

Chemical composition analysis of individual chalcogenide alloy nanostructures

M. Abe^{a)}, M. Kuwahara^{*}, J. Sakai^{**}, H. Uratsuji^{***}, Y. Uehara

Fundamental Technology Center of RIEC, Tohoku University
Katahira, Sendai, Japan

a) maho@riec.tohoku.ac.jp (corresponding author)

^{*} Electronics and Photonics Research Institute, AIST
Tsukuba, Ibaraki, Japan

^{**} Groupe de Recherche En Matériaux Microélectronique Acoustique Nanotechnologies,
Université François Rabelais de Tours
Tours, France

^{***} SHIBAURA ELETEC Company Ltd.
Yokohama, Kanagawa, Japan

ABSTRACT

We have determined the chemical composition of nanometer-scale alloys made of Sb and Te by scanning electron microscopy (SEM) combined with energy dispersive X-ray spectroscopy (EDX). 5 nm-thick Sb₂Te₃ was first deposited on a highly oriented pyrolytic graphite (HOPG) substrate by a radio-frequency (RF) magnetron sputtering method. No conspicuous nanostructures were observed in the SEM images at this stage. Then the sample was annealed at 200 °C in an Ar gas atmosphere for five-minutes. SEM observations informed that nanostructures with lateral sizes of around 20 nm, which are isolated from each other, were successfully produced. EDX measurements revealed that the chemical composition of each nanostructure is Sb : Te = 1 : 3, while the gross composition of the sample surface is Sb: Te = 2: 3, even after the annealing process. This discrepancy in chemical composition indicates that Te atoms are much more mobile than Sb on the HOPG surface for the adopted annealing condition. As a result, the Te atoms exclusively cohered to form Te-rich nanostructures.

Key words: Chalcogenide alloys, Nanostructures, Chemical composition

1. INTRODUCTION

Chalcogenide alloys have attracted many researchers because of their unique material properties, i.e., significant changes in electronic and optical properties upon amorphous to crystalline phase transitions. Such properties are currently applied to optical disks and are intensively investigated towards non-volatile phase change memories. [1, 2] In the high-storage-capacitance memories, the size of each element is reduced to nanometer scale range, where some kind of size effect may additionally appear. Therefore, exploring properties of individual nanostructures made of these materials are very interesting. While scanning probe microscopy (SPM) is a powerful tool for surface structural analyses with required spatial resolution, its capability for chemical composition analyses is poor. In this paper, we report determination of the chemical composition of individual chalcogenide-alloy-nanostructures by scanning electron microscopy (SEM) combined with energy dispersive X-ray spectroscopy (EDX).

2. EXPERIMENTS

Highly oriented pyrolytic graphite (HOPG) was chosen for the substrates of samples because of its atomic level flatness of surface. 5 nm-thick Sb₂Te₃ was first deposited on the surface in an Ar gas pressure of 0.5 Pa by a radio-frequency (RF) magnetron sputtering method. No conspicuous nanostructures were seen on the surface at this stage. Then the sample was annealed at 200 °C in an Ar gas atmosphere for five minutes.

The surface structures and chemical compositions of the samples were simultaneously observed by SEM combined with EDX. The SEM was operated with an acceleration voltage of 10 kV throughout the experiments. Two types of EDX spectra are shown in the resultant section; one is for determining element distributions in certain sample areas and the other for determining chemical compositions at specified positions on the sample surfaces. The exposure time was 30 and 5 minutes for the former and latter measurements, respectively.

3. RESULTS AND DISCUSSION

Figure 1(a) shows a typical SEM image of the post-annealed samples. We see that nanostructures with lateral sizes of around 20 nm, being isolated from each other, are successfully produced. EDX spectra were taken from each 128 x 88-divided areas in corresponding SEM images to determine element distributions. Figures 1(b) and 1(c) show the results for Sb and Te, respectively, in which the amount of each element is represented by densities of white dots. By comparing Fig. 1(a) with Figs. 1(b) and 1(c), one sees that relationship between locations of individual nanostructures in the SEM images and the element distributions is hardly found. Figure 1(d) shows the EDX spectrum obtained by integrating all EDX spectra from the 128 x 88 pixels. The ratio of Sb : Te deduced from Fig. 1(d) is approximately 2 : 3, which is reasonably consistent with that of the target used for deposition.

