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IMPROVEMENT OF THE SHALLOW BASE TRANSISTOR TECHNOLOGY BY USE OF A DOPED POLY-SILICON DIFFUSION SOURCE

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In connection to an emitter diffusion source to be used in a shallow base transistor, doped poly-silicon method was investigated. As the result, an npn transistor of less than 3000 Å base depth was able to be produced reliably and reproducibly.(1) In addition the method provides a better solution to the electrode problem common in transistor. Cross section of the transistor structure made in this work is shown in Fig. 1.

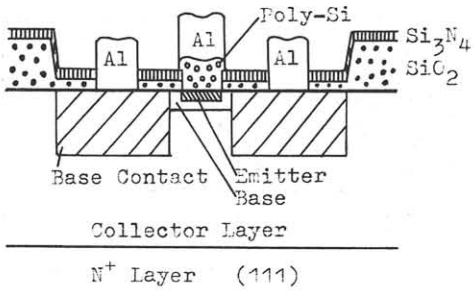

Fig.1 Schematic construction of the npn transistor.

Examining the diffusion properties of impurities from the poly-silicon doped with As or P, several interesting results were obtained. The poly-silicon were made by CVD technique using SiH_4 with AsH_3 for As diffusion and with PH_3 for P at 700°C. As molar ratio ($r=AsH_3/SiH_4$) changes, the diffusion profile of As varies as shown in Fig. 2. When r is 2-4 x 10^{-2}, surface concentration of more than $10^{20}cm^{-3}$ is obtained at driving temperature of 1000°C. The high concentration at low temperature process of this degree is not attainable in an arseno-silicate glass.(2)(3) The surface concentration and the diffusion depth of As are greatly influenced by environments during the drive-in. In order to achieve a high surface concentration, it is at least required to have an oxidation ambient, while the diffusion depth sensitively depends on the thickness of the oxidized layer. In the case of P diffusion, the profiles follow an error function distribution quite well.(4) Poly-silicon thickness of about 1000Å was sufficient as an emitter diffusion source for shallow base transistor. As to the masking

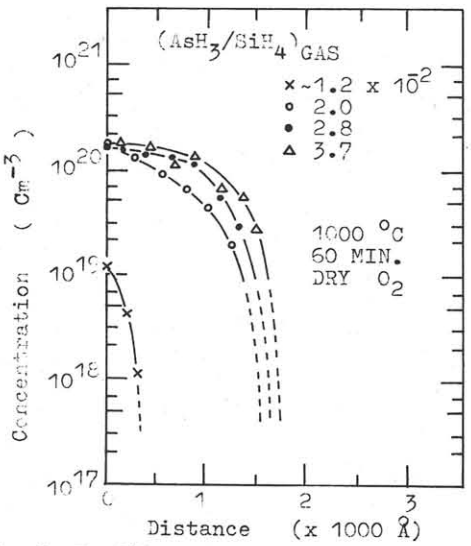

Fig.2 Profiles of As diffused layers.

effect, the oxide film of 250 Å thick was found to be sufficient to protect the diffusant during the redistribution at 1150°C and 6 hrs. both for As and P cases.[5]

A transistor made by this method was compared with those of conventional method. Table 1 shows the characteristics of those transistors.

Table 1. Test transistor characteristics.

Diffusant	Base Depth	BV_{EB} 10uA	BV_{CB} 10uA	BV_{CE} 1mA	f_T 10V, 20mA	h_{FE} 10V, 7mA	V_{FE} 30mA
As, Poly-Si	2200 Å	5.2V	~34V	~25V	5.0GHz	60~140	0.82V
P, Poly-Si	3400	5.0	~30	~22	3.2	80~120	0.93
P, P S G	2900	5.4	~40	~20	3.5	80~120	0.91

In a transistor made by use of the poly-silicon, the problem of E-B short occurring in the heattreatment of aluminum electrode was extremely improved from the conventional washed emitter method as shown in Fig. 3. Resistivity effect on V_{FE} of the poly-silicon remaining on emitter was measured to be negligible. Diffusion from the poly-silicon offers rather simplified mechanism because of the absence of the oxide film at the interface between the poly-silicon and silicon substrate.[6]

From the transistor process point of view, the diffusion from the poly-silicon can be treated as an conventional two-step diffusion because of its lower deposition temperature, which results in an easy control of h_{FE}.

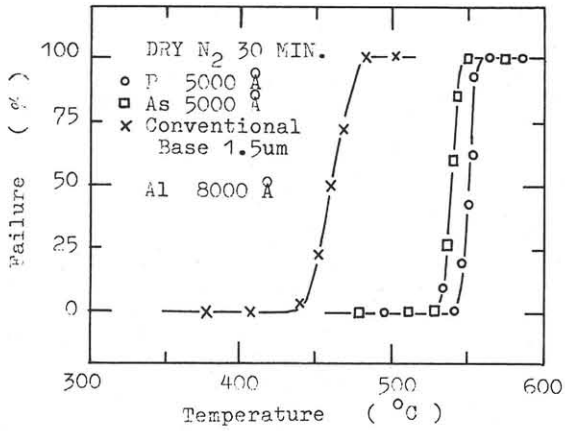

Fig.3 Failure distribution versus heat-treatment temperature.

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