Extended Abstracts of the 2015 International Conference on Solid State Devices and Materials, Sapporo, 2015, pp2-3

Building a Sustainable Society through Innovative Devices and Materials

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1. Introduction

With the advancement of science and technology, our quality of life has been improved. We have had many benefits through science, technology, and economic growth. However, we are facing with several social issues as a result of unbalanced research and development (R&D) activities. That is, the relationship between economy and environment is out of balance, and finally it has dawned on us that our social common capital [1] is vanishing. We have started to think about our responsibilities to build a sustainable society.

Communication technologies such as portable smart gears have become an important aspect of our daily lives. This technology has enabled communication regardless of location and time. However, information technology (IT) infrastructure has drawbacks of high energy consumption because large-volume data generated by users requires considerable energy for transmission in the core network. IP router as a communication system can be a good example. Figure 1 illustrates the trend of the annual energy consumption of IP routers in a network. It includes the extrapolated lines up to 2030, and shows that the energy consumption rate is increasing gradually year after 2014 [2]. This tendency would continue for a while without any effort for reduction of power consumption because communication traffic volumes are also increasing, which requires more routers. The power consumption problem can be solved by developing low-power semiconductor technology, which can be a key enabler of various innovations. Low-power semiconductor technology has possibilities to lead to innovative green-IT systems that improve energy efficiency in various systems. The IP router is the driver, and energy-efficient networks that use the power saved routers are expanding gradually. Indeed, not only hardware technologies, but also software and service technologies contribute to IT systems.

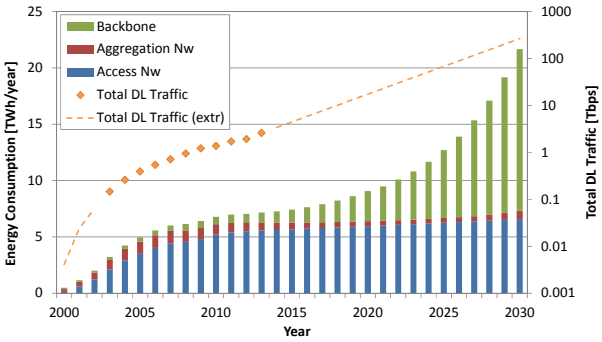

Fig. 1 Annual energy consumption of IP routers and the traffic volume in IT networks. (DL: Download)

2. P-type and N-type innovations

In any case, we need to find out the clue of the solutions through different innovations. Figure 2 illustrates the abstract concept of two types of innovation: P-type and N-type. A P-type innovation is performance-centric; it focuses on high numbers of things or the best efficiency approach for achieving a target with limited resources. Mass production technology with low power consumption is an applicable example of a P-type innovation. It adds an affluent condition to our life, but we can see a throwaway culture connected directory to an environmental burden at the same time. The other type is N-type. The N-type innovation is a nature-oriented approach, which considers environmental viewpoints. Reusable, adaptive, and well-planned life-cycle technologies can be N-type innovations. We must consider these two types of viewpoints when observing the solutions in our R&D efforts, and attempt to maintain a very close relationship with both approaches as they can easily be exclusive conditions. The coverage of the two approaches will be a key for R&D towards a sustainable society.

3. Device and material technologies for IoT

Nowadays, several things can be determined using digital technologies such as network functionalized tools, equipment and virtualization. As is well known, several things are already connected to cyberspace through Internet technologies. The concept of Internet of Things (IoT) allows connecting multiple devices that have important functionalities in our society to each other. IoT pushes for a data-driven society with diversified digital platforms. Figure 3 illustrates IoT and its related devices and material technologies including system applications. The platform of IoT interfaced sensing devices such as portable devices and memory chips suggest that the small intelligent devices create big data for the platform. It can create value for soci-

