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Formation of Single-Orientation Epitaxial Islands of $TiSi_2$ on Si (001) Using Sr Passivation

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Metal silicide thin films such as $TiSi_2$, $CoTi_2$, and NiSi are an essential part of integrated circuit (IC) devices in modern Si technology since they can be used for ohmic contacts, Schottky barrier contacts, gate electrodes, and local interconnects. As the size of IC devices has been reduced, the requirements of material properties such as low contact resistance, good adhesion to Si, and thermal stability, have become more stringent [1]. Moreover, the large lattice mismatch between $TiSi_2$ and Si has made it difficult to grow epitaxial $TiSi_2$ films on Si substrates. However, epitaxial nanoislands of $TiSi_2$ can be achieved if their mismatch is relieved for nanometer-scale films, such as source/drain contacts in IC devices [2]. This paper demonstrates that epitaxial nanoislands of $TiSi_2$ can be grown on Si (001) substrate using Sr passivation of Si substrate and the decomposition of $SrTiO_3$ during annealing at above 800°C. Samples were grown using a DCA 600 molecular beam epitaxy (MBE) system and prepared for cross-section TEM observation using standard mechanical polishing and ion-milling procedures. High-resolution images were recorded with a JEM-4000EX high-resolution electron microscope operated at 400-keV with a structural resolution of ~1.7Å. Annular dark-field (ADF) images in scanning transmission electron microscopy (STEM) mode and X-ray energy-dispersive spectroscopy (EDS) spectra were obtained using a JEOL 2010F operated at 200-keV. Atomic force microscopy (AFM) using Digital Instruments Dimension 3000 was performed in order to analyze the surface morphology and the size distribution of the $TiSi_2$ islands.

Cross-sectional electron micrographs show the epitaxial nanoislands of $TiSi_2$ grown on the Si substrate, as visible in Fig. 1(a). The lattice-plane agreement observed in the higher magnification view of a $TiSi_2$ island shown in Fig. 1(b) indicates that Si [110] is parallel to $TiSi_2$ [100]. Moreover, the $TiSi_2$ islands are partially buried into the Si substrate with typically about half of each island below the top surface of Si substrate. Figure 2(a) shows an ADF image in STEM mode and Fig. 2(b). shows the corresponding EDS spectrum for the particular $TiSi_2$ island marked with x in Fig. 2(a). The EDS results confirm that the decomposition of $SrTiO_3$ above 800°C has caused Sr and O to diffuse out from the sample, leaving epitaxial $TiSi_2$ islands on the top surface of the Si substrate. The AFM results in Fig. 3 show that the sizes of $TiSi_2$ islands are on the order of 20-100 nm laterally and that they cover approximately 55% of the Si surface. A histogram for the size distribution of $TiSi_2$ islands, as shown in Fig. 3(b), indicates that the mean size of $TiSi_2$ islands is about 71 nm and that the overall mean surface roughness of the sample is 1.4 nm. Thus, these epitaxial $TiSi_2$ islands could be used as a source/drain contacts in IC devices [3].

References

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[3] This work was supported by the Office of Naval Research (ONR) under grant N000 14-09-1-0908, the National Science Foundation (NSF) under grant DMR-0548182, and the U.S. Department

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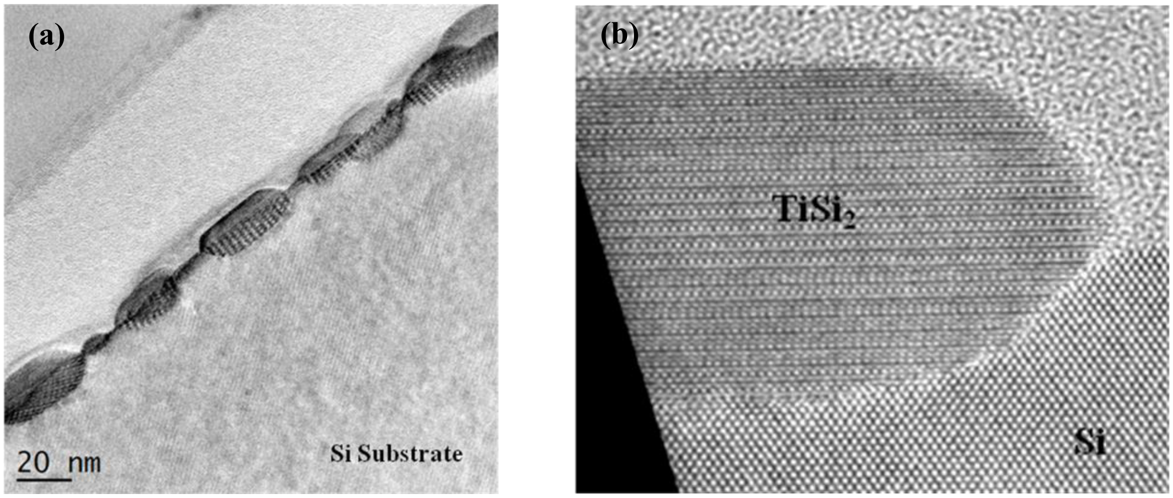

