

## Early 1960s

### **Transition to thermal oxidation and vapor-phase diffusion by horizontal diffusion furnaces**

#### **~ Process Technology ~**

The transistors up to the 1950s were in alloy junction types and grown junction types. The basic patent of semiconductor device by diffused junctions was filed by Western Electric in 1949. In 1954, C. J. Frosch and L. Derrick of Bell Telephone Laboratories found that the silicon oxide film formed on the silicon surface served as a mask for diffusion of impurities such as phosphorus and boron into silicon. And in 1959, a planar transistor was invented by J. A. Hoerni of Fairchild, and in the same year the patent of IC based on the planar technology was applied for by R. W. Noyce of Fairchild. In the planar technology, a silicon oxide film formed in the first vapor phase impurity diffusion process is left unremoved, to which an opening is made, and the second impurity diffusion is performed therefrom to form a PN junction. Since it forms a circuit with a two-dimensional structure in combination with lithography, it is called a planar process, and has been applied to many subsequent devices, becoming the cornerstone of integrated circuit advancement.

For oxidation and diffusion, a horizontal diffusion furnace was used, in which a reaction tube was horizontally placed in an electric furnace, wafers were placed in the reactor tube, and gases were introduced with needle valve control. In the oxidation, oxygen gas or oxygen containing water vapor was flown into the furnace heated to about 800 to 1,100°C to form a silicon dioxide film. A gas containing group V elements (for example, phosphorus oxychloride ( $\text{POCl}_3$ )) is used to form a n-type diffusion layer, and group III elements (eg. boron tribromide ( $\text{BBr}_3$ )) to form a p-type diffusion layer, respectively.

Initially, in-house horizontal diffusion furnaces were used for production, but from the mid-1960s, commercial equipment began to be used. In 1963, Kokusai Electric (now Hitachi Kokusai Electric) developed the first pure domestic product of diffusion furnace in Japan, and in 1968, Tel-Thermco started domestic production.