Studies of indium nanostructures growth models on A^3B^6 layered templates

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Introduction

The A^3B^6 layered crystals structure [1] and morphology of indium nanostructures on A^3B^6 layered templates has been extensively studied in the last years [2,3]. However, despite the generally observed results in the process of forming metal nanostructures with surface of layered crystal as substrate, it is important to consider the detailed mechanisms of the growth of these nanostructures. The properties of a growing surface layer are closely related to its quantitative parameters, such as roughness, skewness and kurtosis. This makes it possible to determine the preferable models of growth while formation of nanostructures and in turn models of growth are very powerful tools that can help to predict and control properties of new hetero nano systems.

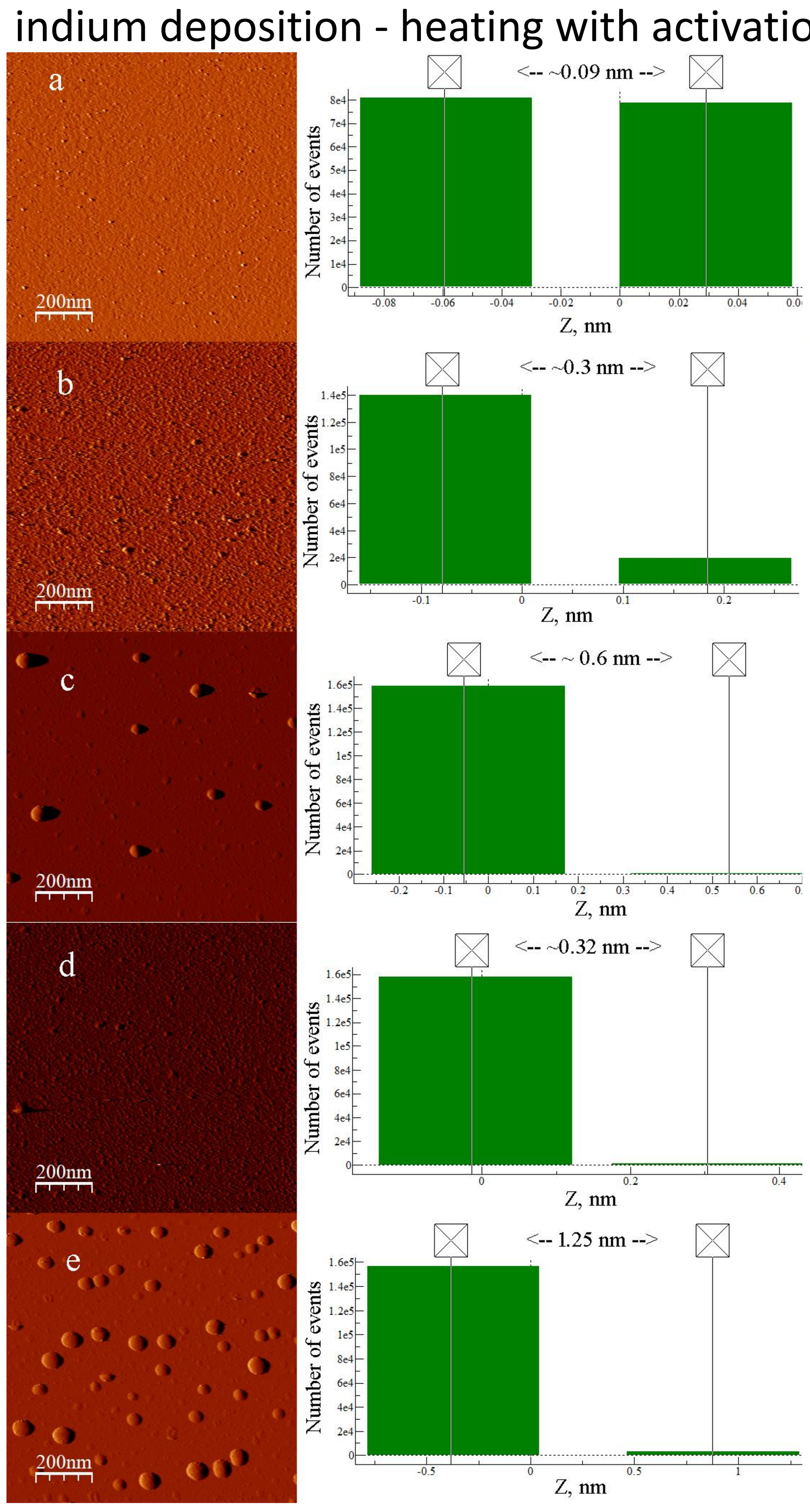
Experimental

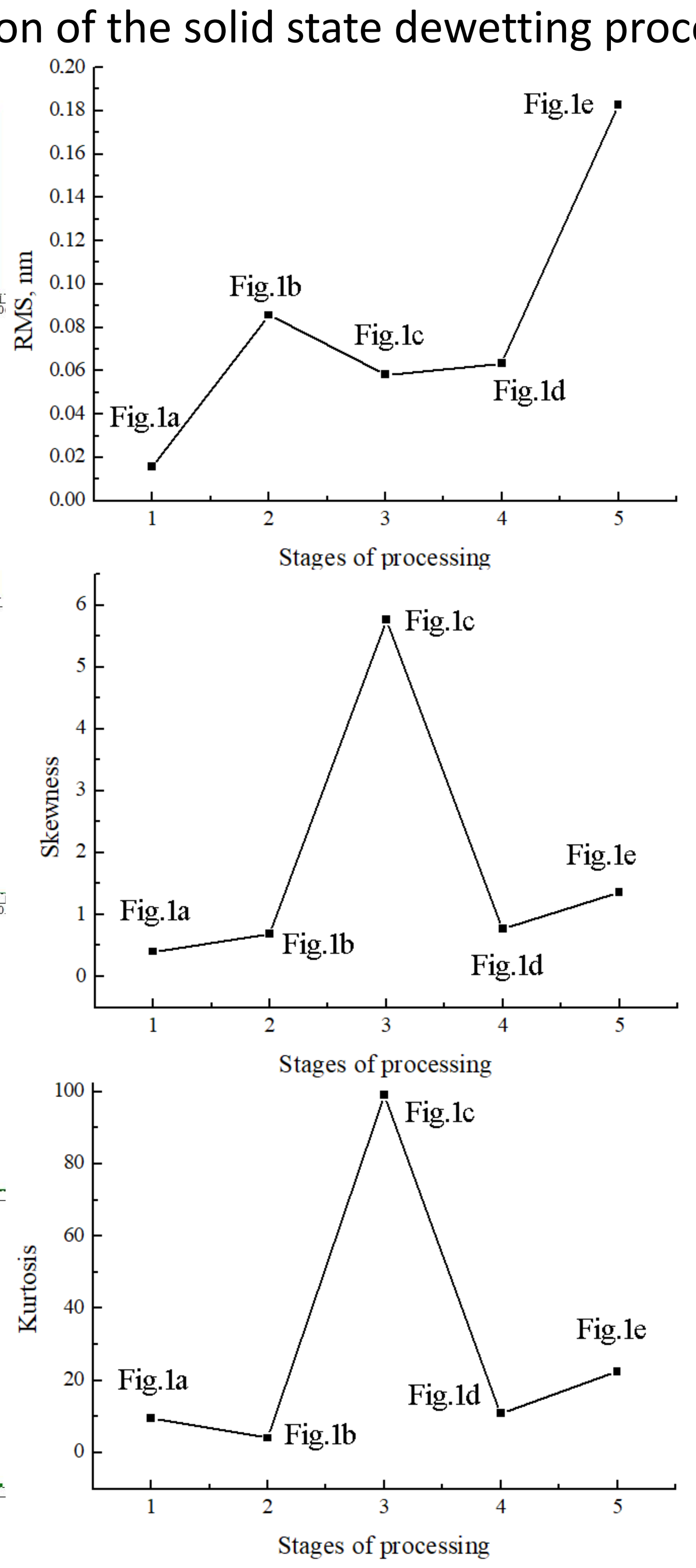
The growth kinetics of In deposited nanostructures on surfaces of 2D A^3B^6 layered semiconductor crystals was studied by Omicron NanoTechnology STM/AFM System with acquiring of surface roughness parameters from a large scale 1x1 μm^2 images. In fact, the surfaces of the chalcogenide layered semiconductors, such as, In_4Se_3 InSe, InTe, Sb_2Te_3 were used as templates. The scanning tunneling microscopy (STM) 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. 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.

