1D3.3 : Fabrication of metallic nano-islands on H-passivated Ge(001)surface

Unit 1: Surface preparation for atomic scale contact and nano-packaging	WP1.3: Metallic nano-pad fabrication
Lead participant: Krakow (P10)	Other participants: -
Person Months (Krakow): foreseen17/real 17	Person Months (other participant): -
Start date: M 10	
Planned end date: M 24	Real end date: M 36

Description of the results:

Our previous experience with deposition and growth of gold nanostructures on the reconstructed Ge(001) (see previous reports on WP 1.3 activities) demonstrated that in the temperature range required for the AtMol devices, it is essentially impossible to obtain clean metallic Au islands, without part of the Au material intermixed with the surrounding Ge substrate [see ref. 1]. This finding came a surprise, since several previous report were claiming that gold was able to form well defined Au nanowires on a single Ge(001) substrate [2-3]. It was also found that any post-deposition thermal treatment resulted in substantial long range disordering of the island surrounding surface, making proper H passivation of the inter-island surface practically impossible. The next candidate with some supporting reference data [4] is Ag, and under the task 1T3.2 of the project we performed a systematic study of atomic Ag beam deposition and growth on clean, reconstructed face of Ge(001) at various substrate temperatures and post deposition annealing.

As a result of those studies we have established that for example, well defined, submicrometer size metallic silver islands were formed by evaporation of silver (equivalent of 4 ML or more) at elevated temperature (around 675K) of the (2x1) reconstructed Ge(001) surface. At those conditions the growth of silver follows a Volmer-Weber mechanism and the Ag islands could be well characterised under both the high resolution electron microscope of our 4-probe system (**Erreur ! Source du renvoi introuvable.** and 2), as well as with the LT-STM microscope (**Erreur ! Source du renvoi introuvable.**). Please, note the faceted side walls of the island which reflects an equilibrium shape of Ag nanostructures.

Lowering the amount of deposited Ag and/or the substrate temperature during growth resulted in reduction of the size and the height of the respective islands. For example, 0,25 ML Ag deposition at room temperature (see Fig. 3) yields 2 types of structures. 2D short nanowires have a hight of 0,1 nm well aligned along the reconstruction rows of Ge(001). More abundant 3D rectangular islands have size of a few nanometers and a height of 0,7 nm. From Fig. 3 it is clear that Ag island do not modify the contrast of the surrounding substrate surface (no change of the electronic band structure), at least for the 2 bias voltages: -2V and +1V.

For extending the results into a hydrogen passivated germanium, 2 parallel strategies were applied: - the first involved Ag deposition on previously H passivated Ge(001), - the second applied Ag deposition on clean, reconstructed Ge(001) followed by H passivation. In the first case (see Fig.4), deposited Ag atoms tend to nucleate at the surface dangling bonds. A comparison of the high resolution images of the surface prior and after deposition of 0.05 ML Ag (Fig.5), indicates a striking difference in the dangling bond appearance after Ag nucleation. Further increase of the amount of deposited Ag results in high density of relatively small rectangular islands formed on H passivated Ge(001) substrate as seen in Fig. 6. Therefore, for fabricating low density of relatively large Ag structures on H:Ge(001) only the second strategy is effective. In our report on 4D1.1 we demonstrate that Ag islands fabricated with this method on hydrogenated germanium have sufficient size and distribution of interspacing for surface conductance measurements in a 4-probe geometry.