FIG. 1. (a) Cross-sectional electron micrograph showing epitaxial nanoislands of $TiSi_2$ along the top surface of Si (100) substrate; (b) Higher magnification image.

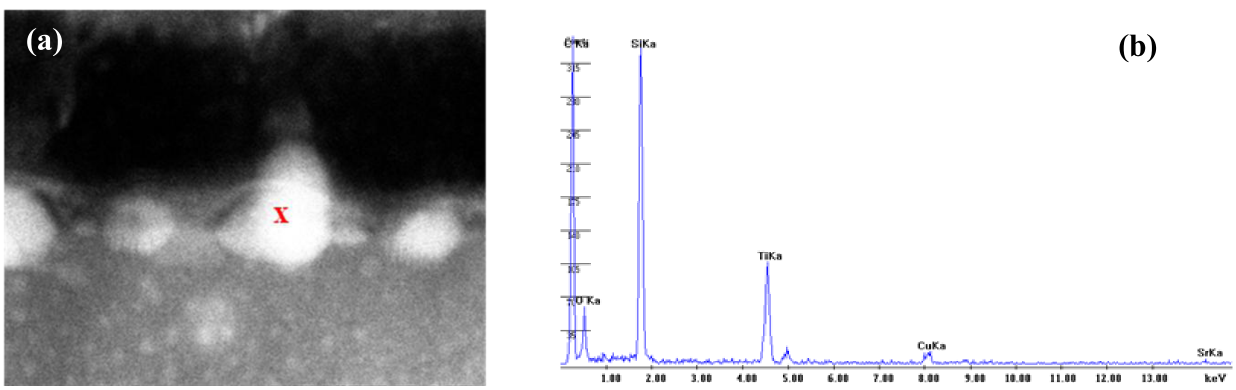

FIG. 2. (a) ADF image in STEM mode (x indicates the position of electron beam during the EDS analysis); (b) EDS spectrum from the TiSi2 nanoisland (small oxide peak from Si native oxide).

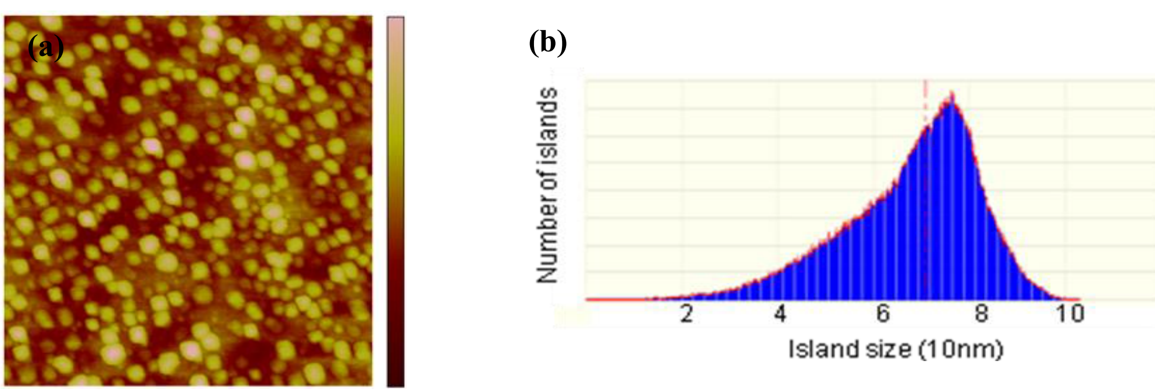

FIG. 3. (a) AFM image showing top surface of sample; (b) Histogram showing the size distribution of $TiSi_2$ islands.

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