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# $SiO_x$ Nanowires Produced on Molybdenum-Coated Si Substrates

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We synthesized $SiO_x$ nanowires with diameters of 30–140 nm, for the first time by the simple heating of the Mo-coated Si substrates. X-ray diffraction, selected area electron diffraction, and energy-dispersive X-ray spectroscopy indicated that the nanowires were in an amorphous state, comprising Si and O only. Fitting the photoluminescence spectrum with Gaussian functions revealed that the nanowires exhibited significant photoluminescence intensities near blue and green light regions. We extensively discussed the possible growth mechanism of $SiO_x$ nanowires.

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## 1. Introduction

One-dimensional (1D) nanowires are promising materials for future nanodevices owing to their small dimensions and novel properties. Not only amorphous silica ($SiO_x$) is widely used in silicon based integrated devices and can also be produced as nanowires, but also $SiO_x$ emits intense and stable blue light at room temperature [1, 2]. Accordingly, many researchers have put their enthusiasm in preparing the $SiO_x$ nanowires by various methods: while a technique such as heating the bare-Si wafers up to 1300°C has been previously reported [3], the majority of $SiO_x$ nanowires fabrication methods with a relatively low growth temperature regime around 1000°C have used metal catalysts, such as Au [4] and Fe [1]. In this communication, we report the production of $SiO_x$ nanowires by the simple heating of molybdenum (Mo)-coated Si substrates. Although Mo-based catalysts have been utilized in various chemical reactions [5, 6] and in fabricating carbon nanotubes [7], to our knowledge, synthesis of any inorganic 1D nanomaterial on the Mo substrate has not been reported to date.

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## 2. Experimental

For preparing the molybdenum (Mo)-coated Si substrates, we used $p$-type (100) Si (resistivity = 1–30 Ω cm) onto which a layer of Mo (about 3–5 nm) was deposited by the sputtering process. The sputtering was carried out at a pressure of $8 \times 10^{-4}$ Pa in high purity argon (Ar) gas (99.999%) with dc sputtering power of about 33 W, at room temperature. The substrate was placed in a quartz tube [8] which was heated in a tube furnace at 1000°C for 2 h. An air flow was introduced during growth at an ambient pressure of about 300 mTorr. Samples were analyzed using glancing angle (0.5°) X-ray diffraction (XRD, X'pert MPD-Philips with Cu $K_{\alpha_1}$ radiation) with the contribution from the substrate being minimized, scanning electron microscopy (SEM, Hitachi S-4200), and transmission electron microscopy (TEM, Philips CM-200) equipped with energy-dispersive X-ray (EDX) spectroscopy. Photoluminescence (PL) spectra of the samples were measured in a SPEC-1403 PL spectrometer with a He–Cd laser (324 nm, 55 mW) at room temperature.

## 3. Results and discussion

Figure 1a displays the top-view SEM image, revealing that the substrate surface is covered with a large quantity of curved 1D nanostructures. Statistical observation of many SEM images indicated that the diameter of nanowires ranged from 30 to 140 nm. Figure 1b shows the enlarged SEM image, indicating that no metal nanoparticle can be seen at tips of the nanowires. It is interesting to note that the nanowires have a relatively rough surface. The inset of Fig. 1b shows the XRD pattern of the product. Since no reflections are clearly discerned, we deduce that the nanowires are fully amorphous. In our glancing-angle XRD measurements, the peaks originate mainly from the nanowires, not from the substrates. Figure 2a shows a TEM bright field image of the product. The 1D nanostructures display the wire-like shape and have no spherical droplet at the tips, agreeing with SEM images. The corresponding selected area electron diffraction (SAED) pattern is shown in the inset of Fig. 2a. The highly diffusive SAED ring pattern identifies that the nanowires are of amorphous nature. The EDX analysis indicated that the compositions of the product contained Si and O, regardless of position in the nanowires from the stem to the ends. The typical EDX spectrum, recorded from the tip part of a single nanowire, is shown in Fig. 2b. Since the Cu-related peaks are arised from TEM Cu grid, the EDX spectrum suggests that the product comprises Si and O elements.

