Potential Device Applications of Neo-Silicon and its Material Characterization

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Importance of silicon-based nano-materials greatly increases for advanced electronics devices. The nano-silicon materials is a heterogeneous material in the nano-scale range in which surface/interface chemical modification, local strain, carrier trapping, scattering, quantum confinement, tunneling and ballistic effects would dramatically appear even at room temperature. Controlled nano-silicon materials, in which non-bulk characters are enhanced, should be called as neo-silicon.

In this presentation, two potential applications using neo-silicon-based materials are discussed. Needs of more intensive research are stressed to control and to characterize the structure and electronics properties of neo-silicon materials.

1. Ultra-low-power High-speed Nonvolatile Memory

In order to realize an ultra-low-power high-speed nonvolatile memory, development of a transistor having the large on-off current ratio is the most promising approach. However, it is difficult to realize by using bulk crystalline silicon. Neo-silicon is a candidate to realize this device. The single electron memory by using a nano-silicon was operated at room temperature for the first time by Yano et al. in 1993 [1]. Osabe et. al. reported the few electron memory by using a nano-silicon thin film so-called SESOTr (Single-Electron Shut-Off Transistor) [2]. They are the approach from flush memory side. The approach along DRAM concept was announced in 1997 by Nakazato et al. They proposed and fabricated new type nano-silicon-MOSFET so called PLEDTr (Phase-state Low Electron-number Drive Transistor) [3, 4]. Possible current leakage mechanisms such as due to hopping conduction in the nano-silicon and barrier materials, however, must be clarified.

2. Ballistic Cold Electron Emitter - - Vacuumless EL

Cold electron emission from porous Si was reported by koshida et. al. [5, 6]. Efficient, stable and low noise electron-emitting natures are revealed. They are discussing these natures as ballistic transport through the stacked nano-Si dots in porous Si layer operated under the high electric field. The ballistic electrons can excite the phosphor without acceleration in the vacuum. The vacuumless EL is one of the most promising applications of neo-silicon.

Physical mechanism of the high emissivity of these emitters is not revealed. Electric field enhancement by needle shape in the range of nm sizes, work function lowering, chemical modification by hydrogen/chemical bonding structure change are seems to play an important role in the electron emission processes.

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