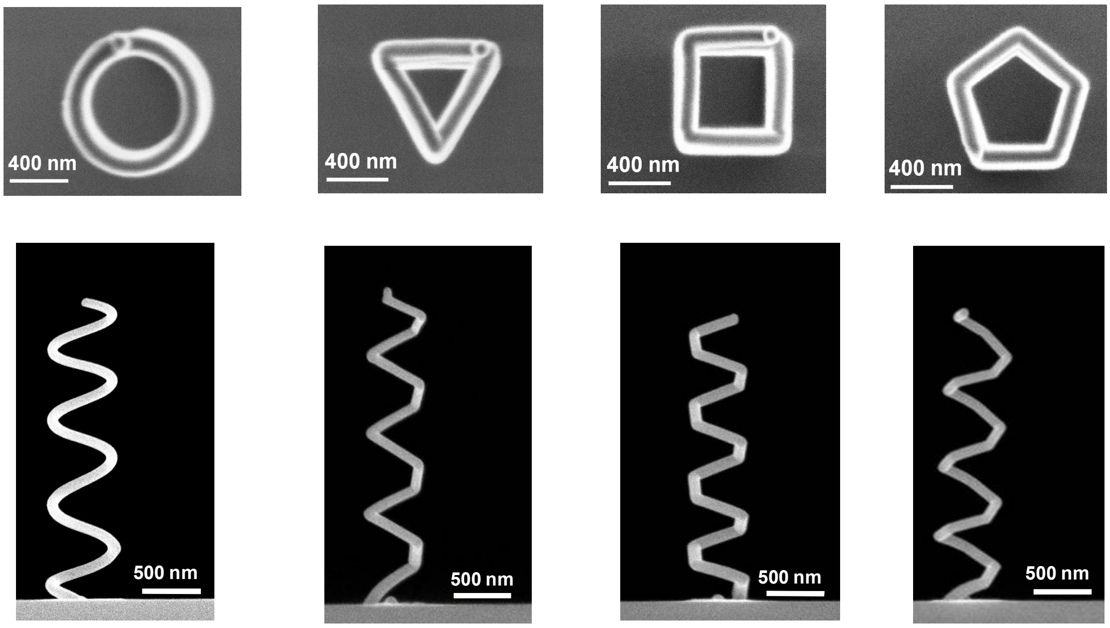
Figure 1(a) shows the top-view SIM (scanning ion microscopy) and side-view SEM (scanning electron microscopy) images of the circle-nanospring which is the typical spring. The diameter of the circle-nanospring is 700 nm. Figures 1(b), (c) and (d) show triangle-, square- and pentagon-nanospring, respectively. The top-view shapes of polygon-nanosprings are the polygons inscribed in circle 700 nm in diameter. n is the parameter indicating number of angles. We fabricated the polygonal-nanosprings with n from 3 to 8. The number of turns and coil section-diameter of all nanosprings were 4 and 110 nm, respectively. These circle and polygon-nanosprings were fabricated by irradiation of gallium ion under the phenanthrene ($C_{14}H_{10}$) atmosphere. The gallium ion accelerated at 30 kV was focused within 5 nm at a current of 1 pA.

The measuring method of spring constant is following. (a) The nanosprings were fabricated on Si substrates. (b) The nanosprings were hooked to the top of the cantilever. (c) We extended the nanosprings and measured the displacements of the nanosprings and the cantilever as shown in Fig. 2. (d) To obtain the springs constants of nanosprings, the measured displacement of nanosprings and the cantilever were instituted into the Hook's low.

Figure 3 shows the relationship between the number of the angles and the spring constant. The first plot from the right shows the spring constant of the circle-nanosprings. The spring constant increased as the n increased.

We will present the theoretical results of the relationship between the number of the angles and the spring constant, and compare it to the experiment result shown in Fig. 3.

1) K. Nakamatsu, et al. :J. Vac Sci. Technol. B 23(2005)2801.



(a) circle (b) triangle (n=3) (c) square (n=4) (d) pentagon (n=5)

Fig. 1 SIM (top-view) and SEM (side-view) images of circle and polygon-nanosprings with 110 nm section diameter and 4 number of turns.

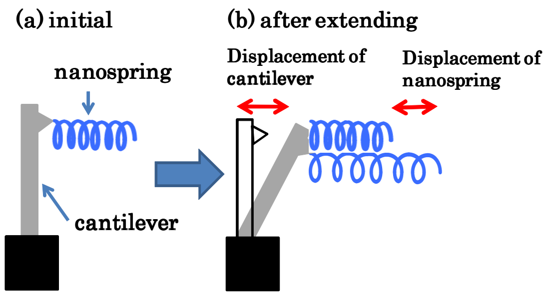


Fig. 2 Schematic of measuring method

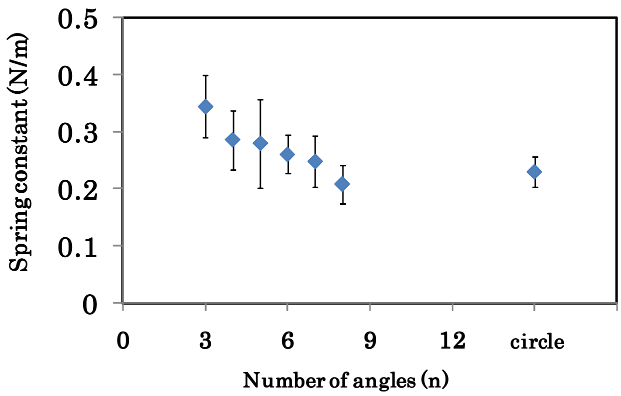


Fig. 3 Relationship between number of angles and spring constant