A—4—1 Arsenic Implanted Emitter and Its Application to UHF Power Transistor

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There has been a strong interest in arsenic (As) implanted shallow junctions because of the small and concentration-dependent diffusivity of the species. This property is advantageous for the fabrication of emitters in high speed bipolar devices and source-drain in high complexity MOS LSI. This paper will describe the basic feature of As implantation into Si and its application to shallow emitters of UHF power transistors.

It is well known that heavy dose implantation such as over 1×10^{15} As^+/cm^2 makes an implanted region amorphous. However, a high quality crystalline layer and improved junction characteristics can be obtained by the high temperature annealing in a N_2 atmosphere. Figure 1 shows the TEM photographs of As implanted layers and the respective junction characteristics. When annealed in an oxidizing atmosphere, the secondary defects such as dislocation loops grow and extend to the junction region, and thereby the junction becomes leaky. On the other hand, the superior junction characteristics have been obtained in the sample annealed in N_2. In this case, the surface defects, which might be due to the out-diffusion or precipitates of As, are observed only in the surface region. The surface defects can be eliminated by encapsulation with a surface protecting layer. The reverse current of As implanted junction annealed in N_2 had almost the same magnitude as that of phosphorus diffused junction, and the main component of which was a generation current in the depletion layer.

Figure 2 shows the impurity profile in As implanted and diffused layers. The profiles were measured by using He^+ backscattering method. The profile is step-like owing to the concentration-dependent diffusivity, which results in high emitter efficiency relative to the conventional phosphorus

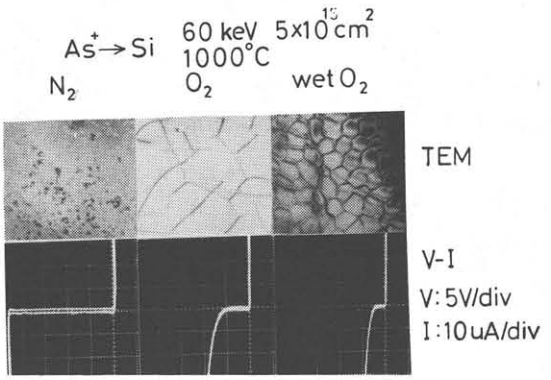

Fig.1 TEM photograph of As implanted layers and respective junction characteristics.

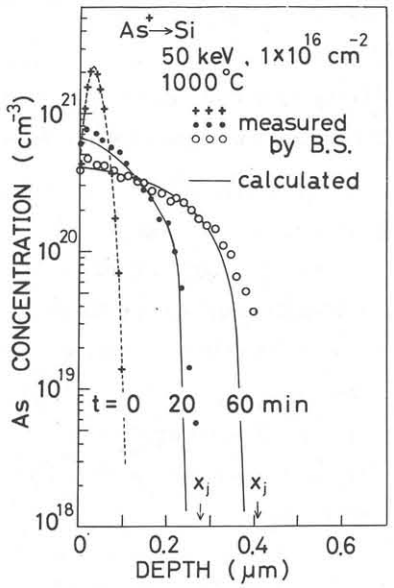

Fig.2 Implanted and diffused As profiles.

diffusion. The solid lines in Fig.2 are the numerical solutions of non-linear diffusion equation with the concentration-dependent diffusivity, which includes the following effects;[1] 1)increase of the equilibrium vacancy concentration in the heavily As doped region, 2)internal electric field due to the concentration gradient of As, 3)formation of As-vacancy complexes. The computer simulation can predict the As profile fairly well. By choosing the optimum condition for As implantation and diffusion with the aid of the computer simulation, the transistor characteristics such as a current gain h_{FE} can be precisely controlled. This is also due to the fact that the emitter-push effect is very small in the As implanted emitter. Figure 3 shows the relation between the base width W_B and the magnitude of the emitter-push or -pull effect in the double implanted transistor with boron base and As emitter. There reported that the emitter-pull effect occurs in the double diffused transistor with boron base and As emitter. In the double implanted transistor, it was observed that the emitter-push effect did occur in the wider base transistor, while the emitter-pull effect occurred in the narrower base transistor. The emitter-push or -pull effect is very small compared with the phosphorus emitter, which results in precise controllability of h_{FE} and the low output capacitance, and thereby the high frequency characteristics are improved.

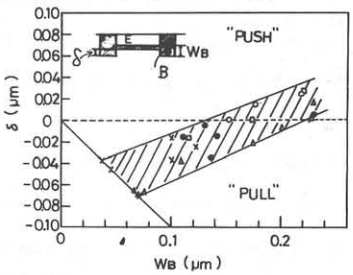

Fig.3 Relation between base width W_B and magnitude of emitter-push or -pull effect.

The As implanted emitter is applied to UHF power transistors with the boron implanted base. The transistor cell has a interdigitated structure with washed emitters of 2.0μm width. The typical transfer characteristics of common emitter configuration are shown in Fig.4. The device performance is characterized by a power gain of 5 dB with an associated collector efficiency of 60 %, and a saturated power of 22 W, at 900 MHz with 12.5V dc supply voltage. These transistors have ability to withstand infinite VSWR for all phase angles when operated at rated output power.

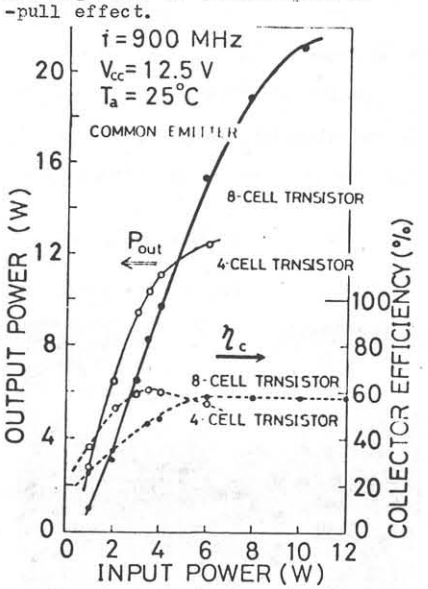

Fig.4 Transfer characteristics of UHF power transistor with As implanted emitter.

In summary, the high performance UHF power transistor is developed by using As implantation. It is verified that the following characteristics are advantageous for the As implanted emitter of the UHF power transistor; 1)the emitter profile is step-like, 2)the shallow emitter can be easily obtained, 3)secondary defects are almost eliminated, 4)the emitter-push effect is very small and controllable.

(1)S.M.Hu; J.appl.Phys., 39 (1968) 4272