Extended Abstracts of the 1997 International Conference on Solid State Devices and Materials, Hamamatsu, 1997, pp. 552-553 **A-6-7(LN)**

Ultra-Shallow Junotion Formation by AsH3 Adsorption Method

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1. Instroduction

Table 1 shows the technical comparison for the recent N-type doping methods. Even though the technical originality of several doping methods, process feasibility and controllability are still questionable in sub 0.1 μm MOSFET fabrication. In paticular, low energy and new implantation method cannot avoid a thermal annealing to cure the implantation damage. AsH_3 adsorption in GSMBE provides ultra-shallow junction with wide temperature margin which means good controllability, and no extra anealing and simple integration which mean good process feasibility in sub 0.1μm MOSFET fabrication.

2. Experimental

A GSMBE apparatus is shown schematically in Fig.1. The base pressure of the main chamber was less than 3×10^{-10} Torr. AsH_3 gas diluted to 10% concentration by H_2 gas was used as the N-type doping gas for junction formatoin. The standard process sequence was carried out as shown in Fig.2. After thermal cleaning, 10SCCM AsH_3 gas was injected into main chamber at the variable temperatures and adsorption times for the arsenic doping.

3. Results and discussion

Fig.3 shows the typical arsenic SIMS depth profile for AsH_3 adsorption. Very shallow (Xj; 300 Å) and heavy doping (Cp; above $1 \times 10^{20} cm^{-3}$) profile was obtained at 850°C, 5 min doping condition. Fig.4 shows the temperature effect of AsH_3 adsorption. The As peak concentrations and junction depths (@ $10^{18} cm^{-3}$) showed the saturation trend at above 550°C. The stable junction characteristics can be achieved at the temperature range from 700°C to 950°C as shown in Fig.4. These experimental results were quite well matched to arsenic coverage simulation data of Fig.5-(1) [1]. Fig.6 shows the change of arsenic concentration at the increasing adsorption times. It was found that arsenic concentrations reached to some maxinum values and then went to decrease with increasing doping time. Initial stage of increasing concentration can be explained from the simulation data of adsorption time dependence(Fig.5-(2)) but the second stage of decreasing concentration cannot be well understood. This mechanism will be verified from the further experiments. The higher Cp (peak concentration) and longer peak time for one of 850°C compared with 700°C can be attributed to higher surface desorption and diffusivity. Fig.7 shows in-situ anealing effect at 850°C. As shown in Fig.7, increasing anealing time gave negative effect for the sheet resistance, which means that extra anealing is not necessary for junction formation. Finally, Fig.8 shows the strong correlation between arsenic concentrations and junction depths.

4. Conclusion

From the results of junction characteristics, it is suggested that AsH_3 adsorption method is very effective for N-type ultra-shallow junction formation.

References

[1] L.Kipp, The American Physical Review B, Vol. 50, N8, 15 August 1994, p.5448 - 5455.

method	controllabilty	process and scaling feasibility	simple integration	damage and defect free
SPD	bad	good	good	must aneal
ion implant	good	good	very good	must aneal
doped epi.	good	bad	fair	need aneal /epi -defect
delta. doping	fair	bad	fair	must aneal
inversion ST	fair	very bad	fair	skip aneal
AsH3 doiping	good	good	very good	skip aneal

Table1. N-type doping technology comparison. SPD means solid phase diffusion method.

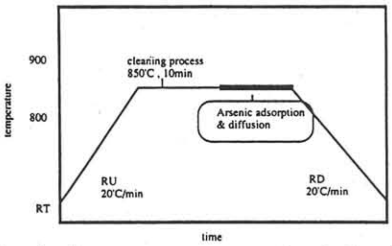

Fig. 2. Standard process sequence for AsH3 adsorption.

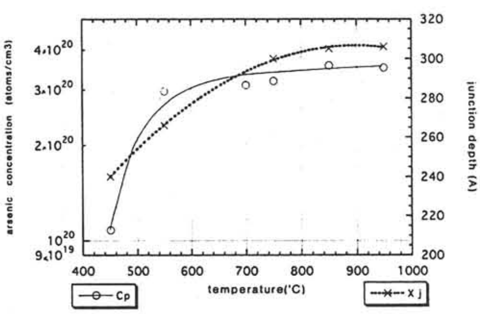

Fig. 4. Temperature dependence of junction characteristics. The only 5min adsorption without extra anealing was done.

