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Effect of composition rate on erbium silicide work function on different silicon surface orientation

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I. Introduction

In order to reduce source/drain parasitic resistance (R$_{SD}$) in LSI, it is essential to reduce contact resistance (R$_c$) for high performance MISFETs [1, 2]. As the Schottky barrier height (SBH) between silicide and silicon must be low to achieve low contact resistivity [3]. On the other hand, the three dimensional MISFETs are essentially requiring some different orientations of silicon [4]. We have already reported the low R$_c$ with low SBH is realized using erbium silicide (ErSi$_x$) for n$^+$ silicon on Si(100) and properties of ErSi$_x$ on Si(100), (111) and (551) surfaces [5, 6]. In this paper, we investigated ErSi$_x$ film densities and properties on Si(100), (111) and (551) surfaces.

II. Experimental

ErSi$_x$ was used for low work function material in this study. In order to protect the as well as Er or ErSi$_x$ from being oxidized, two unique processes were employed for the silicidation. They are the total N$_2$ ambient surface cleaning and transfer process and the in-situ W metal capping on Er before silicidation [7]. Silicon wafers were loaded into a N$_2$ sealed cleaning chamber after total room temperature 5 step cleaning [8] and a chemical oxide was formed by dipping in O$_3$ dissolved ultra-pure water. After removing the chemical oxide with a diluted HF (0.5wt %) solution, the wafers were transferred to clustered sputtering and lamp anneal equipments in a N$_2$ ambient. Er was deposited by the sputtering, followed by lamp annealing to form ErSi$_x$. The silicidation annealing temperature was 600^{o}C for 2 min. In this case, all of the deposited Er was reacted to become ErSi$_x$ [5]. The hard X-ray photoelectron spectroscopy (XPS) and X-ray refractive (XRR) measurement were performed at beam line (BL46XU) of Super Photon Ring 8 GeV (SPring-8) (Project No. 2012A1620 and 2012A1772).

III. Result and Discussion

Fig. 1 shows the XPS Si 1s spectra arising from ErSi$_x$/Si(100) (111) and (551). The Er deposition thickness are 3, 5 and 10 nm. In order to reduce the influence of the signal from the Si substrate, the spectra measured at photo electron take-off angle of 20^o. So the quantity of Er in the ErSi$_x$ film is fixed by the Er deposition thickness. The peak height of Si 1s is normalized by the peak height of Er 3d$_{5/2}$ spectrum. Then, the peak height in Fig.1 indicates the Si/Er ratio. The Si 1s peak on Si(100) increase with a decrease of the ErSi$_x$ thickness. On Si(111), the peak is small. And the peak on Si(551) decrease with a decrease of the ErSi$_x$ thickness. It means the quantity of Si atoms in the ErSi$_x$ film is different. When the ErSi$_x$ thickness increase, the quantity of Si atoms decrease on Si(100) and increase on Si(551).

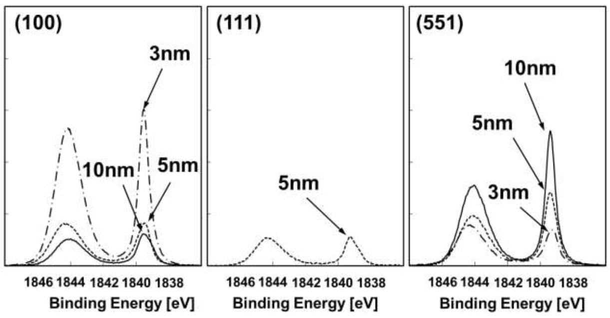

Fig. 1 XPS spectra arising from ErSi$_x$ as a function of Er deposition thickness on Si(100), (111) and (551).

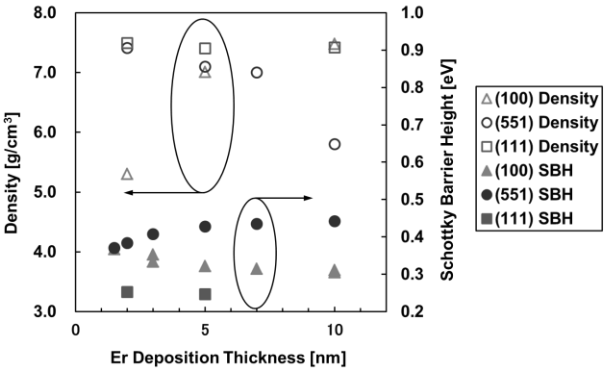

Fig. 2 Extracted film densities and SBHs of ErSi$_x$/n-Si as a function of Er deposition thickness on Si(100), (111) and (551) surfaces.

Then, in order to investigate in more detail the relationship between SBH and composition ratio of Er and Si, film densities extracted from results of XRR measurement were evaluated. Fig. 2 shows the ErSi$_x$ film densities as a function of Er deposition thickness on Si(100), (111) and (551). The film densities on Si(100) increase with an increase of the Er thickness. The higher film densities keep on Si(111). And on Si(551), the film density decrease with an increase of the Er thickness. When the ErSi$_x$ film density has higher value of about 7.3 g/cm^3, and the changes are independent of the Si surface orientations. The density of Er is 9.07 g/cm^3 and Si is 2.33 g/cm^3. It is considered that the film density becomes larger value, when the quantity of Si atoms in the ErSi$_x$ exists smaller. These results are consistent with the results of XPS measurement. When the quantity of Si atoms is smaller, the Si 1s peak height become smaller and the film density become higher.

The SBHs of the fabricated Schottky barrier diodes are also shown Fig. 2. The SBHs are extracted using the thermionic emission theory [3]. These XPS peak height and film density changes are related to the SBHs changes. Then, Si has higher work function than Er. It is considered that the ErSi$_x$ contains more Si atoms, as a result; the work function is higher.

IV. Conclusion

We have investigated the properties of the ErSi$_x$ on Si(100), (111) and (551) surfaces. The ErSi$_x$ density affects the work function of ErSi$_x$. A controlling the composition ratio of Er and Si are key parameter for reducing R$_c$ for high performance MISFETs.

Reference

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