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**Materials**

# Effect of Fe metal on the growth of silicon oxide nanowires

*Wei-long Liu*[1)], *Shu-huei Hsieh*[1)], *Ching He Chen*[2)], *and Wen-jauh Chen*[3)]

1) Department of Materials Science and Engineering, Formosa University, Yunlin 632, China Taipei

2) Department of Materials Engineering, Pingtung University of Science and Technology, Pingtung 912, China Taipei

3) Graduate School of Materials Science, Yunlin University of Science and Technology, Yunlin 632, China Taipei

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**Abstract:** Silicon oxide ($SiO_x$) nanowires are generally grown on Si substrate under the catalysis of Au in $N_2$ atmosphere at elevated temperatures. Because the price of Au metal is quite high, Fe metal is then used to replace a part of Au for catalyzing the growth of $SiO_x$ nanowires. The results show that the Fe film can be used as the diffusion barrier of Au. $SiO_x$ nanowires are grown on Au/Fe/Si substrate at 1030°C. Under the catalysis of Fe/Au, the efficiency for the growth of $SiO_x$ nanowires is promoted.

**Key words:** silicon oxide ; nanowires; Au catalyst; Fe substitution; Si substrate

## 1. Introduction

Because silicon oxide ($SiO_x$) nanowires possess some particular physical properties and have much potential for applications as blue light emitters, optical sensors [1], and reinforcing composites [2], they have greatly attracted the attention of the researchers. Zhang *et al*. prepared aligned $SiO_x$ nanowires on anodic alumina by a sol-gel method [3]. Zhang *et al*. prepared ordered amorphous $SiO_x$ nanowires on a Ga ball placed on top of a Si wafer [4]. Park *et al*. synthesized amorphous $SiO_x$ nanowires on NiO-catalyzed silicon substrate [5]. Jiang *et al*. produced $SiO_x$ nanowires by using Fe-Co-Ni alloy nanoparticles as catalyst and showed that they had a strong blue-green emission at 525 nm, which might be related to oxygen defects [6]. Zhang *et al*. displayed that $SiO_x$ nanowires could be formed on tin balls by chemical vapor deposition *via* a vapor-liquid-solid (VLS) process [7]. Wang *et al*. reported that amorphous $SiO_x$ nanowires could be grown on silicon wafers by using Pt as catalyst [8]. Park *et al*. used Au and Pd-Au thin films as catalysts to grow amorphous $SiO_x$ nanowires on Si substrate *via* a solid-liquid-solid (SLS) mechanism [9]. Lin *et al*. synthesized amorphous $SiO_x$ nanowires from silicon monoxide powder under supercritically hydrothermal conditions [10]. Wang *et al*. fabricated $SiO_x$ nanowires on patterned nanodots containing exposed hydrogen silsesquioxane (HSQ)/Fe-$SiO_2$ nanocomposites [11]. Zhang *et al*. used low melting point metal Pb as catalyst for the large-scale growth of highly aligned $SiO_x$ nanowires *via* VLS process [12].

In the present work, the Au and Fe/Au films were used as catalysts for the growth of $SiO_x$ nanowires. Due to the expensive price of Au, a part of Au catalyst was replaced by Fe in order to reduce the cost of $SiO_x$ nanowire preparation. The growth behavior of $SiO_x$ nanowires using the Au film as catalyst was compared with that using the Fe/Au film as catalyst. The effect of Fe metal on the growth of $SiO_x$ nanowires was further studied.

## 2. Experimental

N type silicon wafer with (100) surface and 4-7 Ω·cm resistivity was used as substrate for the growth of $SiO_x$ nanowires. Before being coated with the catalyst films of Au and Au/Fe, the substrate surface was successively cleaned in the following solutions: acetone with ultrasonic vibration for removing the dust and organic substance, a mixture solution of $H_2SO_4$ and $H_2O_2$ for removing the grease and inorganic impurities, and 10% HF solution for removing the native $SiO_x$.

The Fe film was coated on the silicon surface in an electron beam evaporation deposition chamber at a vacuum pressure of $1\times10^{-6}$ torr with a voltage of 6.5

**Corresponding author:** Wen-jauh Chen, **E-mail:** chenwjau@yuntech.edu.tw

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kV, a current of 27 mA, and a deposition rate of about 0.1 nm/s. The Au film was coated on the surface of Fe film or silicon substrate under the condition of 6.5 kV, 130 mA, and about 0.1 nm/s deposition rate. The $SiO_x$ nanowires were grown on the substrate of Au (20 nm)/Si or Au (10 nm)/Fe (10 nm)/Si in a tube furnace. After the substrate was put into the tube furnace at 600°C, the furnace temperature was then increased up to about 1050°C and kept for a period of time in the $N_2$ gas with a flow rate of 1600 $cm^3$/min. The sample was finally taken out when the furnace temperature was decreased down to 600°C.

