Preface

Fundamental Research and Serendipity

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The last five years of the 1990's have been very important from the historical view point of science and technology. Two epoch-making discoveries were made 100 and 50 years ago, the discovery of electron by J. J. Thomson in 1897 and the invention of transistor by J. Bardeen and W. Brattain in 1947 and the invention of the junction transistor by W. Shockley in 1948. Operation of the transistor is based on the electron motion in a semiconductor and interpreted by quantum mechanics which was founded in 1926, about 30 years after the discovery of electrons. Development of transistors has led to a variety of electron devices, as well as integrated circuits (IC). The scale of integration may be evaluated by DRAM capacity. At present DRAM of 64Mb are the most commonly used, but DRAM of 256Mb will replace the 64Mb DRAM in the market in a few years. Along with the development of DRAM, the size of MOSFET is continuously decreasing and is now of submicron order. The size of MOSFET in Gb DRAM will become 0.1 micron, which is expected to be available in the 21st century.

The success of J. J. Thomson was due to his interest in the strange phenomena in the discharge tube and to his exploration of the essential physics involved with the phenomena. The Brown tube was invented from the research of discharge in vacuum tubes, and led to the invention of a triode (Audion) by Lee deForest in 1906. Triodes played a very important role in communications and in many other fields until they were replaced by transistors. The invention of the transistor was motivated by the idea of W. Shockley who was interested in developing a new device based on the surface charge modulation in a solid by the field effect. From intensive research on the effect Brattain and Bardeen accidentally discovered the point contact transistor and this discovery gave Shockley the idea of a junction transistor.

Science history tells us that a new technology matures and is then replaced by a new innovative technology. For example, the first industrial revolution was achieved by steam engines which were replaced by internal combustion engines and electric machines. We have experienced the latter revolution. What about transistor technology? Has transistor technology already matured or is it still progressing? It is very difficult to answer the questions, because transistor technology is quite different from the older technologies and extends to a wide range of applications. In today's market of semiconductor devices, there are bipolar transistors and MOSFETs based on Si technologies, and also LD, LED, HEMT and various other devices based on compound semiconductors for communications. These are not on the same level of development; some of them are well developed but others are still being developed.

We know that the recent development of optical devices based on GaN replaced the optical devices based on II-VI compound semiconductors which had been believed to be the most probable candidate for green and blue light sources. These results suggest that semiconductor technology is still developing, and has not yet matured, though we cannot exclude the possibility that a new technology may replace. Many people are expecting this kind of new innovation.

I believe that a new innovative discovery will appear suddenly and unexpectedly. This kind of innovation is often referred to as "serendipity". The word "serendipity" was first used by Horace Walpole who wrote a story about three princes in Serendip (Ceylon, now called Sri Lanka) in 1754. They traveled around and discovered unexpected things. Walpole commented in a letter to his friend that this kind of unexpected discovery was "serendipity"[1], and many books have since been published using the word "serendipity". All of them conclude that inventions and discoveries are accidental and unexpected. However, they point out that the most important process of discovery is to have an intuitive sense and open mind toward unexpected discoveries.

Some Japanese are impatient and believe or at least expect that fundamental research will lead to the discovery or invention related to next-generation technology. The goal of "The Quantum Functional Devices Project" promoted by the Research and Development Association for Future Electron Devices is to create new fundamental technologies required for the next generation. Several remarkable results have already been obtained and some of the developed technologies may have been applied to various fields, so the project appears to have been successful so far. Although there may be short-sighted opinions about the project, readers should take a long-term view of the project. It is the duty of a developed nation and the aim of the Project to continue the research project expecting "unexpected results", although it is very difficult. The efforts of the participants of the Quantum Functional Devices Project will help to achieve the final goal.

Reference

1) The term of "serendipity" and examples of unexpected discoveries are well described in the article : Ralph Bray "Serendipity and the Nature of Discovery," Kotai Butsuri (Solid State Physics, Journal in Japanese), **27**(2) 69-80.