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Toward Correlation of Conductance of RuO_2 Nanowire with Plasmon Energy Shift

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Plasmons[1] in RuO_2 nanowires were investigated by electron energy loss spectroscopy attached to high-resolution transmission electron microscopy. It has been found that the plasmon energy increases in proportion to the inverse of the nanowire width. So far the optical techniques such as the photoluminescence spectra measurement or Raman spectroscopy have been used in the investigation. However these techniques do not have enough sensitivity to explore the properties of an individual nano-scale particles, and thus the obtained spectra were always convoluted with the size distribution of the particles.

Electron energy loss spectroscopy (EELS) attached to field-emission gun transmission electron microscopy (FEG-TEM) have been used to overcome this problem. Since the electron probe can be converged to the nanowire width using the condenser lens system of FEG-TEM, we can get the information from an individual nanowire with this technique. RuO_2 nanowires were prepared by a high vacuum furnace with VLS mechanism, and then characterized by a EDX attached on JEOL 2010F FEG-TEM. TEM images and SAD patterns (Fig.1(b)) were recorded to check the nanostructure and preferential growth direction of the individual RuO_2 nanowires. Fig. 1(c) is the high-resolution image of the nanowire in (b). Fig.2 is the plasmon spectra of different size nanowires and Fig.3 shows the palsmon shift with the nanowire size from 13 to 83 nm. And the palsmon peaks shift from 3 to 8.5eV. For the nanowires, the peak shifts toward higher energy shows the increase of the volume plasmon energy is proportional to the inverse square of the nanowire size. For the insulator or semiconductor[2], the increase of the plasmon energy ΔE_P is can be described as $\frac{\Delta E_p}{E_p} = \frac{2\pi^2\hbar^2}{m^* E_g} \cdot \frac{1}{d^2}$, and it shows the characterization of semiconductor differs from the conductor character in RuO_2 bulk[3]. The electronic property obtained from the scanning tunneling microscopy attached to transmission electron microscopy (STM-TEM) also shows the differ resistance from the bulk and thin film of RuO_2 , showed as Table 1.

In summary it has been found by EELS that the plasmon energy in the RuO_2 nanowires increase in proportional to nanowire width and the phenomena can be verified with the electronic properties obtained from STM-TEM.

Reference

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[2]M. Mitome et al., J. Appl. Phys. 72 (2), (1992) 812
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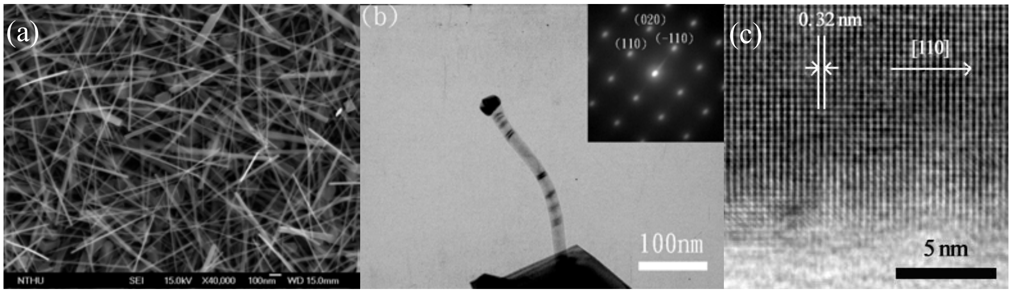

Fig.1 (a)SEM, (b)TEM and the high-resolution images (c) of RuO_2 nanowire. The black ball on the top of the wire in (b) is the gold catalyst

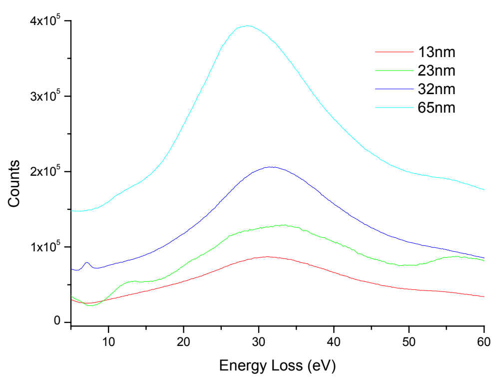

Fig. 2 Plasmon energy shift of different size RuO2 nanowire

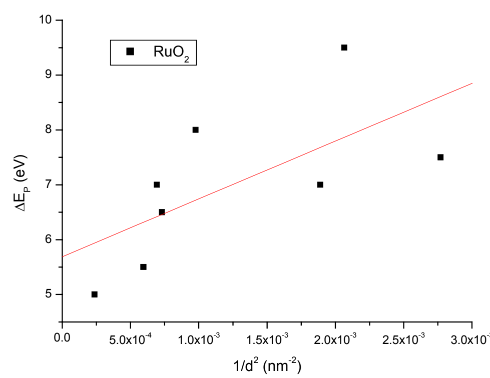

Fig. 3 increase of the plasmon energy with the nanowire size

Table 1 Resistance of different size nanowires obtained from STM-TEM

Nanowire Width (nm)	26.4	28.8	34	42	45	50	75	123	204
Resistance (kΩ)	14.88	13.6	12.27	11.05	26.6	32.6	12.27	27.25	19.7

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