Indium deposited nanosystems formation on 2D layered chalcogenide crystals' surfaces

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Introduction

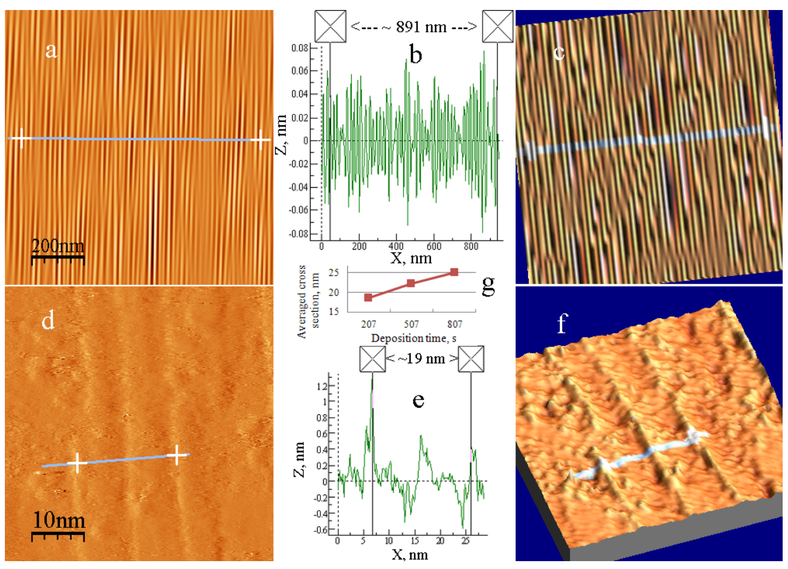
2D layered chalcogenide semiconductors, such as, InSe, In_4Se_3, InTe, Sb_2Te_3 are among newly emerging materials suitable for functional nanoscale devices applications [1]. It looks like that surface of 2D layered crystals are one among most perspective templates for self-assembling of metal nanostructures due to the solid state dewetting (SSD) method [2,3]. Because of intrinsic nature of van der Waals interlayer bonding, layered chalcogenide crystals' surfaces possess relatively good ambient stability, might be just easily obtained by cleavage even in UHV, and, thus, applied as template for fabrication of metal-semiconductor hetero nanosystems.

Experimental

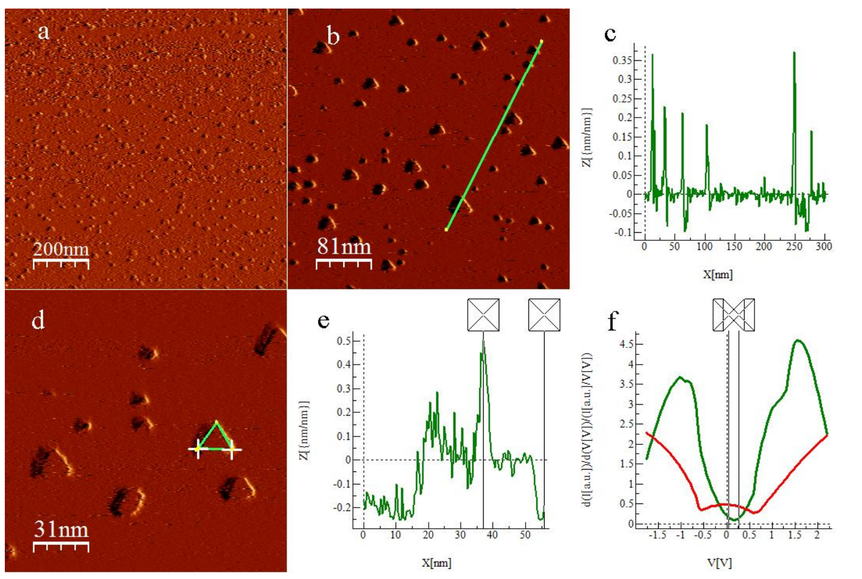
The initial crystals' surfaces before deposition, so-called, templates were characterised by X-ray photoelectron spectroscopy (XPS) and low energy electron diffraction (LEED) and the bulk of the crystal by X-ray diffraction (XRD). The templates have got excellent surface structural quality in macroscale according to LEED and subsequent phase-elemental composition as determined by XPS. The scanning tunneling microscopy/spectroscopy (STM/STS) data were obtained at RT with an Omicron NanoTechnology STM/AFM System in UHV better than 10^{-10} Torr. The constant current mode acquisition was used for STM with 400x400 data points resolution. STS was acquired with 80x80 data points resolution. Thermal evaporator EFM-3 was applied for indium deposition *in situ*. Indium ion current inside the effusion cell was maintained to be constant during the In deposition. The deposition rate was kept at approximately 0.01 ML/min.