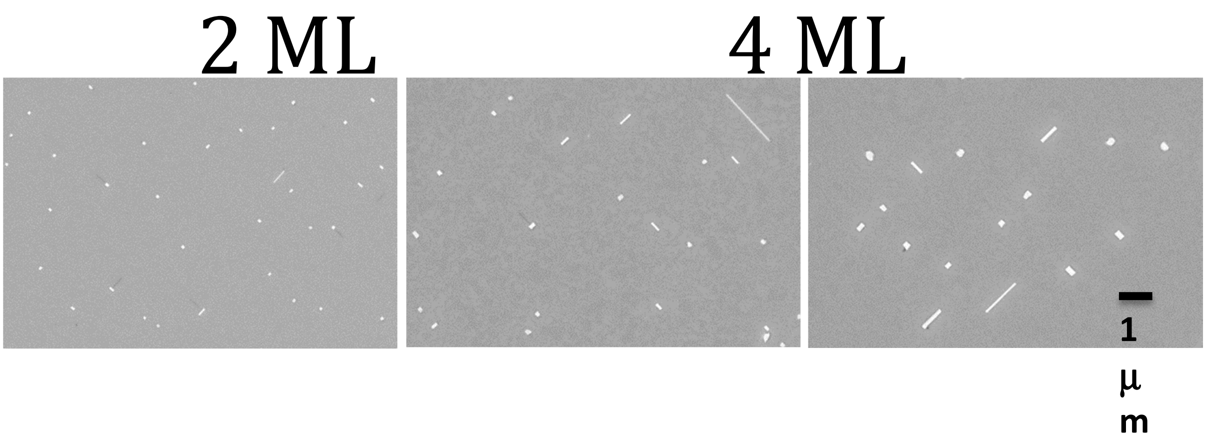

Fig. 1. *High resolution SEM images of Ag rectangular islands and nanowires formed by 2-6 ML deposition of atomic Ag at (2x1) reconstructed Ge(001) kept at 675 K.*

