National Project; Tsukuba Innovation Arena and Green Nanoelectronics

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Abstract

The national project "Green Nanoelectronics" is introduced and explained. As a national project, Tsukuba Innovation Arena (TIA) has started which gathers world-wide top-class nanotechnology facilities and researchers in Tsukuba. One of the TIA projects is Green Nanoelectronics Center (GNC) constructed in AIST, where the consumed electric power in LSI is targeted to reduce to 1/10 – 1/100 of the current power. One of the themes in GNC is development of phase-change materials for low-power consumption. This paper explains the whole structure of TIA and GNC PJ's as well as the target of the research on phase-change materials.

Recently the cost to maintain the facilities and infrastructures for producing and R&D on semiconductor devices has been greatly expanding because of necessity of fine controls to fabricate fine-structured devices. Its cost is so vast that one company cannot hold, though electronics is still a leading business area in Japan. For this reason, Tsukuba Innovation Arena (TIA) has been founded with a core of AIST, NIMS and the University of Tsukuba[1)], whose purposes are as follows;

- to create new world-wide businesses through common infrastructures,
- to provide "Under-One-Roof" fields of industries, governments and universities,
- to provide the world-widely competitive infrastructures to both Japan and foreign countries,
- to reinforce the cooperation through world-wide network,
- to cultivate human resources of scientists and engineers.

For these purposes, R&D is propelled by gathering R&D facilities and human resources in Tsukuba area.

TIA has the following six main research themes.

- Power Electronics: SiC-based technologies
- Nano MEMS: value-added and mass-produced MEMS
- Nano Green: environmental technologies using nano-electronics
- Carbon Nanotubes (CNT): mass-production, application and integration of CNT
- Nano-Material Safety: to evaluate risks and develop control methods to ensure nanomaterial safety
- Nanoelectronics: nano-CMOS, Si photonics, carbon electronics, backend devices, new

materials, EUV lithography

Amongst the above-mentioned themes, the author belongs to Nanoelectronics category, whose target is “low-power electronics devices” to reduce the consumed power to 1/10 – 1/100 of current LSI’s.

Two organizations engage in the target described above; “Green Nanoelectronics Center” (GNC)[2] and “Low-power Electronics Association and Project” (LEAP)[3]. The organization structure of GNC and LEAP is shown in Fig. 1.

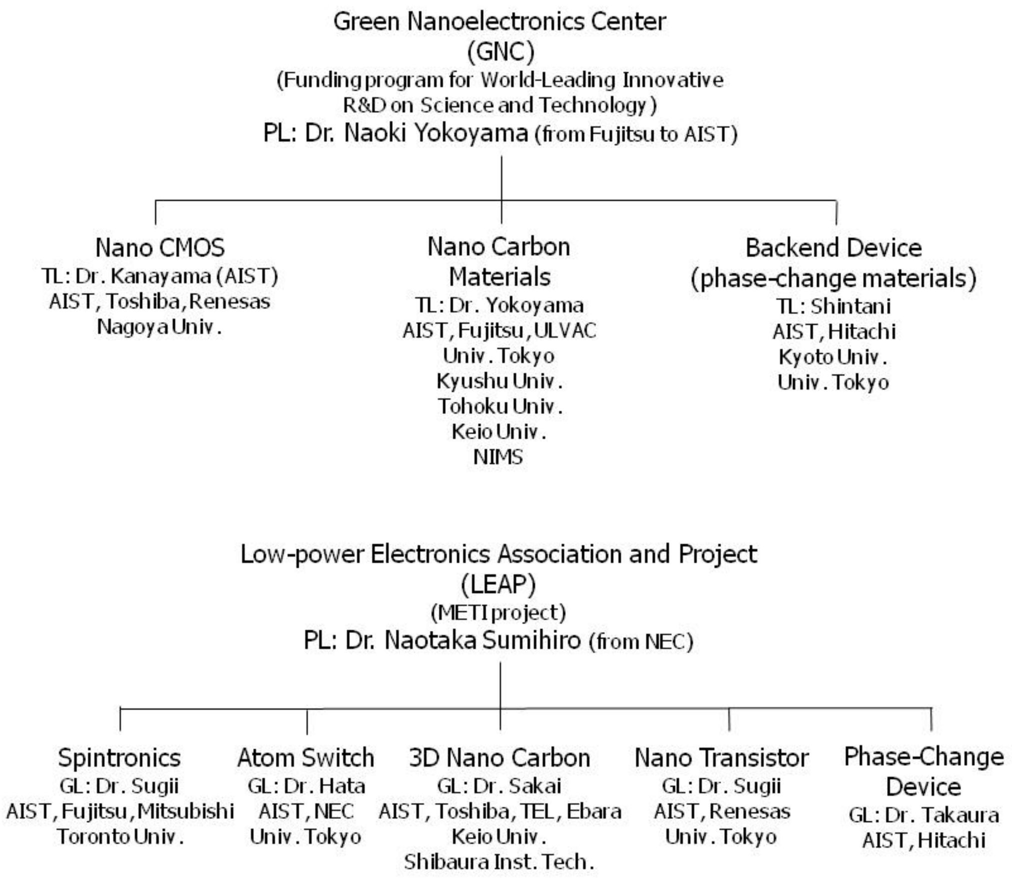

Fig. 1 Organization structure of Green Nanoelectronics Center (GNC) and Low-power Electronics Association and Project (LEAP)

GNC has been established in AIST as one of the projects of “Funding Program for World-Leading Innovative R&D on Science and Technology”, adopted by Cabinet and funded by JSPS. This funding program provides the R&D funds to 30 Japanese leading scientists and engineers whom Cabinet Office selected, in order to create and/or maintain the world-leading R&D in Japan. For electronics, Dr. Naoki Yokoyama, who once was a Fellow in Fujitsu and now belongs to AIST, was selected as the world-leading engineers and a project leader.