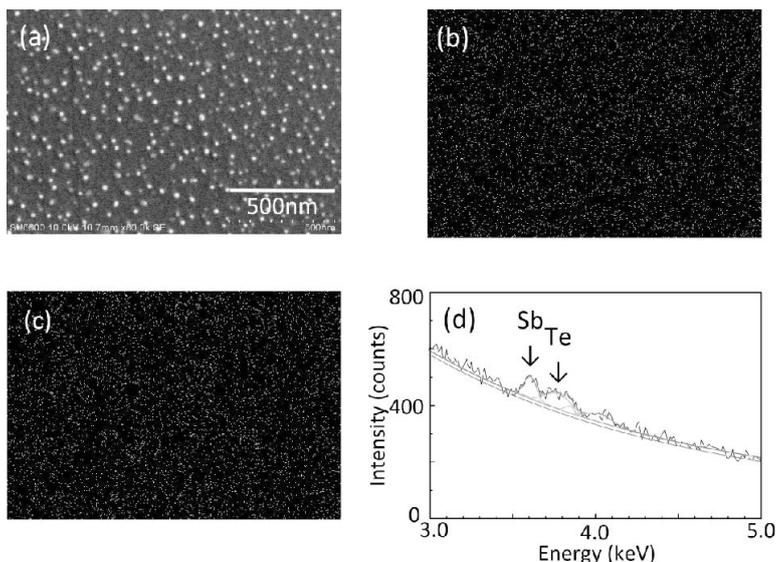


Fig. 1 (a) SEM image of a sample surface area and element distributions of (b) Sb and (c) Te in the area. (d) EDX spectrum of the area.

Figures 2(a) and 2(b) show the EDX spectra of (a) one of the nanostructures and of (b) a location where the flat surface is exposed, respectively. The signals from Te are dominant in Fig. 2(a), even though smaller signals from Sb are also seen. Detailed analyses of Fig. 2(a) reveal that the chemical composition of the nanostructure is approximately Sb : Te = 1 : 3. The EDX signals seen in Fig. 2 (b) are significantly weak in comparison with those in Fig. 2(a), showing that the Sb and/or Te layer covering the surface of the substrate is extremely thin. Since the chemical composition in gross determined from Fig. 1(b) is Sb : Te = 2 : 3 and one of each nanostructure is Te rich, the surface of the substrate must be dominantly covered by Sb.

4. CONCLUSION

We investigated chemical composition of nanostructures produced by RF magnetron sputtering followed by the five-minutes-annealing in Ar. The size and chemical composition of each nanostructure were determined by simultaneous measurements of SEM and EDX. The lateral sizes of nanostructures produced by the present method were around 20 nm and their chemical composition was Sb : Te = 1 : 3. On the other hand, the surface of the substrate was dominantly covered by Sb. This discrepancy in chemical composition strongly suggests that Te atoms deposited on the HOPG are much more mobile than Sb for the adopted annealing condition so that the Te rich nanostructures are formed during the annealing process.

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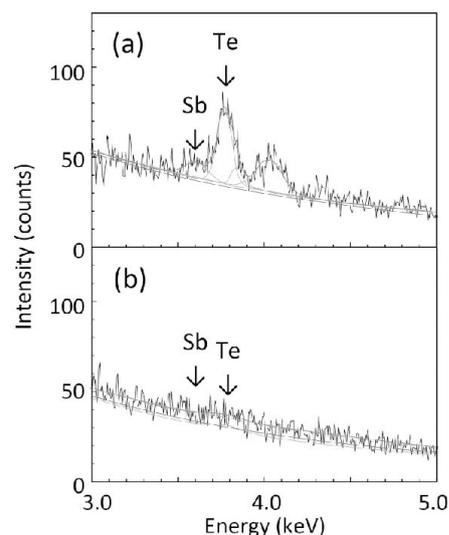


Fig. 2 EDX spectra of (a) a nanostructure and (b) a flat area on the sample surface.