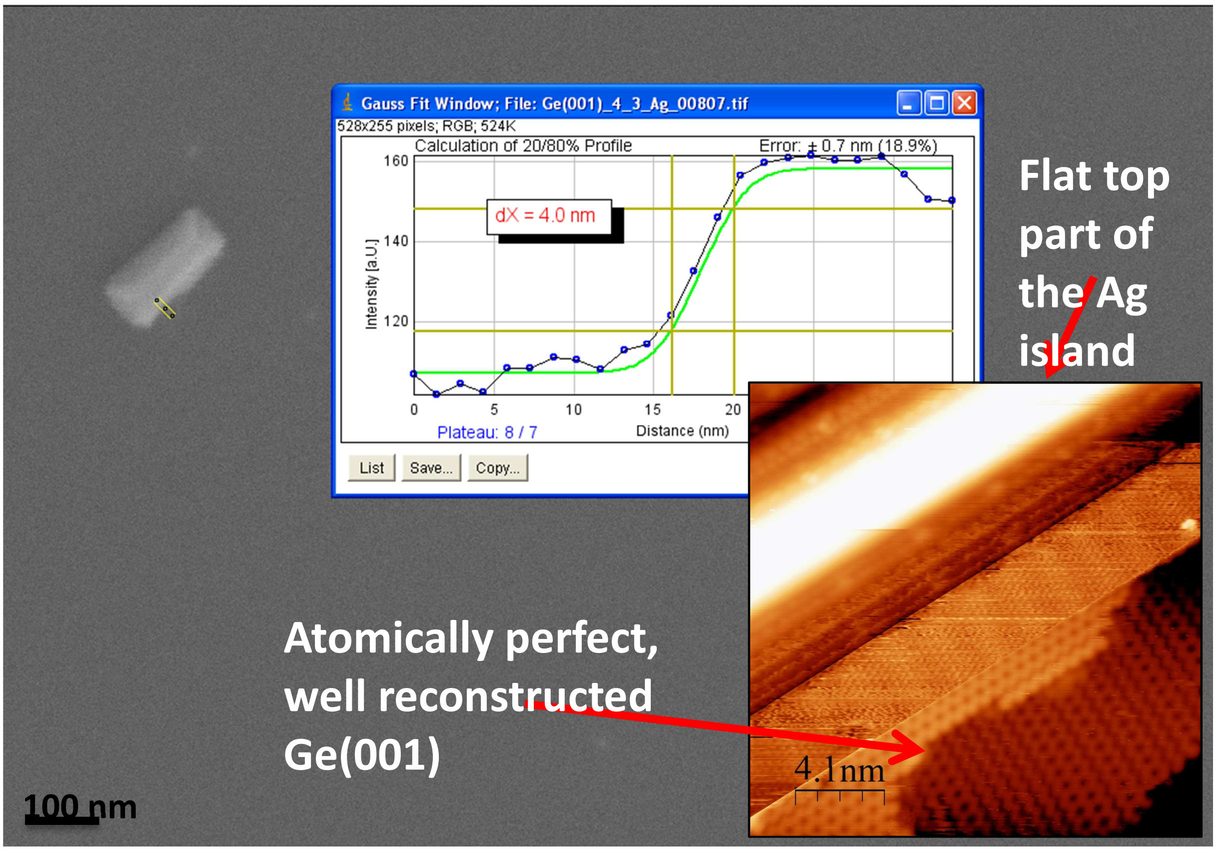

Fig. 2. *Topographical characterisation of the Ag island (left upper part of the figure) grown on Ge(001) with the SEM microscope. The cross-cut through the side wall of the island is shown in the central part of the of the figure. The inset in the right bottom part of the figure shows LHe STM (imaging conditions: -2V, 20pA) images of the island and the neighbour substrate area. The contrast scale if the various sectors of the image was adjusted to show atomic structure details of the island.*

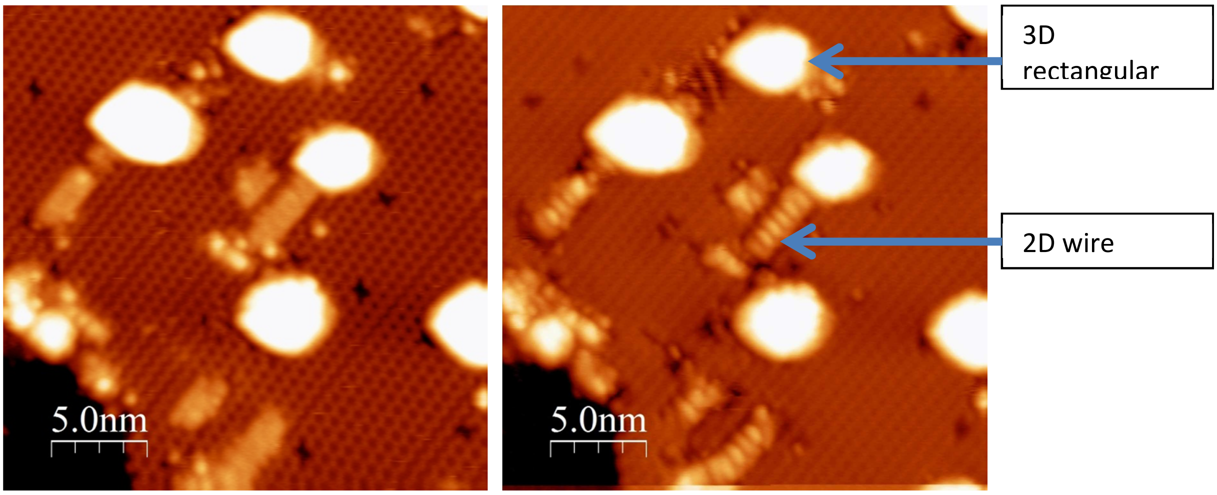

Fig. 3. *Ag nanoislands obtained by deposition of 0,25 ML of the material on Ge(001) at room temperature. LT STM imaging parameters are:-2V, 5pA (left panel) and +1V,5pA (right panel).*