Figure 3b shows the PL emission spectrum of the $SiO_x$ nanowires upon photoexcitation at 3.82 eV. Fitting the spectral feature with Gaussian functions, the best fit of the emission was obtained with two Gaussian functions, of which peaks are centered at 2.32 eV in the green region and 2.89 eV in the blue region, respectively. Wang et al. obtained similar blue emission from $SiO_x$ nanowires fabricated using Au catalyst [4]. Also, Hu et al. reported the similar green emission

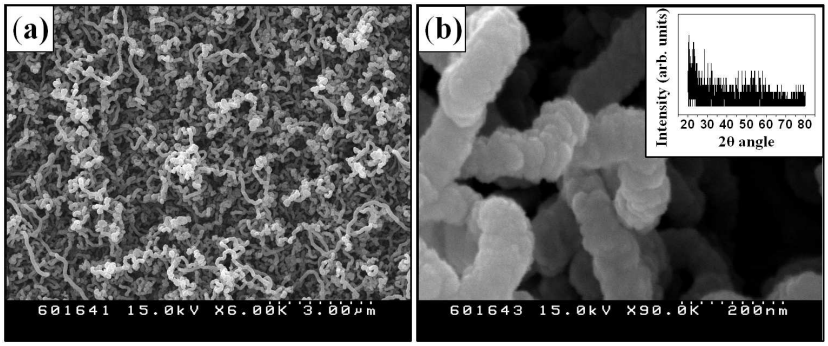


Fig. 1. (a) Low magnification top-view SEM image of the product. (b) Enlarged SEM image of the nanowires (inset: XRD pattern recorded from the product).

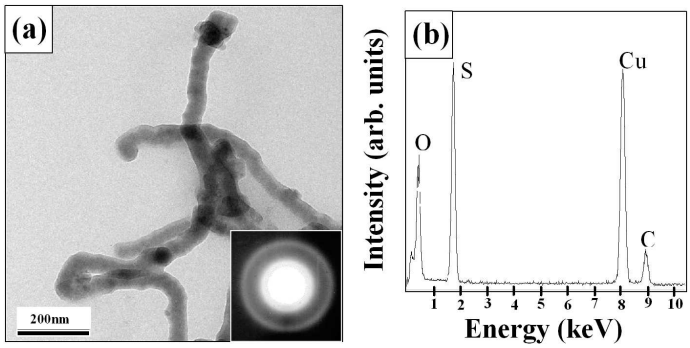


Fig. 2. (a) Low magnification TEM image of the nanowires (inset: corresponding SAED pattern). (b) Typical EDX spectrum recorded from the tip part of a single nanowire.

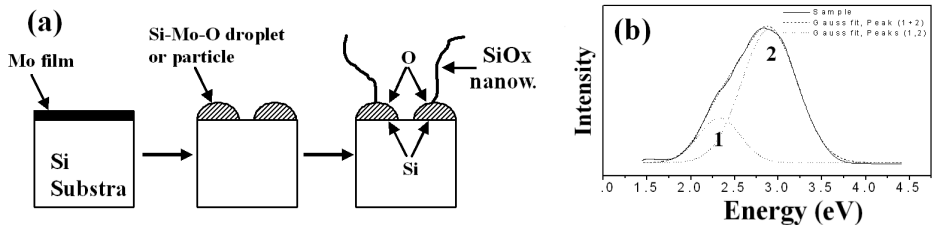


Fig. 3. (a) Schematic outline of the $SiO_x$ nanowires growth. (b) Room temperature PL spectrum of the product upon photoexcitation at 3.82 eV.

from $SiO_2$ nanowires synthesized by thermal oxidation [3]. Both blue and green light emissions in $SiO_x$ are known to be ascribed to neutral oxygen vacancies [1, 9]. In the present study, high-temperature fabrication process can generate oxygen deficiencies, contributing to the observed emissions.

In conclusion, we produced $SiO_x$ nanowires on Mo-coated Si substrate at 1000°C. The diameters of the nanowires in an amorphous state vary from 30

to 140 nm. The nanowires are amorphous, consisting of silicon oxide. Based on the observation that no Mo-containing nanoparticle exists on the ends of the nanowires, we suggest the possible growth mechanism. Upon photoexcitation at 3.82 eV, the PL measurement with the Gaussian fitting shows apparent blue and green light emission bands centered at 2.89 and 2.32 eV, respectively.

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