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Reduction of sheet resistances of PtSi alloying with Hf formed by Kr sputtering

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1. Introduction

Beyond 14 nm technology generation, the contact resistance (R_c) of silicides at source/drain regions is an important element to reduce the series resistance [1]. To obtain low R_c, the silicide materials with low Schottky barrier height (SBH) for n- and p-type Si and low resistance are required [2]. PtSi has low barrier height for p-Si (0.25 eV) and good thermal stability comparing to NiSi, but the SBH for n-type is high. Therefore, we have reported that a modulation of PtSi work function by alloying with Hf, which has low work function and lower surface roughness than PtSi and HfSi has same crystalline structure with PtSi (Orthorhombic) [3]. Currently, to reduce contact resistivity of PtSi for n-Si [4], and to improve surface roughness. However PtSi is made high sheet resistance by higher concentration of Hf.

In this study, we improve sheet resistance of PtHfSi by useing Kr sputter. We investigated a planar orientation dependence of PtHfSi for multi-gate device.

2. Experimental Procedure

Figure 1. shows the fabrication process of Schottky diodes. After the patterning of the contact holes (100x100 μm^2), Pt (12 nm)/Hf (8 nm) stacked layers were in-situ deposited on the n-Si(100) and n-Si(110) at room temperature by RF magnetron sputtering method. The total thickness of stacked layers was fixed at 20 nm. The pressure in the chamber during the deposition was 0.65 Pa (Ar flow rate: 4.0 sccm, Kr flow rate: 2.02 sccm). The stacked layers were annealed by using a rapid thermal annealing (RTA) system in a flowing N_2 ambient at 400ºC/1 hour to form silicide layers as the conventional silicidation process. During the anneal process, silicon-wafer-covering anneal (SWC-anneal) [5] method was utilized to suppress the oxidation of the silicide. The unreacted metal on the SiO_2 was removed by diluted aqua ($HCl : HNO_3 : H_2O = 3 : 2 : 1$) at 40ºC. The sheet resistance of silicide layers was evaluated by a four point probe method. SBH (Φ_{Bn}) was calculated from Richardson plot of fabricated silicide/n-Si/Al Shottky diodes. The x-ray diffraction (XRD), J-V characteristics and atomic force microscopy (AFM) measurements were also performed.

3. Results and Discussion

Figure 2. shows x-ray diffraction (XRD) patterns. It revealed PtHfSi with same crystalline orientation formed on Si(100) and Si(110) after annealing at 400ºC. Figure 3. shows rocking curve for XRD pattern of PtHfSi shown in Fig. 2. PtHfSi formed by Kr sputter show what full width at half maximum was decrease to 50% of sample formed by Ar sputter. The crystalline guality of PtHfSi was improved by Kr sputter. Figure.4 shows AFM images. RMS roughness of all samples was less than 0.6nm. In this case, agglomeration of PtHfSi did not occur after annealing at 400ºC/1hour. Figure.5. shows substrate orientation and sputter gas dependence of sheet resistance of PtHfSi. Kr sputtering leads to lower sheet resistance than Ar sputtering. It was caused by improvement of crystallinity shown in Fig. 3. Figure.6 shows XRD patterns of Pt(40nm)/Si(100) structures, and Fig.7 shows rocking curve for Pt peaks shown in Fig. 6. Full width at half maximum of Pt formed by Ar sputter was 0.35 º, while it was 0.19 º for the sample for the Kr sputtering. Kr sputtering has lower ion bombardment energy and it improved crystallinity [6-8]. Therefore, lower sheet resistance of PtHfSi was realized by improvement of crystallinity of Pt deposited by Kr sputtering.

4. Conclusions

Kr sputter make PtHfSi that has better crystalline and lower sheet resistance.

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Reference

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Fig. 1. Schematics of fabricated Schottky diode structure.

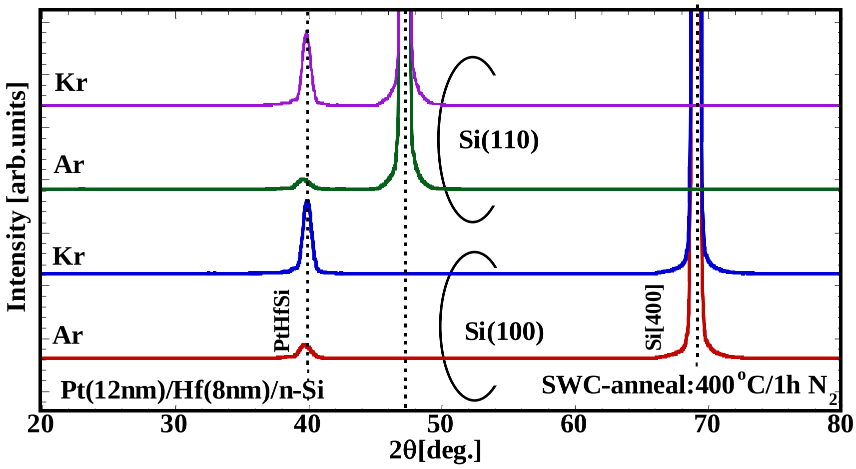

Fig. 2. XRD patterns of PtHfSi/Si(100) and PtHfSi/Si(110) samples after annealing that was deposition by Ar sputter or Kr sputter

