Analytical HRTEM Study of Self-Assembled Metal-Silicide Nanoislands

Magnus Garbrecht[1], Shirley Manor[2], Ilan Goldfarb[2], and Wayne D. Kaplan[1]

1. Department of Materials Engineering, Technion – Israel Institute of Technology, 32000 Haifa, Israel
2. School of Mechanical Engineering, Tel Aviv University, 69978 Ramat Aviv, Israel

mag@technion.ac.il
Keywords: analytical HRTEM, metal-silicides, nanocrystals, heteroepitaxy, self-organization

The research on artificially grown nanostructures (as e.g. quantum wires, quantum dots) is very important for both fundamental research and also for practical reasons because their physical properties make them applicable for electronic devices of the latest nano-technology. The size, shape and interactions of the nanocrystals with each other are important features to gain understanding of the complex relations between the surfaces of deposited metals and the substrates. A long term goal of our investigations is to develop a generic model that is capable of predicting and controlling the self-organizational behavior of the nanocrystals.

Since it was discovered [1-3], self-assembly and self-organization of three-dimensional islands with nanometer size (nanocrystals/nanoislands) on surfaces by heteroepitaxy has been the focus of detailed research. Quantum wires and quantum dots are used in e.g. lasers, LEDs, single-electron transistors and logic gates due to their atom-like electronic structure and properties [4]. Since metal and metal-silicide nanostructures show self-assembling predominantly in a compact or elongated form [5,6] they are promising components for single electron devices.

The samples investigated in this work consist of of several different metal-silicides grown on Si surfaces by solid-phase epitaxy and vapor-phase epitaxy. Figure 1 shows SEM micrographs of $CoSi_2$ islands in plan-view, grown with a high coverage (> 1 ML) of Co on a stepped vicinal Si(111) surface fabricated by solid-phase epitaxy in the group of Ilan Goldfarb [7].

The dark lines visible in the images are steps on the silicon surface. The islands have a flat two-dimensional type shape and cover most parts of the terraces, as opposed to lower Co coverage where the islands predominantly occupy step bunches [7].

Cross-section HRTEM samples were prepared by site-specific dual-beam focused ion beam (FIB) followed by post FIB low energy ion polishing and were investigated in a monochromated and aberration-corrected FEI Titan 80-300 kV S/TEM microscope at the Technion.

Figure 2 (a) shows a cross-section HRTEM micrograph of one of the $CoSi_2$ islands. Before TEM specimen preparation in the FIB, the surface was covered with carbon and platinum to protect the sample from gallium ion damage during the preparation process. The islands are shallow (~5 nm) as opposed to the dimensions parallel to the substrate, which varies from 20 to more than 100 nm. An energy filtered transmission electron microscope (EFTEM) image (b) acquired using the Co L-edge confirms the shape and size of the islands while at the same time (in line with EDS and EELS analysis) gives proof of the chemical composition of the islands.

DOI: 10.3217/978-3-85125-062-6-463 ,

1. D. J. Eaglesham and M. Cerullo, Phys. Rev. Lett. 64, 1943 (1990).
2. Y.-W. Mo, D. E. Savage, B. S. Swartzentruber, M. G. Lagally, Phys. Rev. Lett. 65, 1020 (1990).
3. S. Guha, A. Madhukar, K. C. Rajkumar, Appl. Phys. Lett. 57, 2110 (1990).
4. V. A. Schukin, N. N. Ledentsov, D. Bimberg, Epitaxy of Nanostructures (Springer-Verlag, 2004).
5. I. Goldfarb and G. A. D. Briggs, Phys. Rev. B 60, 4800 (1999).
6. I. Goldfarb, G. Cohen-Taguri, S. Grossman, M. Levinshtein, Phys. Rev. B 72, 075430 (2005).
7. I. Goldfarb, Nanotechnology 18, 335304, (2007).