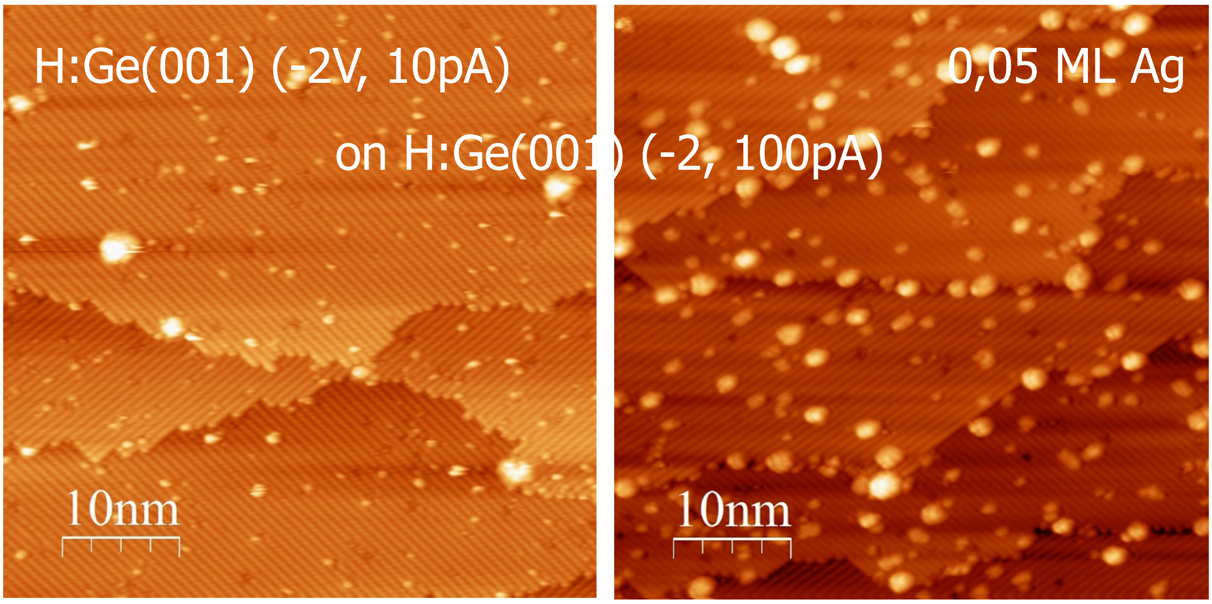

Fig. 4. LT STM image of *H:Ge(001) surface before (left image, -2V, 10pA) and after evaporation of 0,05 ML of silver (right image, -2V, 100pA).*

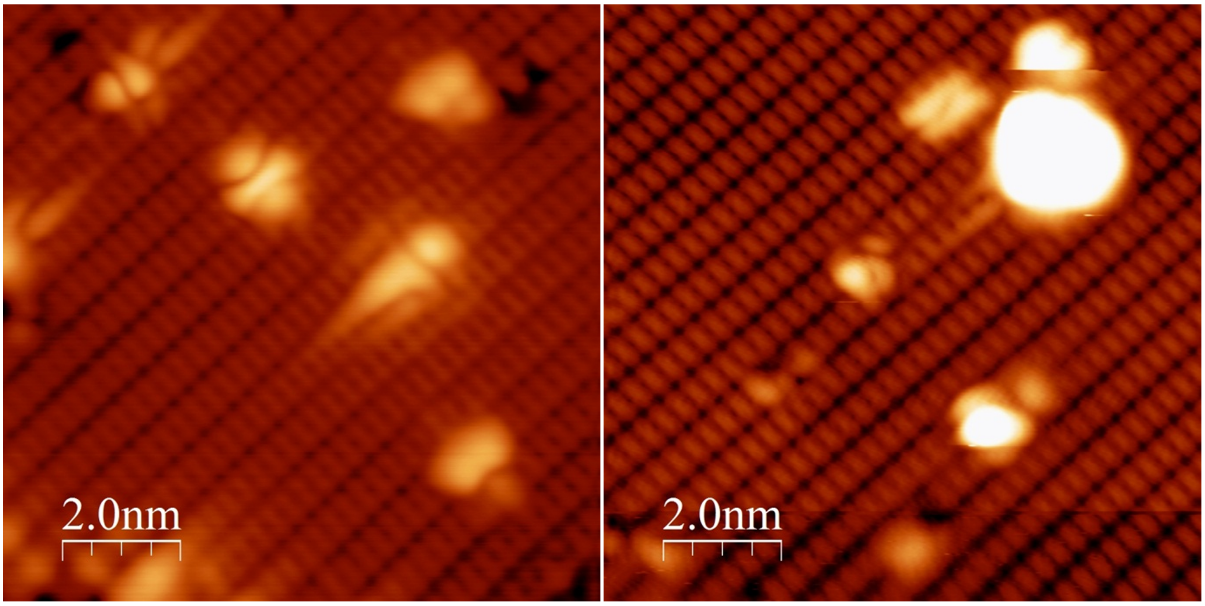

Fig. 5. *H:Ge(001) surface before (left image, +1, 10pA) and after evaporation of 0,05 ML of Ag (right image, +1, 5pA).*

