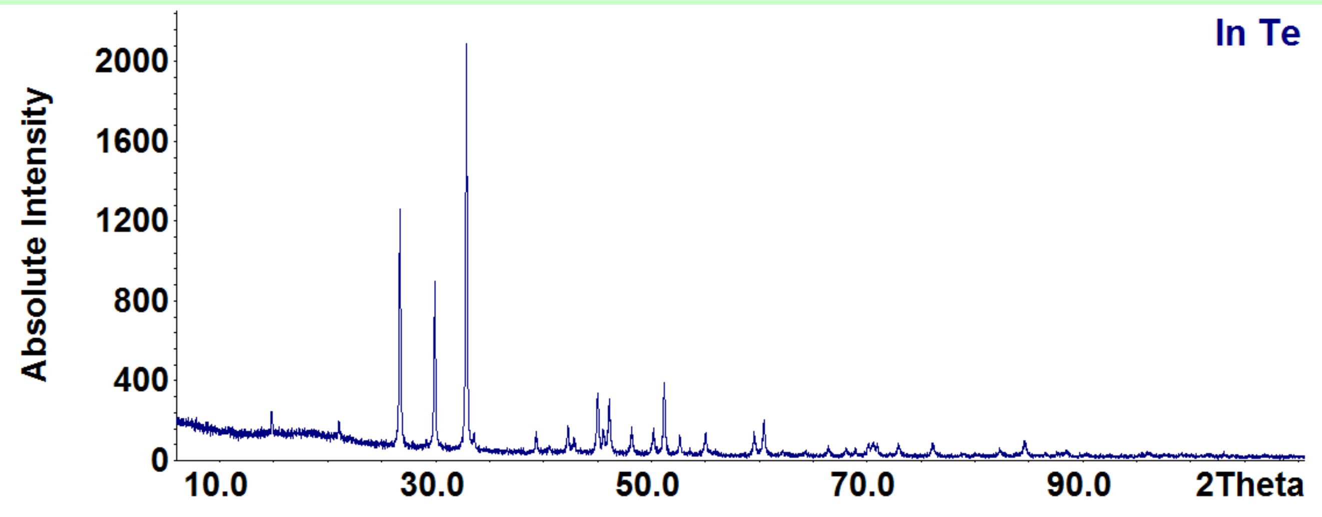
InTe surface application as template for indium deposited nanosystem formation

P.V. Galiy[1], T.M. Nenchuk[1], A. Ciszewski[2], P. Mazur[2], V.I. Dzyuba[1], T.R. Makar[1]

[1]Electronics and Computer Technology Department, Ivan Franko Lviv National University, 50 Dragomanov Street, Lviv, 79005, Ukraine.
E-mail: galiy@electronics.lnu.edu.ua
[2] Institute of Experimental Physics, University of Wrocław, pl. Maxa Borna 9, 50-204 Wrocław, Poland.