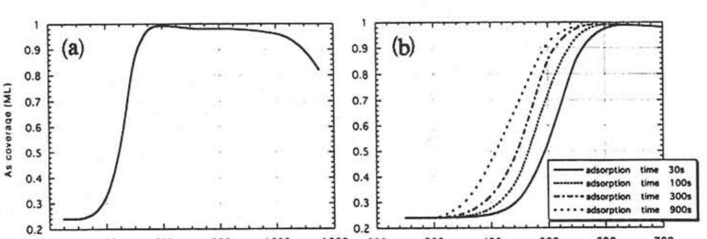

Fig. 5. Arsenic coverage simulation data using a model with Langmuir adsorption and first-order desorption reaction , curve(a) is temperature dependence at adsorption time 300s, (b) is adsorption time dependence at the variable temperature.

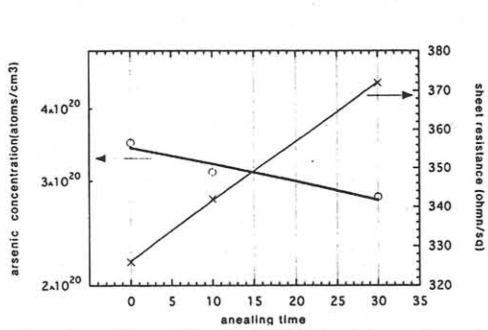

Fig. 7. Anealing effect at 850℃. Adsorption time was 5 min.

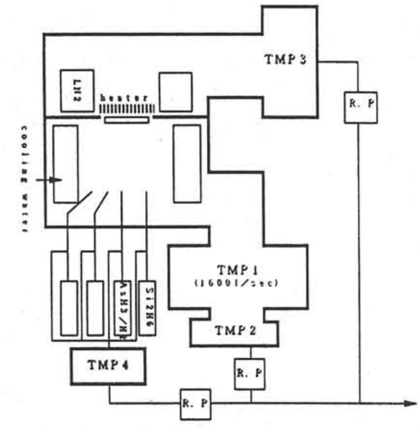

Fig. 1. Schematic diagram of gas source MBE.

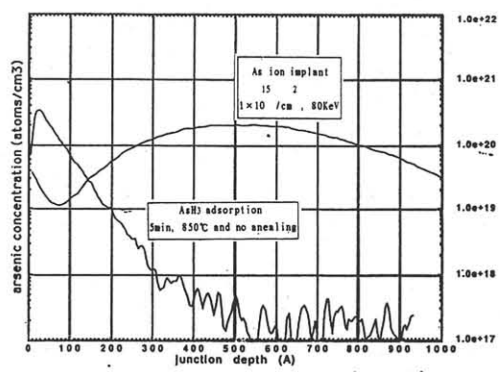

Fig. 3. SIMS depth profile of AsH3 adsorption. Arsenic ion implantation for the comparison was done.

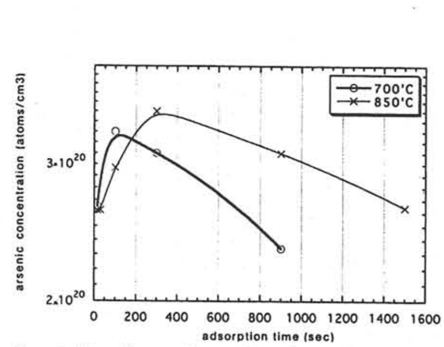

Fig. 6. AsH3 adsorption time dependence of arsenic concentration at temperatures of 850 and 700℃.

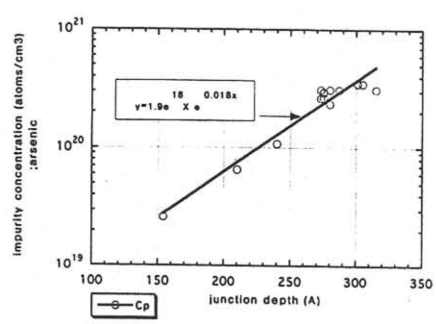

Fig. 8. Correlation result for Cp vs Xj. It showed good exponential relation with R. F of 0.92.