

Effects of Sputtering Gas on Formation of Ultrathin PtHfSi Film

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Abstract

This study investigated the effects of sputtering gas on silicidation of PtHfSi to obtain a high performance silicide. We could form thinner PtHfSi by using Kr sputtering. Additionally, barrier height for electron was reduction by Kr sputtering.

1. Introduction

For MOSFET scaling, the sheet resistance (R_s) and contact resistance (R_c) of silicides at source/drain regions are an important parameter to reduce the series resistance. And thinner silicide is required for application to produce an ultra-shallow junction. To obtain a high performance silicide, the process parameters of the plasma to growth a metal film is very important. Then the metal film growth mechanism is revealed. However, there are a little literatures dealing with characteristics of RF magnetron plasma regarding to a metal film deposition. The energy, momentum, electronic state and ion state of the plasma species impinging of the substrate are important plasma parameters of the growth of the nano structure metal film [1].

In this paper, we investigated effects of sputtering gas to the formation of ultrathin PtHfSi film. Effects of Ar and Kr sputtering gas to the reduction of barrier height of PtHfSi film were also studied [2]. We used Ar and Kr as a sputtering gas and compared PtHfSi formed by Ar sputtering and Kr sputtering.

2. Experimental Procedure

To confirm effects of sputtering gas on our equipment, we measured as deposited Pt and Hf films. The film thicknesses of metal are 20 nm and 40 nm. The sheet resistance was evaluated by a four point probe method. And the XRD measurements was also performed.

Figure 1 shows a schematic diagram of Schottky diodes. After formation of contact holes ($100 \times 100 \mu\text{m}^2$), Pt (12 nm)/Hf (8 nm) stack layer was *In-situ* deposited on n-Si(100) substrate at room temperature(RT) by RF magnetron sputtering. The chamber pressure during deposition was 0.65 Pa (measured by Shullz gauge). The stacked layers were annealed by using a RTA system in a flowing N_2 ambient at $400^\circ\text{C}/1$ hour to form a silicide layer. During the anneal, silicon-wafer-covering (SWC) was utilized to suppress the oxidation of the silicide [3]. The unreacted metal on the SiO_2 was removed by diluted aqua ($\text{HCl} : \text{HNO}_3 : \text{H}_2\text{O} = 3 : 2 : 1$), at 40°C . The sheet re-

sistance was evaluated by a four point probe method. Schottky barrier height (SBH) (Φ_{Bn}) was calculated by thermionic emission model from J-V characteristics of silicide/n-Si(100)/Al Schottky diodes. And XPS measurement was also preformed.

3. Results and discussion

The results in Fig. 2 show that low sheet resistance is able to obtain by using Kr sputtering. Figure 3 shows XRD pattern which the peak intensity of Pt and Hf that deposited by Kr sputtering were stronger than the one with Ar sputtering. These characteristics are typical for Kr sputtering. Due to Kr sputtering has a lower ion bombardment energy compared to Ar sputtering [4], the better crystallinity with lower electrical resistivity was obtained by Kr sputtering. Therefore, it is clearly show that we can obtain Kr sputtering effects on our equipment.

I-V characteristics are shown in the Fig. 4. Figure 5 shows sheet resistance and SBH for electron of PtHfSi calculated from Fig. 4. Kr sputtering leads to lower sheet resistance and lower barrier height. For analysis about these differences, the cross sectional TEM image and depth profiles of atomic concentrations are shown in Fig. 6 and Fig. 7, respectively. In Fig. 6, both of PtHfSi consist of 2 layers. Figure 7 show the top layer is unreacted metal and second layer is silicide. From TEM images, the thickness of silicide layer formed by Kr and Ar sputtering are 5.3 nm and 10 nm respectively. PtHfSi formed by Kr sputtering layer is thinner than one with Ar. Therefore, sheet resistance was decreased by unreacted metal layer. A different of PtHfSi film thickness indicated that the diffusion rate is depended on sputtering gas. It was caused by difference in crystallinity between as deposited Hf and Pt films formed by Ar and Kr sputtering as shown in Fig. 3. In addition, similar atomic concentration profile at PtHfSi/Si interface were achieved by Ar and Kr sputtering as shown in Fig. 7. The SBH also depends on the sputtering gas. It can be concluded that barrier height was directly affected by sputtering gas due to sputtering damage or any mechanisms.

4. Conclusion

Ultrathin PtHfSi film(5.3nm) can be formed by Kr sputtering. This is because the low diffusion rate of Kr sputtering which was caused by good crystallinity of as-deposition films.

Additionally, SBH for electron was decreased by Kr sputtering.

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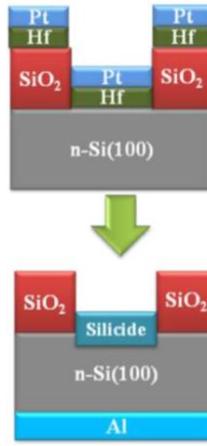


Fig. 1. Schematic diagram of Schottky diodes.