Experimental results

Self-assembled indium deposition induced nanostuctures formation on the UHV cleaved surface of InSe, In_4Se_3, InTe, Sb_2Te_3 layered semiconductor crystals has been studied by STM/STS. The studies of corresponding crystal substrate-indium sub- and monolayer nanosystems' formation were conducted as in "visual" STM mode as in current imaging tunneling spectroscopy (CITS) STS mode. Basically, there are well known the different shapes of metal and semiconductor *I-V* curves that depend on value of tunnelling current, especially, within biases ranges corresponding to energy gaps of studied layered crystals. We analyzed the arrays of studied surface areas usually with 50x50 nm^2 dimensions to obtain reliable conclusions about metal - semiconductor hetero nano systems formation. The studies also included statistical analysis of STM data from large areas by standard roughness analysis tools from the WSxM software taking into account the distribution of pixels' height of the image depending on the degree of In deposition, as well as detailed analysis of high-resolution STM images. In consequence of our studies it was found that obtained indium nanostructures have got 0D or 1D dimensionality consistent with the nano relief of the initial crystals' patterns.



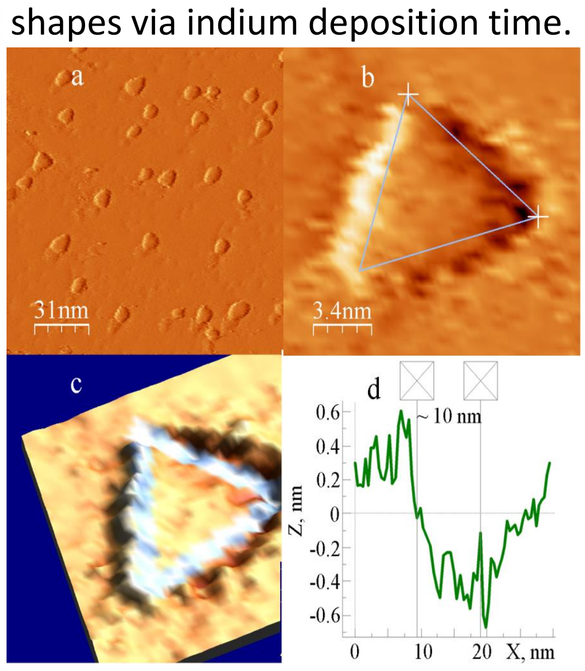
STM study of In_4Se_3 (100) crystal surface: a) 2D FFT image (1x1 μm² area, +1.6 V bias, 155 pA) after 207 s In deposition with subsequent height profile (b) and its 3D representation (c); d) high resolution (52x52 nm^2, +1.6 V bias, 155 pA) image obtained under the same experimental conditions with subsequent height profile (e) and its 3D representation (f); g) averaged cross section size of linear In shapes via indium deposition time.



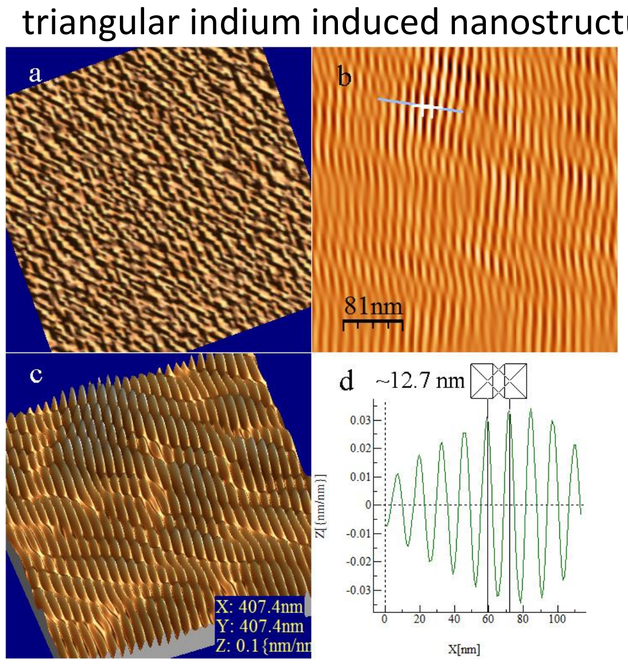
STM/STS study of Sb_2Te_3 (0001) substrate after indium deposition and subsequent annealing at 170°C:

a) STM image 1x1 μm² (tunneling current 124 pA, bias +1.0V) with indium triangular shaped nanostructures;

b) STM image 402.5 x402.5 nm^2 (tunneling current 124 pA, bias +1.0 V) with subsequent profile on (c) indicating height of induced nanostructures; d) STM image 155x155 nm^2 (tunneling current 124 pA, bias +1.0 V) with profile (e) indicating size of triangular nanostructures ~ 17-18 nm; f) STS data show initial surface band gap ~0.2 eV (green curve) and localized states within band gap after indium deposition (red curve).



STM study of In/(0001)InSe surface nanosystem after 95 s In deposition subsequently annealed (200 °C): a) 2D image 160x160 nm^2, +1.5 V bias, 103 pA tunneling current; b) 2D 16x16.7 nm^2 image of zoomed triangular shape nanostructure and its 3D image (c); d) subsequent topographical profile deriving size of triangular indium induced nanostructure.



STM study of In/(001)InTe nanosystem surface after 950s In deposition subsequently annealed (200 °C): a) 3D 407x407 nm^2 image, +1.6 V bias, 81 pA tunneling current; b) 2D FFT filtered image; c) 3D visualization of (b); d) profile with derived periodicity in the array of nanostructures.

Conclusions

Both, STM and STS data give evidence that just deposited indium nanostuctures' has island like, localized nature with next template directed formation of respectively shaped 0D or 1D ones ordered into arrays due to SSD application.

References

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