Introduction

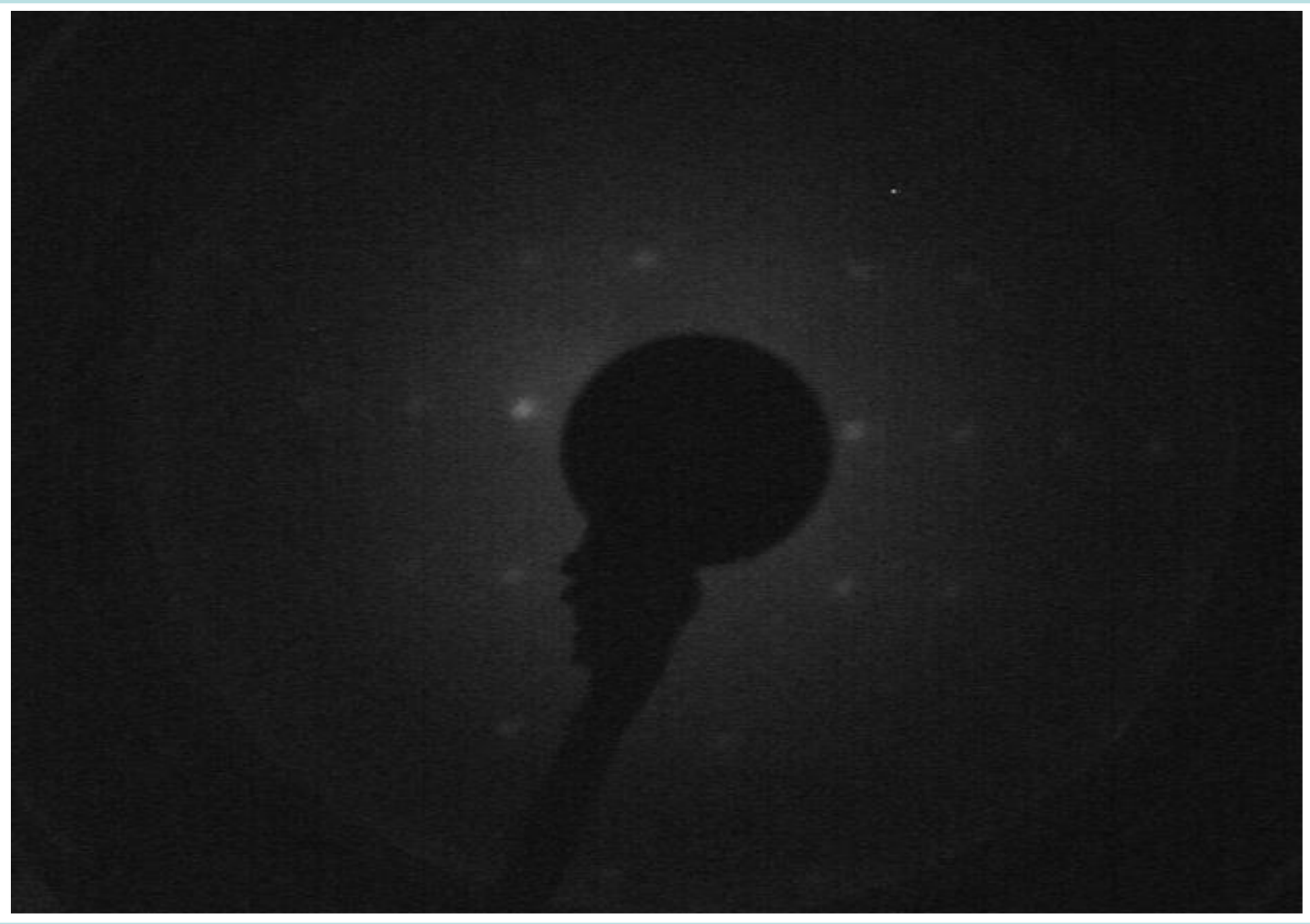
The InTe monocrystal surface is not studied well enough, but like the rest of the 2D layered semiconductors, e.g. InSe, newly emerging nowadays, may now be object of interest for application at functional nanoscale devices.
It looks like that surfaces of 2D layered crystals are one among most perspective templates for self-assembling of metal nanostructures due to the solid state dewetting (SSD) process. From a physical point of view, it is clear that effective pattern assembly requires nanostructure precursor's mobility over the substrate surface, a property that is naturally connected with poor adhesion. Due to InTe intrinsic bulk anisotropy its (001) surface might be just easily obtained by cleavage even in UHV which makes it suitable as a template for obtaining nanosystems with reduced dimension in situ.



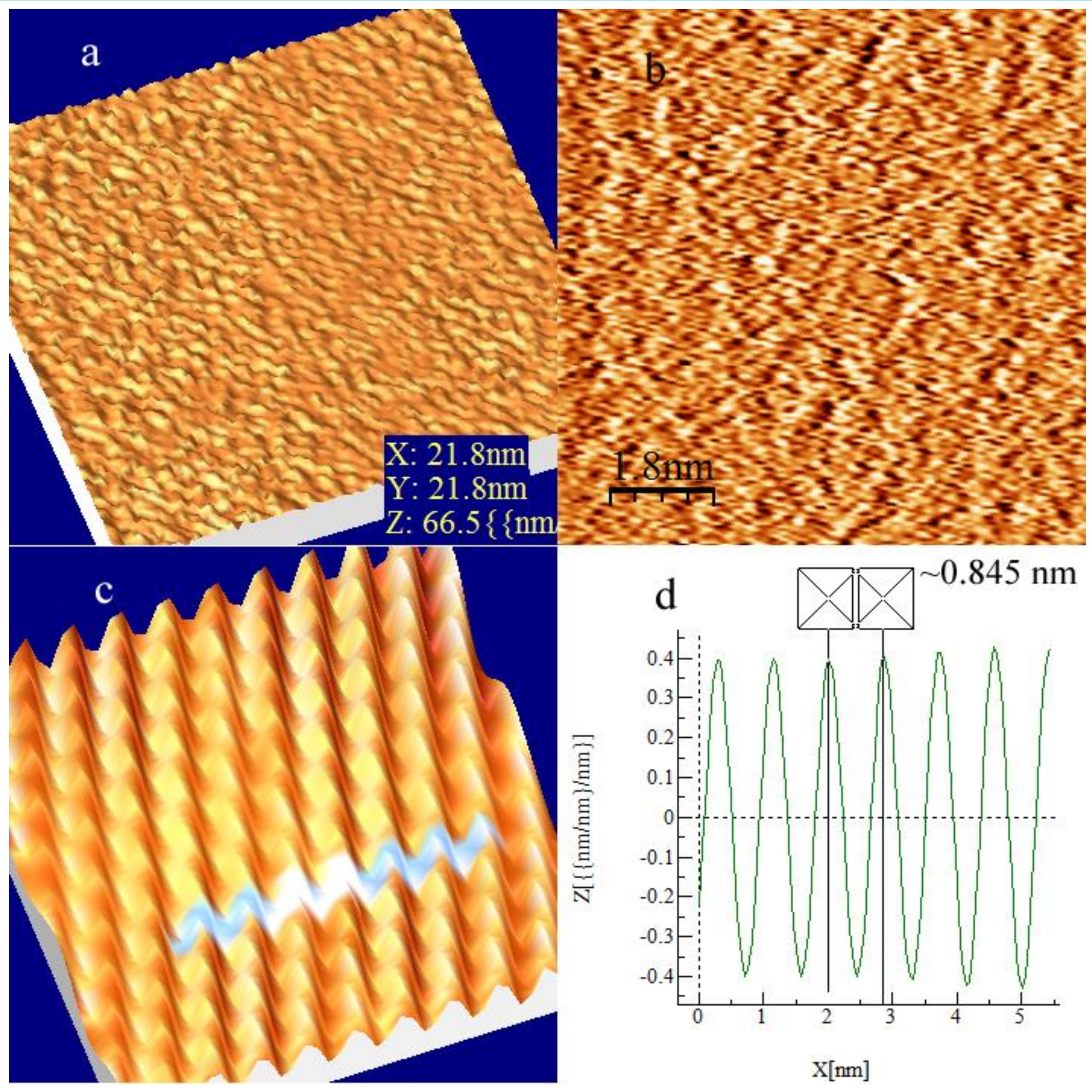
XRD study (STOE STADI P, CuKα1)