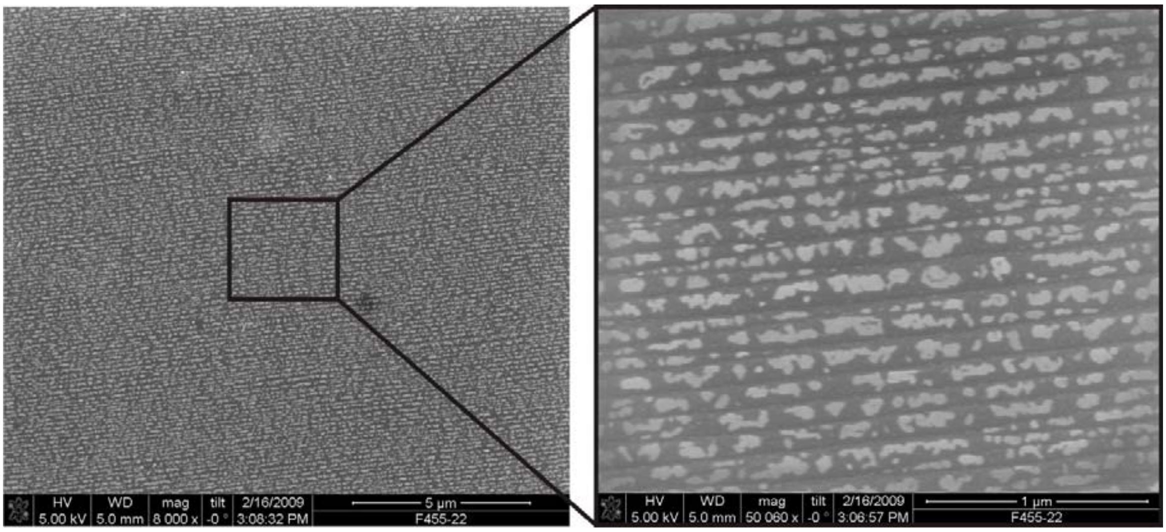

Figure 1. Secondary electron SEM micrographs of the flat two-dimensional $CoSi_2$ islands in plan-view covering predominantly the terraces. The dark lines are steps on the vicinal Si(111) surface.

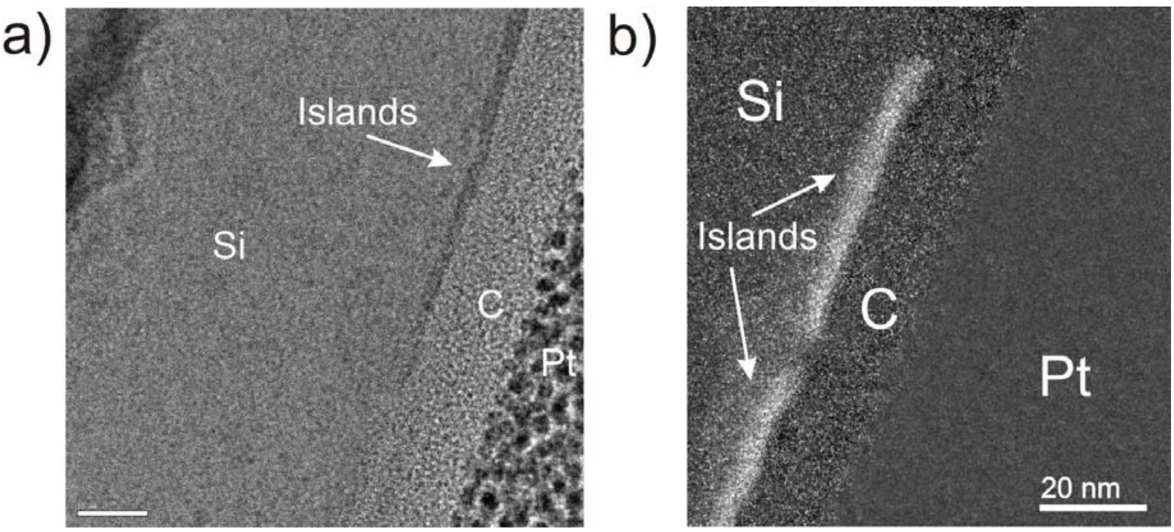

Figure 2. (a) Cross-section HRTEM image showing a flat island with an elongated shape. (b) EFTEM image acquired using the Co L-edge.

DOI: 10.3217/978-3-85125-062-6-463 , © Verlag der TU Graz 2009