LEAP is one of the METI projects, whose target is to give gigantic impact to IT and electronics industries by realizing high-value-added devices (*e.g.*, new functions or user-friendliness) with information non-volatility. Its goal is to realize < 0.4V driving voltage in a logic IC.

Both projects are planned to be propelled for five years.

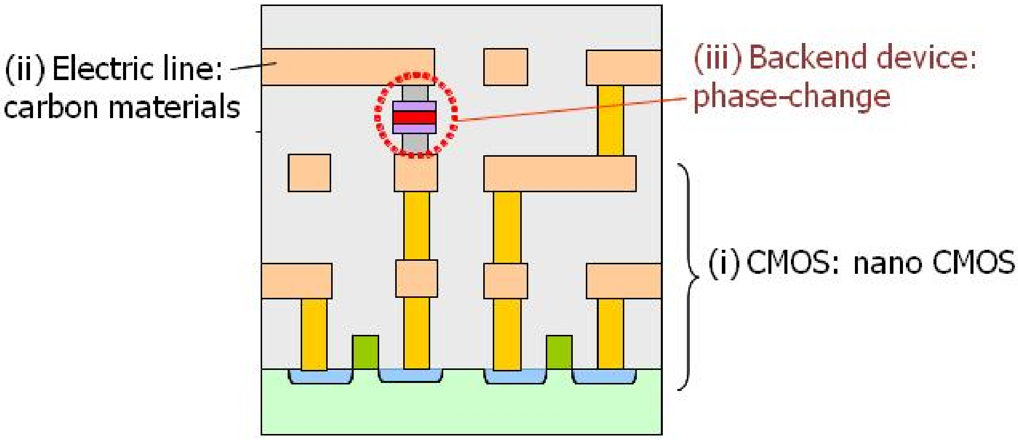

Fig. 2 main elements in LSI

GNC has three main themes to reduce the electric power consumed in all the fundamental elements in LSI (Fig. 2) because the power would never be reduced unless even one of the elements failed to reduce the power. The fundamental elements are CMOS's for electronic control, electric lines and backend devices. For CMOS, GNC focuses on low-voltage-driven nano CMOS technologies including new-material CMOS (Ge, InAs, etc.), new-mechanism CMOS (tunneling effect, avalanche effect, etc.). For electric lines, development and application of carbon nanotubes or graphenes are propelled. For backend devices, reduction of the consumed power by adopting phase-change devices is challenged.

As shown in Fig. 1, R&D on phase-change memories are propelled in both projects collaboratively. GNC engages in phase-change materials, LEAP in phase-change devices (GNC phase-change theme will finish in two years).

GNC phase-change team works on the science and technology for phase-change materials to reduce the electric power consumption, whose center is super-lattice-like (SLL)[4)5)] or "meta-material"[6)] phase-change materials using Ge switching mechanism[7)]. As in ref. 6, the direction of the movement of Ge atoms is controlled in phase-change meta-materials, which reduces entropy (and thus energy) in phase-transition. The goal of GNC phase-change team is 1) to find the phase-change meta-materials different from $GeTe/Sb_2Te_3$ to reduce energy more, 2) to design the cell structure suitable for phase-change meta-materials, 3) to establish the science of phase-change meta-materials, 4) to establish the technology on film deposition of phase-change materials. There are two main purposes of the research on film deposition; to control the atomic arrays to enhance the effect of meta-materials, and to deposit the phase-change materials in small holes for high-density memories. For these purposes, the study on film deposition includes the establishment of Chemical-Vapor Deposition (CVD) technique for phase-change materials, which needs more studies.

The last but not the least, GNC phase-change studies are conducted under collaboration with two universities; Kyoto University for theories of phase-change CVD[8], and the University of Tokyo for electric circuits and systems of phase-change devices to enhance the usability of phase-change devices with new materials. Under these collaborations, we will propel the encompassing studies of phase-change devices; material, process, device, and system.

In conclusions, TIA and its purposes were introduced. Among many R&D themes in TIA, phase-change studies are explained in some details which are propelled in both GNC and LEAP.

1) http://unit.aist.go.jp/tiapo/ci/

2) http://www.yokoyama-gnc.jp/ (in Japanese)

3) http://www.leap.or.jp/ (in Japanese)

4) T. C. Chong, L. P. Shi, X. S. Miao, P. K. Tan, R. Zhao, and A. P. Cai, “Study of the Superlattice-Like Phase Change Optical Recording Disks”, *Jpn. J. Appl. Phys.* **39**, 737-740 (2000).

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6) J. Tominaga, R. Simpson, P. Fons and A. Kolobov, “Phase-Change Meta-material and Device Characteristics”, *Proceedings of E/PCOS 2010*, 54-59 (2010).

7) A. Kolobov, P. Fons, A. Frenkel, A. L. Ankudinov, J. Tominaga and T. Uruga, “Understanding the phase-change mechanism of rewritable optical media”, *Nature Mater.* **3**, 703-708 (2004).

8) K. Ichikawa and A. Tachibana, in this proceeding.