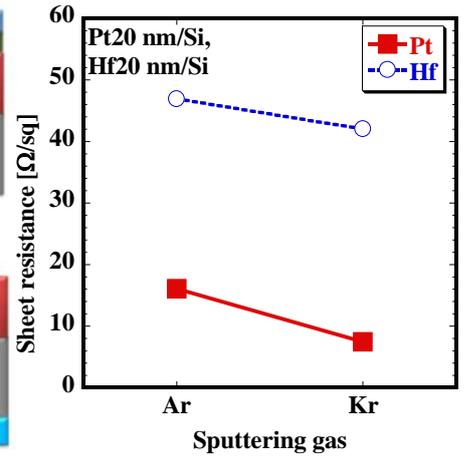


Fig. 2. Sheet resistance of as deposition films.

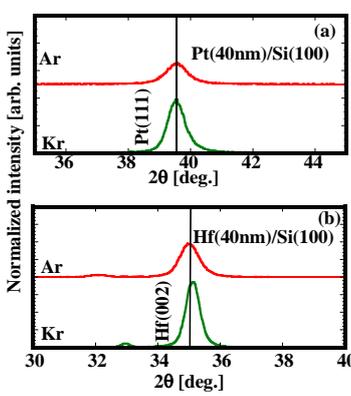


Fig. 3. XRD pattern of as deposition films (a) Pt and (b) Hf.

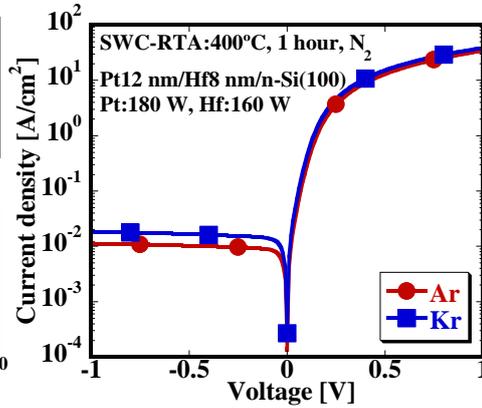


Fig. 4. J-V characteristics of PtHfSi.

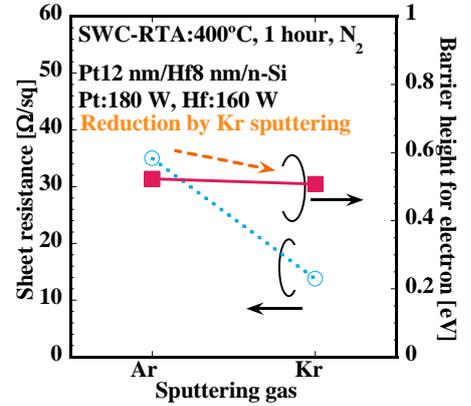


Fig. 5. Sheet resistance and barrier height for electron of PtHfSi.

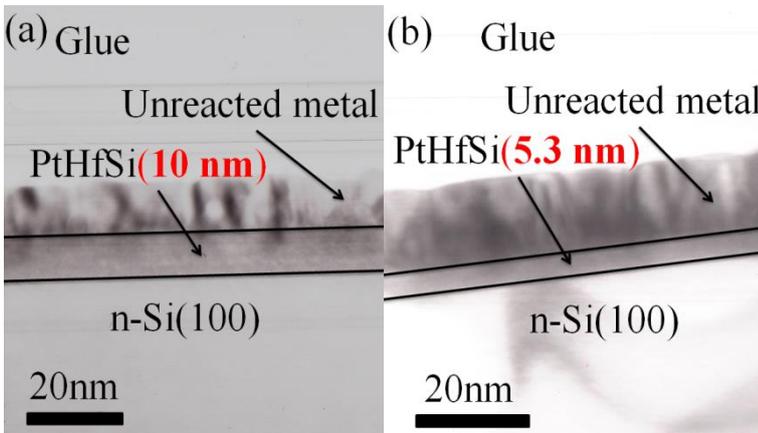


Fig. 6. Cross-sectional TEM images of PtHfSi/nSi(100) formed by (a) Ar sputtering and (b) Kr sputtering.

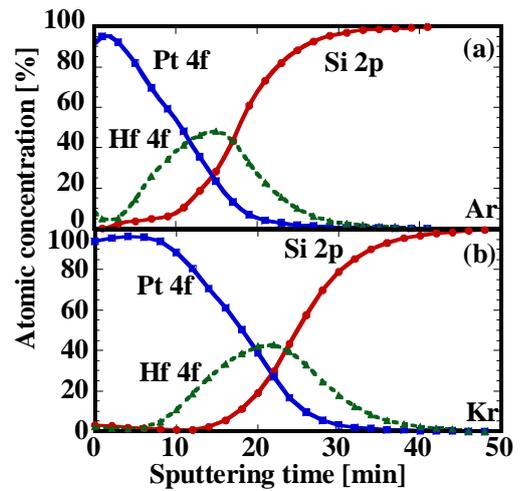


Fig. 7. Depth profiles of atomic concentrations of PtHfSi formed by (a) Ar sputtering and (b) Kr sputtering.