Schottky barrier height between erbium silicide and various morphology of Si(100) surface changed by alkaline etching

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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) [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, some different orientations of Si must appear in the three dimensional MISFETs [4]. We have already reported that the low R_c with low SBH is realized using erbium silicide ($ErSi_x$) for n^+ silicon on Si(100) and also reported that the properties of $ErSi_x$ on Si(100), (111) and (551) surfaces and the SBHs is smaller on Si(111) than the others [5, 6]. On the other hand, when Si(100) surface is etched by an alkaline solution, Si(111) orientation appears on Si(100) surface [7]. In this paper, we investigated the influence of Si(100) surface morphology for the SBHs between $ErSi_x$ and n-type Si.

II. Experimental

$ErSi_x$ was used for a low work function material and the 2.38%-tetra-methyl ammonium hydroxide (TMAH) was used for an alkaline solution in this study. Si(100) surface was etched by the TMAH at room temperature. In order to protect 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 [8]. Silicon wafers were loaded into the N_2 sealed cleaning chamber after the TMAH etching and the total room temperature five step cleaning [9] and a chemical oxide was formed by the dipping in the O_3 dissolved ultra-pure water. After the removing the chemical oxide with a diluted HF (0.5wt %) solution, the wafers were transferred to the clustered sputtering and lamp anneal equipment in a N_2 ambient. Er was deposited by the sputtering, followed by the lamp annealing to form $ErSi_x$. The silicidation annealing condition was 600°C for 2 min. In this case, all of the deposited Er was reacted to become $ErSi_x$ [5].

III. Result and Discussion

Fig. 1 shows the atomic force microscopy (AFM) images and the values of average roughness (R_a), rout mean square of roughness (R_{rms}) and peak to valley (P-V) of Si(100) surface as a function of the TMAH etching time, respectively. For the 10 min TMAH etched surface, although values of R_a, R_{rms} and P-V are almost the same as the initial values, the surface morphology is rougher than the initial. The 60 min TMAH etched Si surface is rougher and values of R_a, R_{rms} and P-V are larger than the initial Si surface. It is considered that the Si(111) surface is began to appear among Si(100) surface by the alkaline solution etching.

Table 1 shows the SBHs of the fabricated Schottky barrier diodes as a function of the TMAH etching time. The SBHs extracted using the thermionic emission theory [3]. Although the value of SBH is not changed for the 10 min TMAH etched surface compared with the initial Si surface, the value of SBH decrease for the 60 min TMAH etched surface.

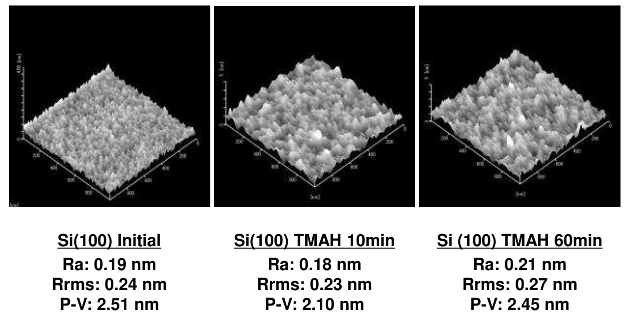

Fig. 1 AFM images of Si(100) surface as a function of TMAH etching time.

Table 1 SBHs of the fabricated Schottky barrier diodes as a function of TMAH etching time.

	(100)	(100) TMAH 10min	(100) TMAH 60min	(111)
Barrier Height [eV]	0.322	0.324	0.302	0.246

Fig. 2 shows the J/T^2-1/T plot of the fabricated Schottky barrier diode of the TMAH 60 min etched Si surface. Circle plots show the measured values. Triangle plots are the values when the contact area is assumed to 1.2 times larger than the patterned area and the line is a theoretical value of 0.302 eV. The slope of the experimental result is different from the case of the enlargement of surface area by the roughened the surface.

This means that the SBH is not determined only the area size. We have already reported that the formed $ErSi_x$ films have different physical and electrical properties by the Si surface orientations [5]. It suggests that the surface morphology generated by the alkaline solution etching and the orientation affect the value of SBH.

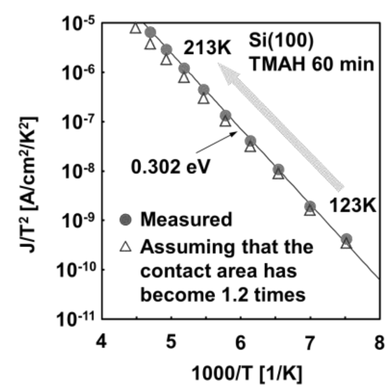

Fig. 2 J/T^2-1/T plot of the fabricated Schottky barrier diode of the TMAH 60 min etched Si surface.

IV. Conclusion

We have investigated the SBH between $ErSi_x$ and n-type Si(100) surface with an alkaline solution etching. The Si surface morphology affects the SBH between $ErSi_x$ and n-type Si. A controlling the Si surface morphology is the key parameter for reducing R_c of high performance MISFETs.

Reference

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