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Diffused Emitter and Base Silicon Transistors*

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Silicon n-p-n transistors have been made in which the base and emitter regions were produced by diffusing impurities from the vapor phase. Transistors with base layers 3.8 × 10^{-4}-cm thick have been made. The diffusion techniques and the processes for making electrical contact to the structures are described.

The electrical characteristics of a transistor with a maximum alpha of 0.97 and an alpha-cutoff of 120 mc/sec are presented. The manner in which some of the electrical parameters are determined by the distribution of the doping impurities is discussed. Design data for the diffused emitter, diffused base structure is calculated and compared with the measured characteristics.

INTRODUCTION

The necessity of thin base layers for high-frequency operation of transistors has long been apparent. One of the most appealing techniques for controlling the distribution of impurities in a semiconductor is the diffusion of the impurity into the solid semiconductor. The diffusion coefficients of Group III acceptors and Group V donors into germanium and silicon are sufficiently low at judiciously selected temperatures so

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that it is possible to envision transistors with base layer thicknesses of a micron and frequency response of several thousand megacycles per second.

A major deterent to the application of diffusion to silicon transistor fabrication in the past was the drastic decrease in lifetime which generally occurs when silicon is heated to the high temperatures required for diffusion. There was also insufficient knowledge of the diffusion parameters to permit the preparation of structures with controlled layer thicknesses and desired dopings. Recently the investigations of C. S. Fuller and coworkers have produced detailed information concerning the diffusion of Group III and Group V elements in silicon. This information has made possible the controlled fabrication of transistors with base layers sufficiently thin that high alphas are obtained even though the lifetime has been reduced to a fraction of a microsecond. In a cooperative program with Fuller, diffusion structures were produced which have permitted the fabrication of transistors whose electrical behavior closely approximates the behavior anticipated from the design. This paper describes these techniques which have resulted in high alpha silicon transistors with alpha-cutoff of over 100 mc/sec.