Thermite Reaction Between CuO Nanowires and Al for the Crystallization of a-Si

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Nanoenergetic materials were synthesized and the thermite reaction between the CuO nanowires and the deposited nano-Al by Joule heating was studied. CuO nanowires were grown by thermal annealing on a glass substrate. To produce nanoenergetic materials, nano-Al was deposited on the top surface of CuO nanowires. The temperature of the first exothermic reaction peak occurred at approximately 600°C. The released heat energy calculated from the first exothermic reaction peak in differential scanning calorimetry, was approximately 1,178 J/g. The combustion of the nanoenergetic materials resulted in a bright flash of light with an adiabatic frame temperature potentially greater than 2,000°C. This thermite reaction might be utilized to achieve a highly reliable selective area crystallization of amorphous silicon films.

Keywords: Thermite reaction, CuO nanowire, Selective area crystallization, RF sputtering

1. INTRODUCTION

Energetic materials are a class of materials having high amounts of stored chemical energy that is able to be rapidly released in the form of thermal energy. Energetic materials are generally composed of an oxidizer and a fuel which are physically mixed together. Energetic materials are used in explosives, pyrotechnics, and propellants; their properties make it possible to produce a greater amount of energy as compared to the input energy. Many technologies used for synthesizing nanoenergetic materials have been proposed. One of the simplest methods is a nanopowder mixed with fuel metal and oxidizer particles [1]. In addition, nanoenergetic materials can also be prepared by sol-gel [2], nanostructured multilayer foils [3,4], and nanocrystalline porous silicon with oxide [5]; these methods have difficulty in obtaining a homogeneous mixture, as well as hazardous and elaborate procedures. In this study, Al/CuO-based nanoenergetic materials were produced by integrating CuO nanowires grown from Cu thin film with nano-Al deposited onto a glass substrate. The fabricated nanoenergetic materials were characterized by scanning electron microscopy (SEM), X-ray diffraction (XRD), and differential scanning calorimetry (DSC). We investigated the heat flows and heat energies released from the CuO nanowires with deposited nano-Al; the results suggest that these could potentially be used for a-Si crystallization [6].

2. EXPERIMENTS

The nanoenergetic material sample was prepared as shown...
in Fig. 1. Figure 1(a) shows the deposited Cu film as well as the other layers. 1-um-thick Cu thin film was deposited onto a glass substrate by RF sputtering. A 100-nm-thick SiO2 film as a buffer layer and a 50-nm-thick Ta film as an adhesion layer were also deposited onto the glass substrate by RF sputtering. Figure 1(b) shows the top-view SEM image of the deposited Cu layer without the nano-wire structure. The native oxides of the Cu thin films were removed by a solution of 10 ml HCl and 60 ml de-ionized water. The samples were placed in a quartz tube in the middle of a horizontal tube furnace; static air was used for annealing. The samples were annealed in a horizontal tube furnace at various temperatures for four hours, in order to determine the optimum annealing temperature. The annealed samples were allowed to naturally cool to prevent peel-off due to thermal stress. CuO nanowires grew from the 1-μm-thick Cu thin film [7]. Nanoenergetic materials were produced by depositing a 1-μm-thick Al on top by RF sputtering. The CuO/Al-based nanoenergetic materials on the glass substrate were characterized by SEM and XRD. The thermite reaction of CuO nanowires with the deposited nano-

3. RESULTS AND DISCUSSION

In order to study the influence of annealing temperatures on the growth of CuO nanowires, the samples were annealed in a horizontal tube furnace at various temperatures for four hours. Figure 2 shows the 30˚-tilted SEM images of the Cu films annealed in static air for four hours at 400˚ C, 500˚ C, 600˚ C, and 700˚ C. Uniform CuO nanowires only grew in the temperature range from 400 to 500˚ C, as shown in Fig. 2(a) and (b). Only a few nanowires were formed when the temperature was 600˚ C or higher, as shown in Fig. 2(c). When the temperature was 700˚ C or higher, no nanowires were formed and the film surface was coated with small particles, as shown in Fig. 2(d). Based on the SEM images of the CuO nanowires, the optimum annealing temperature condition was determined to be 500˚ C for four hours, thus yielding uniform CuO nanowires. Figure 3 shows 30˚-tilted