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Early 1960s

Using an epitaxial technique to manufacture silicon transistors

~ Process Technology ~

In the 1960s, planar silicon transistors were made also in Japan. A transistor consists of three basic elements called an emitter, a base, and a collector. In a silicon transistor, the substrate functions as a collector, and a collector current is extracted from the back side of the substrate. In order to efficiently extract the collector current, it is better to have lower resistance substrate, and the heavily doped substrate with dopant element (also called impurity) which lowers semiconductor resistivity is used. The substrate doped with high density n-type dopant is called n+ substrate, and that with p-type is called p+ substrate, both of which have much lower resistivity than ordinary semiconductor. A transistor cannot be made directly on the n+ or p+ substrate, so a low impurity concentration epitaxial layer is formed on the front side of such a high concentration substrate and a transistor is made in this layer. An epitaxial layer is a single crystal layer grown continuously on the single crystal of the substrate, and one of its features is that a layer in opposite type from the substrate can be formed.

Japanese manufacturers made silicon wafers in-house, and they formed epitaxial layers on them in-house as well. A method of vapor phase growth is used for the epitaxial growth of Si, in which a single crystal is continuously grown on a substrate by flowing reactant gases on a silicon substrate heated to a high temperature to cause a chemical reaction on the surface of the substrate. Typically, the reduction of silicon tetrachloride ($SiCl_4$) with hydrogen at about 1100 to 1200°C is performed, and a Si layer is deposited on the silicon substrate. If the growth temperature is too low, it will not result in a good single crystal growth, or conversely, if the growth temperature is too high, the high concentration substrate impurities evaporates and are doped into the growing epitaxial layer, making its resistivity low (a phenomenon called auto-doping). Each company made efforts to form epitaxial layers with uniform crystal quality by devising temperature control and flow rate control of reaction gases. Epitaxial growth equipment was also in-house manufactured at each company by combining vacuum tubes and condensers. At that time many presentations were made at academic conferences on the epitaxial growth researches.

In the late 1960s IC production began. In the IC, it is necessary to locally create low resistance regions (according to IC patterns) on the substrate. N+ regions are selectively formed on the substrate using a mask and then an epitaxial layer is formed thereon. For each company, the IC patterns were confidential, and the in -house epitaxial processing continued.

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