Review

Semiconductor Industry in Japan

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The semiconductor industry in Japan, following the same pattern in U.S.A. and Europe, was inaugurated in pre-war days by producing cuprous oxide and selenium rectifiers. Academic study of these products, which had been carried out mainly in the university laboratories, continued until post-war. These semiconductor devices found main use in power circuits for railway signal and communication equipments, and as modulators and/or demodulators for carrier transmission equipment. Considerable study of point contact diodes for use in radar receiver was also carried out during the war, but without marked achievements.

The transistor invented in 1948 was quickly introduced in this country to stimulate research institutes, both private and governmental. In 1950, as the first step of utilizing the microwave technology advanced during the war for the peaceful purposes, the silicon microwave mixer diodes were used to realize the practical use of multiplex communication equipments. This can be said to be the first achievement of the study in this country. In the following year germanium point contact diodes used for practical purpose were produced.

The production of point contact transistors was tried but still did not go beyond the trial stage. Nevertheless, as this country has not ample germanium resources, efforts had been made to obtain this material by the recovery from wasted gas liquor from the carbonization process, and by the extraction from the byproducts the zinc refinery process since 1952 in the recovery processes could not fructify after all due to cost problem. In 1953, alloyed junction type and grown junction type germanium transistors were successfully produced for the trial purpose. In 1955, these transistors were produced in several thousands, which was followed by the mass production in the following year. Most of these transistors were used in pocketable radio receivers and found their way into transistorized carrier transmission equipments in 1957.

In 1958, the famous Esaki (tunnel) diode was invented as an unexpected by-product of the high doping process for emitters aimed at the improvement of grown junction transistor characteristics. The same year also marked the advent of the Kita (silver bonded) diode as a product coming from the utilization of parametric phenomenon in the diode bonding

process. It is considered as an early variable capacitance diode. In 1958, the hyper abrupt junction produced by the alloy diffusion method was put into industrial use. Meanwhile, the grafted base structure with doubly diffused base region was invented as an improved version of the double diffused junction transistor in high frequency characteristics. Later in 1965, the hyper abrupt junction was improved by the low temperature epitaxial growth method, followed by the invention of emitter mesa transistor with a protruding emitter intended to cancel the pushing effect due to emitter diffusion. As a result, the microwave transistor with a 5 GHz cut-off frequency was put to practical use.

Production of high purity silicon by reduction of silicon tetrachloride with zinc was commenced in 1951. The process was gradually replaced by hydrogen reduction of tri-chlorosilane in 1958. Silicon was successfully produced by pyrolytic decomposition of silane around 1960. Study of inter-metallic compound semiconductor, with emphasis on III-V and II-VI compounds, was started around

1955. Success in the epitaxial growth method using gallium arsenide came in 1961 as the first achievement of this kind in the world.

Today, a large variety of semiconductor devices is mass-produced. Japan is only next to U. S.A., the top productive country, in the production of semiconductor devices, both in quantity and amount. The output is given in Table 1. While they are mostly used in consumer equipments, they are finding their way into new markets for use in industrial instruments and control apparatus with the recent rapid progress in electronic computers and desk calculators. Japan was quickest in the world in transistorizing or incorporating solid state electronics into various types of communication equipments represented by microwave communication equipments.

Japan started the study of monolithic integrated circuits in 1955, and their industrialization was commenced in 1965, since then they have been produced in rapidly increasing quantities, with a total of 3,000,000 pieces of them expected to be made in 1967.

Table 1 The Number of Semiconductor Devices Produced in Japan (Unit: million)

Year	Diodes		Rectifiers		Thyristors	Transistors		Others*
	Ge	Si	Ge	Si		Ge	Si	
1065	136	20.1	0.41	16.1		427	25.7	24.4
1966	232	45.0	0.48	27.7		517	97.3	45.4
1967-								
Jan.	24.0	5.13	0.011	9.60	9.074	46.3	11.3	4.08
Feb.	23.5	4.85	0.045	10.04	0.085	47.4	12.2	5.86
Mar.	27.8	4.91	0.040	11.6	0.095	50.9	14.3	4.36
April	28.4	5.13	0.014	11.3	0.104	51.0	13.1	3.44
May	28.3	5.30	0.055	9.7	0.112	50.1	13.0	4.34
June	27.8	6.07	0.034	12.7	0.117	53.9	14.9	4.12

* Others are thermistor, varistor, and other semiconductor devices.