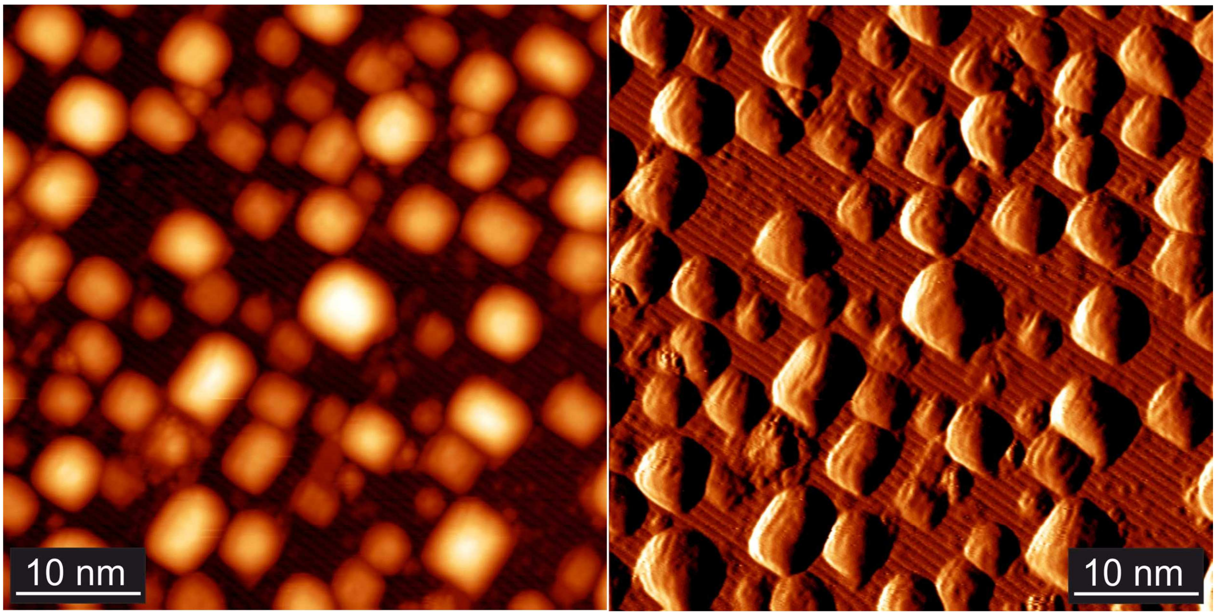

Fig. 6. *Topographic image (left) and current image (right) of silver islands on H:Ge(001) surface after evaporation of 2ML of silver (+2V, 5pA).*

Ref. Publications:

1. M. Wojtaszek, M. Kolmer, S. Godlewski, J. Budzioch, B. Such, F. Krok, M. Szymonski, "Multi-probe characterization of 1D and 2D nanostructures assembled on Ge(001) surface by gold atom deposition and annealing" in "Advances in Atom and Single Molecule Machines", Springer Series on Advances in Atom and Single Molecule Machine, Christian Joachim (2012) ISBN 978-3-642-28171-6.

2. Schaefer, J., Blumenstein, C., Meyer, S., Wisniewski, M., Claessen, R.: New Model System for a One-Dimensional Electron Liquid: Self-Organized Atomic Gold Chains on Ge(001). Phys. Rev. Lett. **101**, 236802 (2008).

3. Mocking, T. F., Kumar, A., Poelsema, B., Zandvliet, H. J. W.: Molecular Bridges.J. Phys. Chem. C **115**, 2268–2272 (2011)

4. L.H. Chan, E.I. Altman, Phys. Rev. B 66, 155339 (2002)