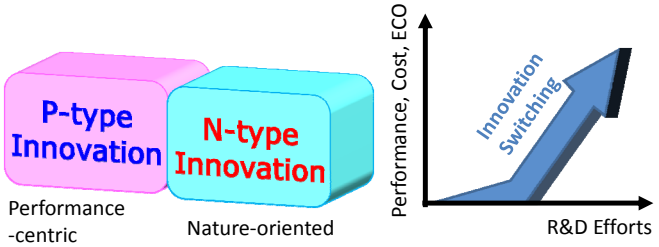

Fig. 2 Conceptual diagram of two types of innovation and towards novelty

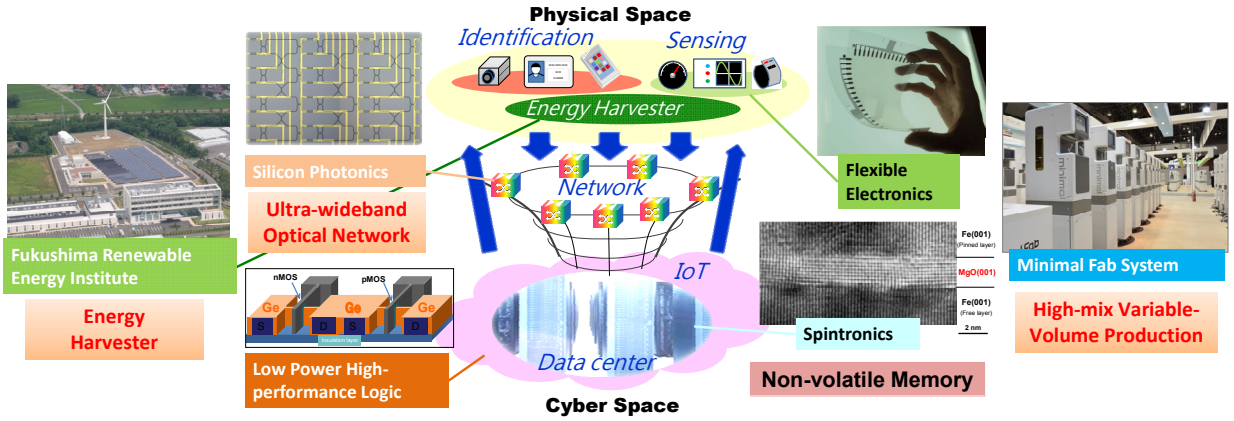

Fig. 3 IoT and its related devices and material technologies including manufacturing system and energy generation (A part of this figure is redrawn from Ref. [3])

ety, including services. On analyzing the device platform in detail, we observe interconnecting technologies at the hardware level. Silicon photonics technologies realize a switching scheme for high-capacity communication links in the optical network with power saving ability. These switching technologies are set between sensing devices and datacenters. Flexible electronics are representative technologies that fit the input side of the platform. Wearable gears and sensors are expected applications of the flexible electronics. In addition, low-power high-performance logic and non-volatile memory are cutting-edge technologies for effective circuit implementations, and similarly normally-off computing is for saving energy. These fundamental technologies would be major functional devices in cyberspace.

AIST is promoting these key devices among research units, and is responding to the increasing need for open innovation. Fig.3 also shows the applications such as energy harvesters and production systems. Fukushima Renewable Energy Institute in Koriyama, Fukushima Prefecture, was established by AIST in April 2014. R&D for renewable energy research is ongoing for developing innovative technologies in collaboration with domestic and international partners. Minimal fabrication system is on the other side in Fig.3. This system realizes high-mix variable-volume production without clean-rooms for effective manufacturing. AIST is promoting the aforementioned R&D projects for developing compatible methods for focusing on P-type and N-type innovations.

4. Equilibrium development for sustainable society

Technological options for a given target application are becoming diverse as new materials, processes, and devices are developed. Social needs are going to further diversify the application fields. Creating innovations under such diverse circumstances requires many trials to integrate the technology and the knowledge from a wide range of disciplines. In this sense, standardization activities help align the direction of the development for reducing the environmental loads; however, the aforementioned innovation types remind us of well-balanced R&D and the direction of the proper mechanism for ensuring sustainability of social

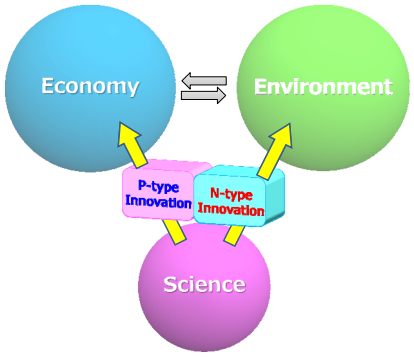

Fig. 4 Two types of innovation for keeping equilibrium between economy and environment

systems. Figure 4 shows the conceptual diagram of the equilibrium condition for the sustainable society. Economy, environment, and science need to be well-separated; however, the interactions between them should be moderate. Otherwise they are rushed into an unbalanced condition, which means a stressful situation for each other. The relativity looks straightforward but the conditions are dynamic and complementary. The convergence of the P-type and N-type innovations works towards maintaining a proper dynamic state in the equilibrium condition. Device technology itself can contribute to a robust relationship between the elements in the equilibrium. The balanced condition makes for an affluent society, and therefore, we need to promote science for supporting economy and environment effectively.

SSDM covers the device and materials research fields with both industry and academia researchers. Thus, I believe that SSDM responds to the positive expectations of our society via PN junction innovation.

References

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