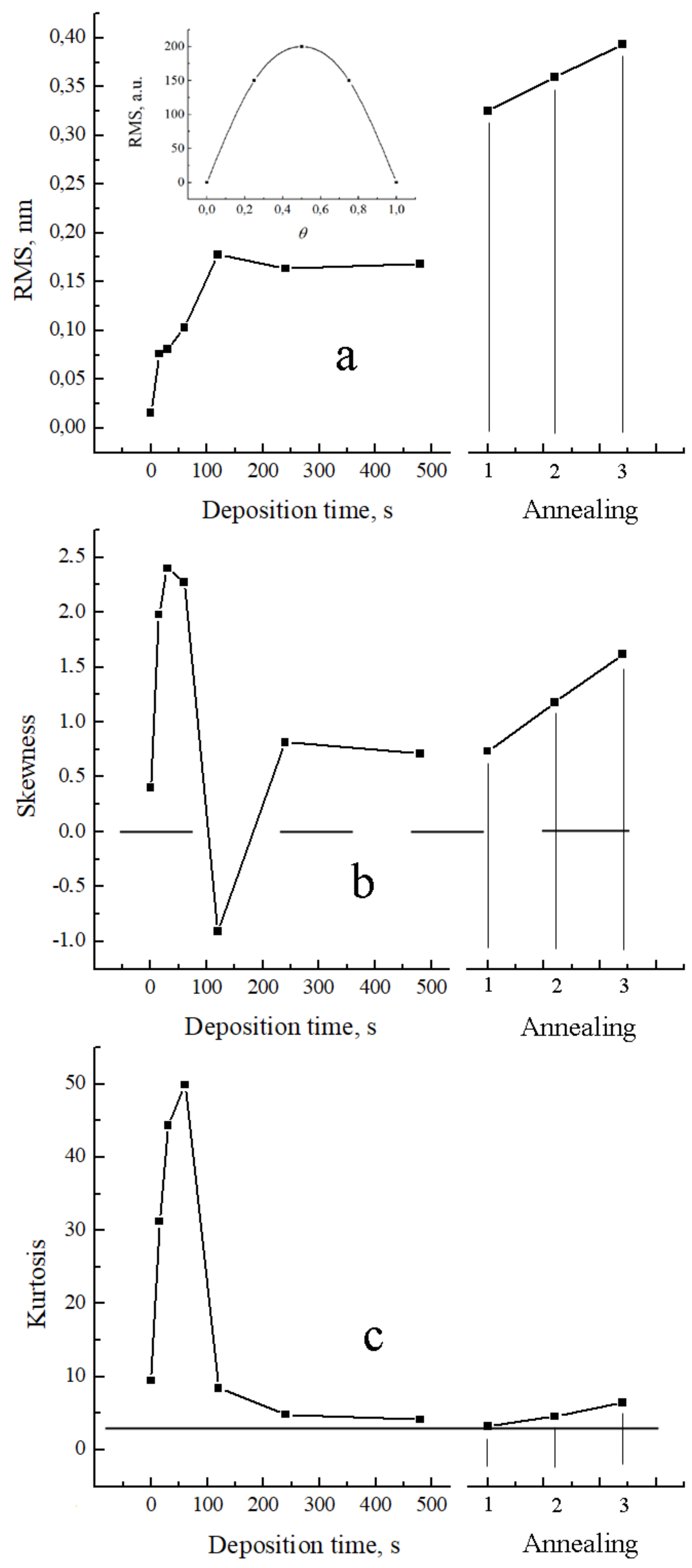
Experimental results

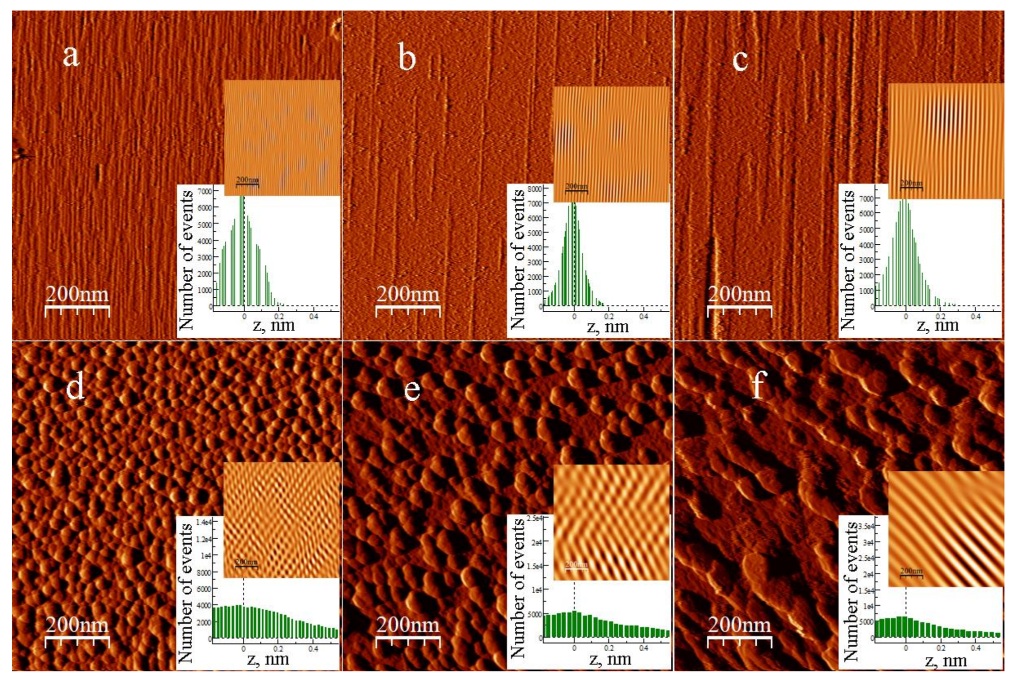
The present work concerns an STM study of the indium deposition on (100) cleavage surface of In_4Se_3 layered semiconductor crystals chosen as a model case, since a similar behavior is also characteristic of the rest of the nano systems indium deposit - surface of InSe, InTe, Sb_2Te_3, respectively.

We have shown the possibility of highly-oriented 1D indium nanostructures' growth with the Volmer-Weber growth mode on In_4Se_3 (100) surface applied as template. The optimal conditions to obtain the most oriented nano wire like nanostructures is thermal-induced Volmer–Weber growth in successive cycles of indium deposition - heating with activation of the solid state dewetting process.









The final stage of indium nanostructures formation on the surface of (100) In_4Se_3: 1x1 μm^2 areas' morphologies studied by STM with subsequent pixels' height distribution histograms and detected periodic structures using 2D FFT filtering.
(a, b,c) Thread of subsequent indium deposition and SSD processing - morphology after each of 3 cycles of final annealing at T> 200 ºC.
(d, e, f) Thread with accumulation of deposited amount and next annealing - morphology after each of 3 cycles of final annealing at T> 200 ºC.

