Intergrain coupling effects on Coulomb oscillations in dual-gated nanocrystalline silicon point-contact transistors

M. Khalafalla[1,3], H. Mizuta*[2,3], Z. A.K. Durrani[1,3], H. Ahmed[1,3] and S. Oda[2,3]

[1] Microelectronics Research Centre, University of Cambridge, Cambridge, UK
[2] Department of Physical Electronics, Tokyo Institute of Technology, Tokyo, Japan
[3] CREST, JST (Japan Science and Technology)
*Phone: 0081 3 5734 3591, Fax: 0081 3 5734 3591, E-mail: mizuta@pe.titech.ac.jp

We investigated the coupling effects between few nanocrystalline silicon grains, 20 – 25 nm size, embedded in 30 nm × 30 nm × 40 nm point-contact transistors (the inset to the Fig.1) formed on a 40 nm thick nanocrystalline Si film. Each device has two in-plane side gates, which are used to control the electrostatic potential on the grains. Several devices were fabricated with oxidation at various different temperatures (650°C – 900°C) and high temperature (1000°C) annealing processes, which are known to modify the grain boundary tunnel barriers [1]. At 4.2 K, for most of the thermally processed devices, we observed the switching of the Coulomb oscillation current peak lines as a function of the two side gate voltages [2]. The results were successfully reproduced by using the Monte Carlo single-electron circuit simulation with a model of two parallel, capacitively coupled Si grains.

The characteristics observed for the devices oxidised at 750°C for 30 minutes (Fig.1) exhibited delocalisation of the electron wavefunctions over the coupled grains. In the strong coupling region (a dotted circle), we observed clearly that the characteristics are decomposed into four Lorentzian current peaks – two main peaks with two small peaks. This is attributed to the tunnel coupling effect across two adjacent Si grains, resulting in bonding- and anti-bonding-like resonance peaks.

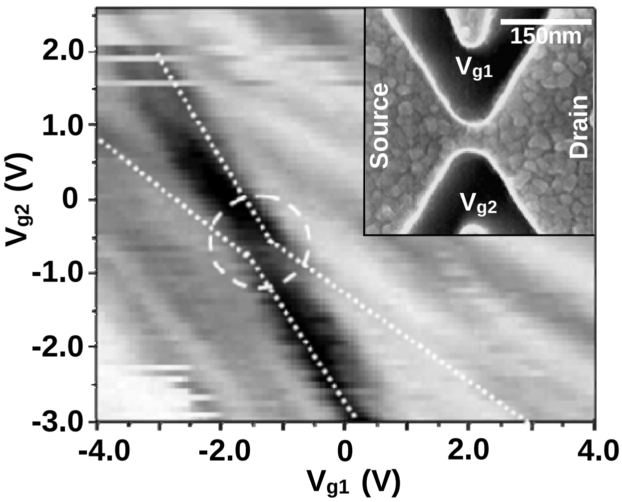

Fig. 1 SEM micrograph of a nano-Si point contact transistor (inset) and gray scale image of current as a function of two side gate bias voltages Vg1 and Vg2.

[1] H. Mizuta, Y. Furuta, T. Kamiya, Y. T. Tan, Z. A. K. Durrani, K. Nakazato and H. Ahmed, “Single-electron charging phenomena in nano/polycrystalline silicon point-contact transistors”, *Polycrystalline Semiconductors VII – Bulk Materials, Thin Films, and Devices,* T. Sameshima, T. Fuyuki, H.P. Strunk, J.H. Werner eds., in Series ‘Solid State Phenomena’, Scitech Publ., Uettikon am See, Switzerland, 419 – 429 2003.

[2] M. Khalafalla, H. Mizuta and Z.A.K. Durrani, IEEE Trans. Nanotechnol. **2**, No.4, Dec. 2003.