Evaluation of Piezoelectric Properties of $BaTiO_3$ Nanoparticle

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Recently, various kinds of piezoelectric nanocomposite materials have been developed for self-powered devices, high power capacitors and large-scale flexible sensors [1-2]. The nanocomposite materials are usually fabricated by dispersing piezoelectric nanoparticles on the polymer matrix [3]. Therefore, control of uniformity and density of nanoparticles is a critical issue to fabricate the high quality nanocomposite materials. Besides, the piezoelectric properties of the nanoparticle itself determine the characteristics of the nanocomposite materials. For all that, there are little discussions about piezoelectric properties of a single crystalline nanoparticle. In this study, we investigated the piezoelectric properties of a single $BaTiO_3$ nanoparticle using the indentation technique. In other words, we measured the electrical response when a single crystalline nanoparticle was mechanically compressed by a conductive indenter. To make an accurate indentation of a single nanoparticle whose size is below a few hundred nm, we used a Hysitron PI95 TEM pico-indentation system. Also, we measured the mechanically induced currents on the $BaTiO_3$ nanoparticles with Keithley 6485 picoammeter. Figure 1 is a typical TEM image which shows a cross-sectional view of the indentation process of a $BaTiO_3$ nanoparticle. Controlling the displacements of the conductive diamond indenter, we could induce compressive stress to the single nanoparticle placed on the Au film coated Si wedge fixture and also measure the mechanical (load) induced on the particle (figure2) and electrical charge from the piezoelectric nanoparticle (figure 3) at the same time. From the TEM-indentation results, we calculated the piezoelectric coefficient value (d_{33}) of a single $BaTiO_3$ particle. The d_{33} value of a 100nm size particle is about 800pC/N which is about 6 times larger than that of polycrystalline $BaTiO_3$ ceramics [4]. The present study reveals that size effect of nanoparticles on the enhancement of the piezoelectric property.

References

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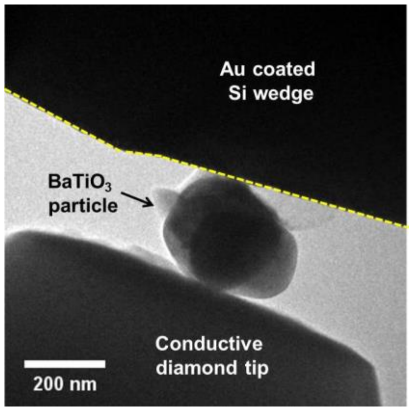

FIG. 1. A cross-sectional view of the indentation process of a $BaTiO_3$ nanoparticle.

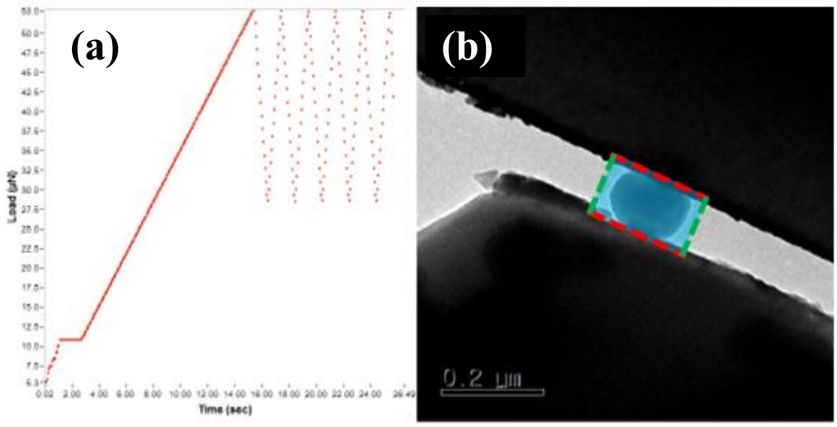

FIG. 2. (a) Compressive load induced on a $BaTiO_3$ nanoparticle, (b) a cross-sectional view of the indentation process of a $BaTiO_3$ nanoparticle. The piezoelectric charge generated at surfaces (red dotted line) was measured.

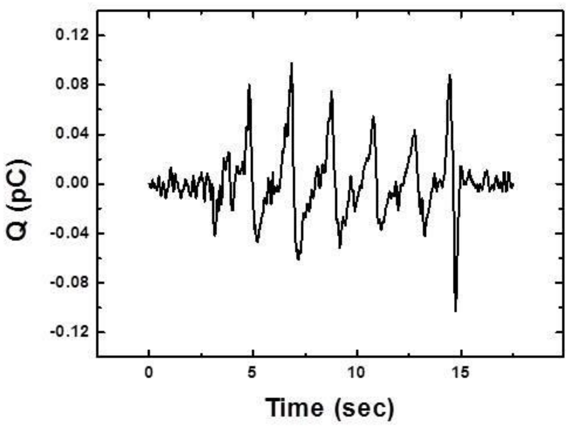

FIG. 3. Piezoelectric charge measurement of a 100nm $BaTiO_3$ nanoparticle with applied compressive force according the figure 2 (a).