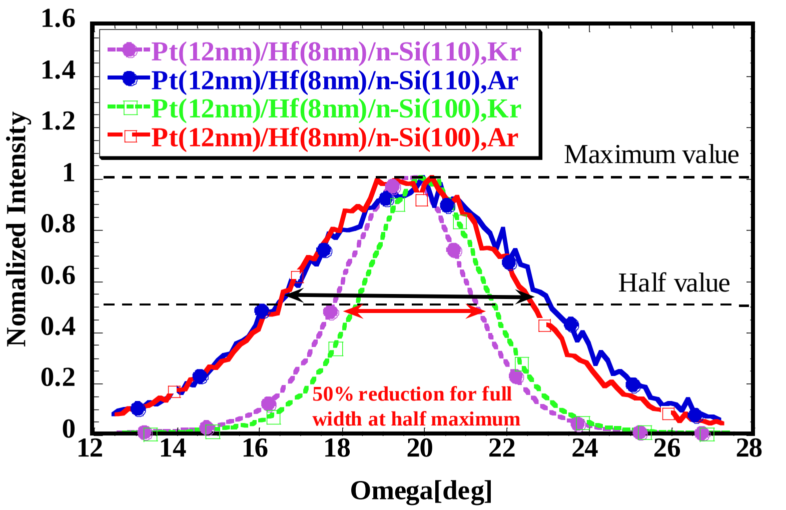

Fig. 3. Sputter gas and planar direction dependence of rocking curve patterns for PtHfSi shown in Fig.2.

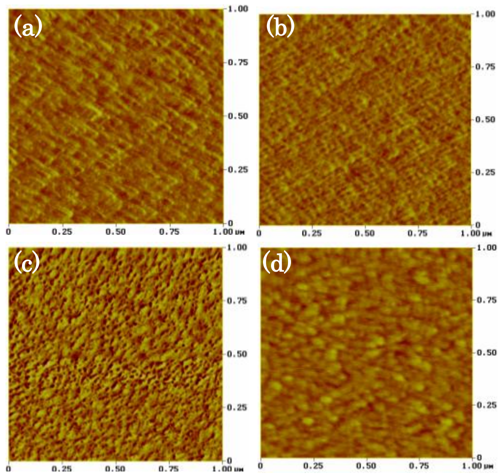

Fig. 4. AFM images of PtHfSi.
(a) and (b) are PtHfSi/Si(100)and PtHfSi/Si(100) made by Ar putter respectively.
(c) and (d) are PtHfSi/Si(100)and PtHfSi/Si(100) made by Kr sputter respectively.

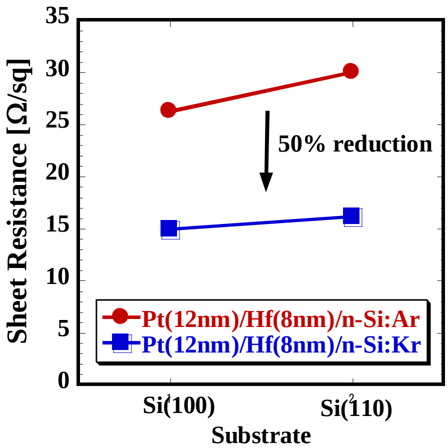

Fig. 5. Sheet resistance of PtHfSi versus planar orientation and sputter gas dependence.

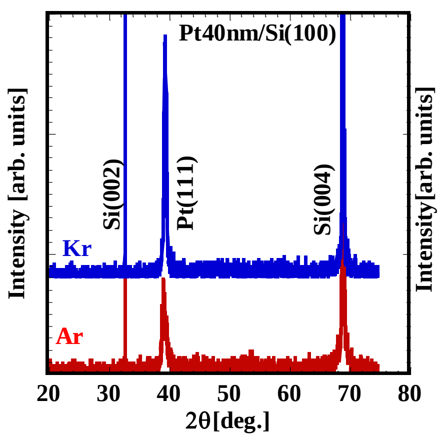

Fig. 6. XRD patterns of Pt/Si(100) samples that was deposited by Ar sputter and Kr sputter.

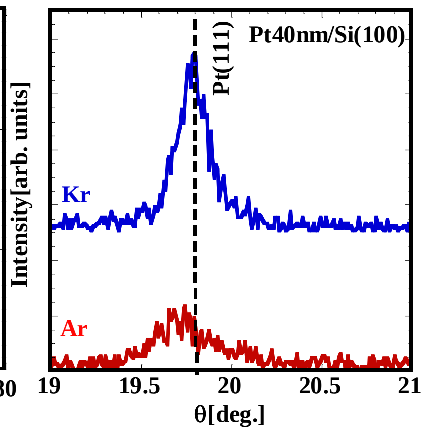

Fig. 7. Sputter gas dependence of rocking curve patterns for Pt(111) shown in Fig.6.