Kinetics of (100) In_4Se_3 surface 1x1 μm^2 area's morphology studied by STM (on left) with subsequent pixels' differences in height distributions (on right): a) initial surface before indium deposition (+1.93 V bias, 46 pA); b) after indium deposition (60 s) (+4.7 V bias, 112 pA); c) next thermotreatment at T>200 ºC (+2.5 V bias, 105 pA); d) after following indium deposition (60 s) (+2.5 V bias, 119 pA); e) after next thermotreatment at T>200 ºC.

Kinetics of surface parameters calculated from STM topographies of 1x1 μm^2 areas on In_4Se_3 (100) surfaces shown on Fig.1 in the consecutive processes of indium deposition and SSD: (a) RMS roughness; (b) and (c) show the corresponding data of skewness and kurtosis analyses, respectively.

Kinetics of surface parameters calculated from STM topographies of 1x1 μm^2 areas on In_4Se_3 (100) surfaces in the processes of consistent indium deposition with accumulation of deposited amount and final 3 cycles of annealing at T> 200 ºC: (a) RMS roughness, *Inset*: RMS kinetics for layer by layer growth mode; (b) and (c) show the corresponding data of skewness (skewness for normal pixels' heights distribution is equal to zero) and kurtosis (kurtosis value for a standard normal distribution is three) analyses, respectively.

Conclusions

We managed to establish that the growth modes in the thermally deposited indium coating, and resulting formation heterogeneous metal-semiconductor nanostructures' arrays are determined by the sequence of experimental procedures, namely: indium deposition, heating of the deposited layer, as well as the amount of In deposit on the surface.

References

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