The $SiO_x$ nanowires, Fe/Au and Au catalysts, and Si substrates were characterized using scanning electron microscopy (SEM, JEOL-JSM-6380) and transmission electron microscopy (TEM, JEOL-JEM 2010). The procedure of preparing the sample for TEM cross-section view consists of the following steps: (1) the as-plated samples were cut into 2 mm×3 mm pieces and were glued on a glass plate by thermoplastic resin for grinding the Si substrate; (2) several pieces of ground samples were stuck together by AB adhesive, and their two lateral sides were thinned by grinding; (3) the samples were stuck to a Cu ring with 3 mm diameter by AB adhesive and put into an ion thinning machine for further thinning the lateral thickness of samples; (4) after the samples were broken through by ion beams, they then could be observed for TEM cross-sectional views. Most of the micrographs were taken under two-beam diffractions with deviation parameter $s_g$ slightly positive.

## 3. Results and discussion

Fig. 1 shows the SEM views of the samples at 1000°C for 30 min in $N_2$ gas with a flow rate of 1600 $cm^3$/min for Au (20 nm)/Si and Au (10 nm)/Fe (10 nm)/Si substrates, respectively. It can be seen that no $SiO_x$ nanowires are grown on the two substrates. Fig. 1(a) shows that the Au (20 nm) film has agglomerated into many nanosized particles. Fig. 1(b) reveals that only the Au (10 nm) film agglomerates into nanosized particles and the Fe (10 nm) still keeps at film state.

Fig. 2 shows the SEM views of the samples at 1030°C for 30 min in $N_2$ gas with a flow rate of 1600 $cm^3$/min for Au (20 nm)/Si and Au (10 nm)/ Fe (10 nm)/Si substrates, respectively. Fig. 2(a) reveals that there are $SiO_x$ wires grown on Au (20 nm)/Si substrate, in which the diameter of $SiO_x$ wires is about 500 nm and the length of $SiO_x$ wires is not uniform, a part of them being very short and some of them being several μm. Fig. 2(b) reveals that the $SiO_x$ nanowires grown on Au (10 nm)/Fe (10 nm)/Si substrate are quite long and tangled with each other.

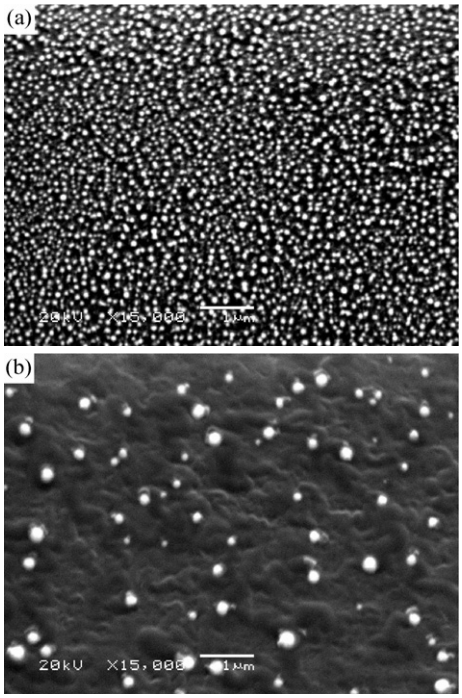


**Fig. 1. SEM views of samples at 1000°C for 30 min in $N_2$ gas with a flow rate of 1600 $cm^3$/min: (a) Au(20 nm)/Si substrate; (b) Au(10 nm)/Fe(10 nm)/Si substrate.**

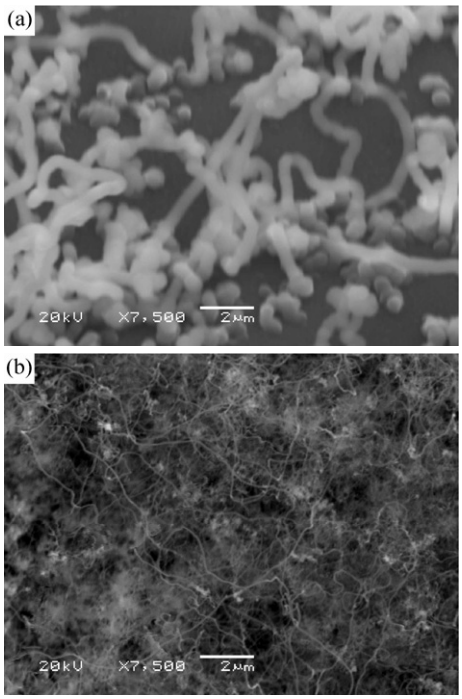


**Fig. 2. SEM views of samples at 1030°C for 30 min in $N_2$ gas with a flow rate of 1600 $cm^3$/min: (a) Au(20 nm)/Si substrate; (b) Au(10 nm)/Fe(10 nm)/Si substrate.**

Fig. 3 shows the SEM views of the samples at 1050°C for 30 min in $N_2$ gas with a flow rate of 1600 $cm^3$/min for Au (20 nm)/Si and Au (10 nm)/Fe (10 nm)/Si substrates, respectively. Fig. 3(a) shows that only a little amount of $SiO_x$ nanowires are grown on Au (20 nm)/Si substrate and their length is about 1 μm.