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Spontaneous Deposition of Cobalt Oxide Nanoplates for Application to Acetone Gas Sensors

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Abstract

The development of sensing materials, which influence the practical gas sensing performance, is critically important for the further evolution of semiconducting metal oxide gas sensor. Especially, cobalt oxides have attracted great interest in their potential applications as solid-state sensors because of their chemical stability and semiconducting properties. In this study, we are reporting the spontaneous deposition of Co_3O_4 nanoplates on interdigitated electrodes and its application to gas sensors. Inducing the phase transition of *h*-CoO to $Co(OH)_2$ and consecutive thermal oxidation on silicon substrate results in efficient deposition between Co_3O_4 and the substrate without any additional deposition processes. The efficient deposition of Co_3O_4 nanoplates is applicable for acetone gas sensors.

Key words: CoO, $Co(OH)_2$, Co_3O_4, Phase transition, Gas sensor

Introduction

Cobaltous oxide (CoO) typically crystallizes in two crystal phases, cubic rocksalt CoO with octahedral Co^{2+} and hexagonal wurtzite CoO with tetrahedral Co^{2+} ions.[1] Especially, the meta-stable *h*-CoO phase has attracted great interest because it involves various fundamental themes of materials chemistry, such as phase transitions, and distinctive physicochemical properties.[2] In addition to CoO, spinel Co_3O_4 has also been a central issue because of its superior catalytic, magnetic, and electrochemical features.[1] The Co_3O_4 nanostructures have recently been used for solid-state gas sensors, where the sensing characteristics are mainly influenced by the morphology and porosity of the nanostructures.[3]

In the present study, we report the spontaneous deposition of Co_3O_4 nanoplates on an electrical device. Inducing the phase transition of *h*-CoO to $Co(OH)_2$ and consecutive annealing process on the electrical devices results in efficient deposition between Co_3O_4 and the substrate without any additional deposition processes. This finding demonstrates the phase transition of nanomaterials can be an effective way of designing high performance gas sensors, and also provides a new insight into gas sensor fabrication without complicated processes.[4]

Experimental Details

The *h*-CoO nanocrystals were obtained by a solvothermal reaction.[1] When the *h*-CoO nanocrystals were spin-coated onto interdigitated electrodes, and then deionized water was added, the conversion from *h*-CoO to *β*-$Co(OH)_2$ took place at room temperature.[5] Consecutively, the *β*-$Co(OH)_2$ nanoplates were annealed at 300 °C for 2 h under an atmospheric pressure of air to yield spinel Co_3O_4 nanoplates. And the gas sensing properties of synthesized Co_3O_4 nanoplates were measured using a computer-controlled characterization system which included a

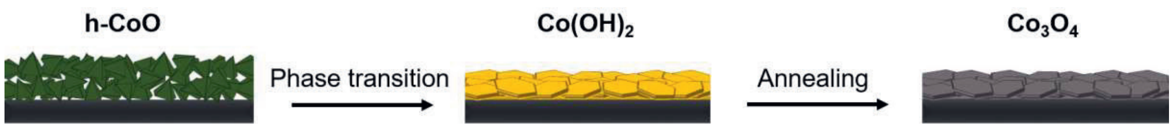

Fig. 1. Schematic illustration of the synthesis of Co_3O_4 nanoplates on the silicon substrate.

temperature-controlled steel chamber, mass flow controllers (MFCs), and a digital multimeter.[3]

Results and Discussion

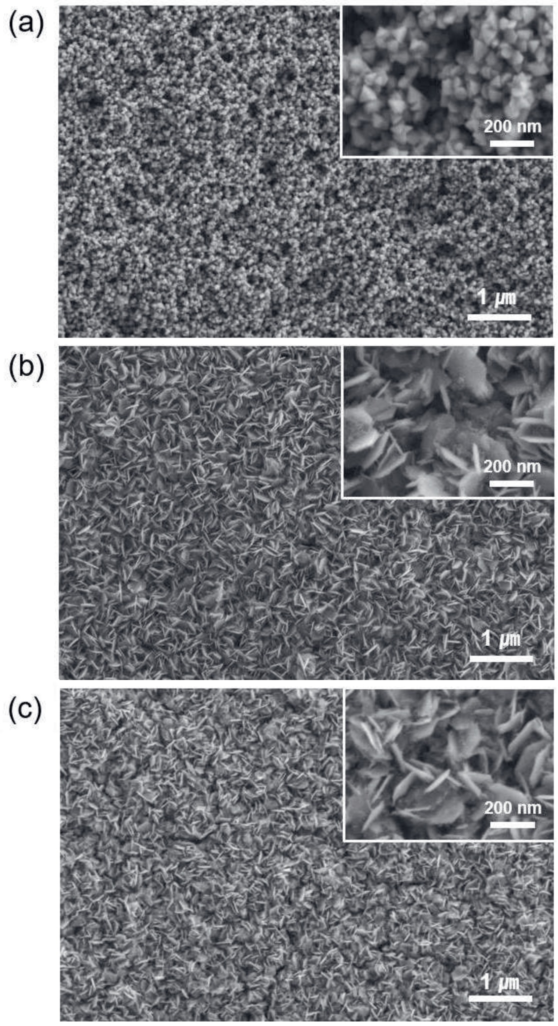

Fig. 2. SEM images of (a) h-CoO pyramids, (b) $Co(OH)_2$ nanoplates, (C) Co_3O_4 nanoplates on the silicon substrate.

The synthetic approach of Co_3O_4 nanoplates involved three sequential reactions; preparation of *h*-CoO, phase transition to $Co(OH)_2$, and oxidation (Fig. 1). Figure 2a shows SEM image of the *h*-CoO pyramids which have an average side edge length of 40 ± 6.4 nm. The direct addition of water drives the phase transition of *h*-CoO to $Co(OH)_2$ on the silicon substrate. The $Co(OH)_2$ nanocrystals exhibited a hexagonal plate shape with an average side edge length of 70 ± 11 nm (Fig. 2b). Consecutive dehydration and oxidation of $Co(OH)_2$ yielded Co_3O_4 nanocrystals with the shape identical to the original one of the hexagonal nanoplate (Fig. 2c). The plate-shaped morphology of the as grown Co_3O_4 can be clearly observed in the SEM images (Fig. 2c), indicating that efficient deposition occurred on the electrical devices via phase transitions without any additional deposition processes.

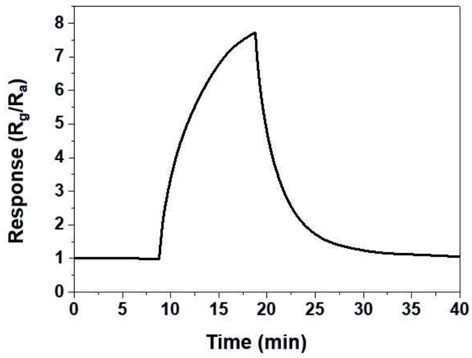

Fig. 3. Response curve of Co_3O_4 nanoplate gas sensor to 1ppm acetone at 200 °C.

Gas-sensing properties of Co_3O_4 nanoplates were investigated using a characterization system with a temperature-controlled hot chuck in a water-cooled steel chamber. The gas response is defined as the ratio of resistance, R = R_g/R_a, where R_a and R_g are the resistance in an air and in a gas atmosphere, respectively. The real-time gas response of Co_3O_4 nanoplates were measured under the standard condition with the exposure of 1 ppm acetone gas at 200 °C (Fig. 3). The Co_3O_4 nanoplates exhibited quite higher gas sensitivity, and better stability than previous results.[3]

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