Materials Innovation for Versatile Electron Devices in IoT Era

Akira Toriumi
Department of Materials Engineering, The University of Tokyo
Tokyo 113-8656, Japan
toriumi@material.t.u-tokyo.ac.jp

We have enjoyed simple materials of Si, SiO_2 and Al in CMOS technology for a long time. Meanwhile metal/high-k gate stacks changed Si technology dramatically. Now we need not hesitate to employ new materials for developing new devices and applications, which will come into existence not only in current CMOS technology but also in new fields required for the IoT era. In this talk, several examples of materials-related functions for electron devices we are now studying are discussed.

(i) Further Si device extension

Let's start talking about SiO_2-IL scavenging in conventional HfO_2 gate stacks. The EOT reduction is not our business, but the scavenging mechanism of SiO_2-IL underneath HfO_2 is our fun. It is now understandable that the "vacancy" is the main player in "Si chemical potential gradient". For further extending Si CMOS, deeper understanding of such subtle phenomena will be needed for precise performance control. The scavenging is one of those examples.

(ii) Non-Si channel materials

High mobility channel has always been desired for high speed and/or low power logic applications. It is, however, not so easy to implement new materials in the current Si-LSIs. We have focused on Ge MOSFETs, and recently demonstrated very high carrier mobility in Ge FETs. It makes us anticipate a real cooperation of electronics with photonics on Ge.

(iii) Two-dimensional materials

Research on graphene and TMD (Transition Metal Dichalcogenides) is now in fashion. Two-dimensional (2D) materials are quite attractive not only for physicists but also for materials and electronics engineers. In the electron device society, 2D materials are favorably regarded as the short channel savior from the Poisson solution viewpoint, or transparent electrodes. Moreover, van der Waals stacked layers will potentially provide us with new functional applications, though it may take a while to accomplish final products.

(iv) Functional dielectric films

FE (ferroelectricity) in HfO_2 and MIT (metal-insulator-transition) in VO_2 are very attractive in terms of new electronic functionality of oxides. 20 years ago, ferroelectric devices were in fashion for high-speed non-volatile memory. Now we can use "Hf" instead of Pb, Sr or Bi for ferroelectric film. MIT in VO_2 occurs around the room temperature, and may be used for sensors at room temperature. We are more interested in FE-MIT (field-effect metal-insulator transition) for possible electronic applications.

The materials discussed above are limited examples. Some people, particularly big authorities in related fields, are inclined to confidently judge a new material potentiality from "intrinsic" properties on the basis of tentative results they can understand. New materials, however, not always but sometimes bring innovative functions. This is just what we really need in the coming IoT era beyond the simple size scaling. Never give up for a bright future of electron devices.

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