Methods

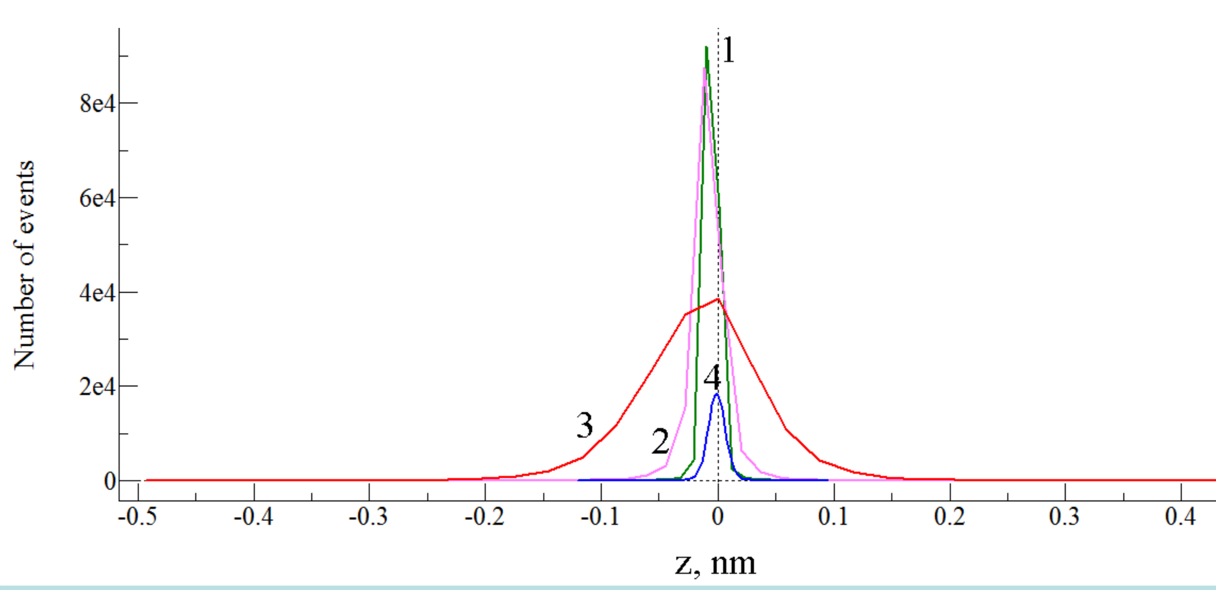
InTe layered semiconductor crystals have been grown by Bridgman-Stockbarger method from previously synthesized In-Te melts, which have homogeneous structure. The X-ray Powder Diffraction (XRD) data of the grown crystals showed tetragonal crystal structure of the TlSe type (I4/mcm space group, lattice parameters a = 8.4414(6) Å, c = 7.1333(5) Å). The initial surface before deposition, so-called, template was characterised by X-ray photoelectron spectroscopy (XPS) and low energy electron diffraction (LEED). The templates have got excellent surface structural quality in macroscale according to LEED and subsequent phase-elemental composition of InTe as determined by XPS. LEED data were acquired by ErLEED 100 optics designed by SPECS Surface Nano Analysis GmbH.
Samples for STM/STS/AFM studies had special 3x4x6 mm^3 shape for cleavage *in situ*. InTe samples were cleaved by stainless tip *in situ* and just obtained (001) surface plane was studied by STM/STS/AFM. STM/STS/AFM data were obtained by Omicron Nano Technology STM/AFM System operating with UHV better than 10^{-10} Torr at room temperature. The acquisition of STM data was conducted in the constant current mode. Free software WS&M v.4.0 from Nanotec Electronica was used while analyzing and processing of scanning probe data. 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 indium deposition. The deposition rate was kept at approximately 0.07 ML/min. Such rates allowed organizing an activation-migration movement of deposited In with localization on growth activation centers under consequent annealing during 3-5 min.



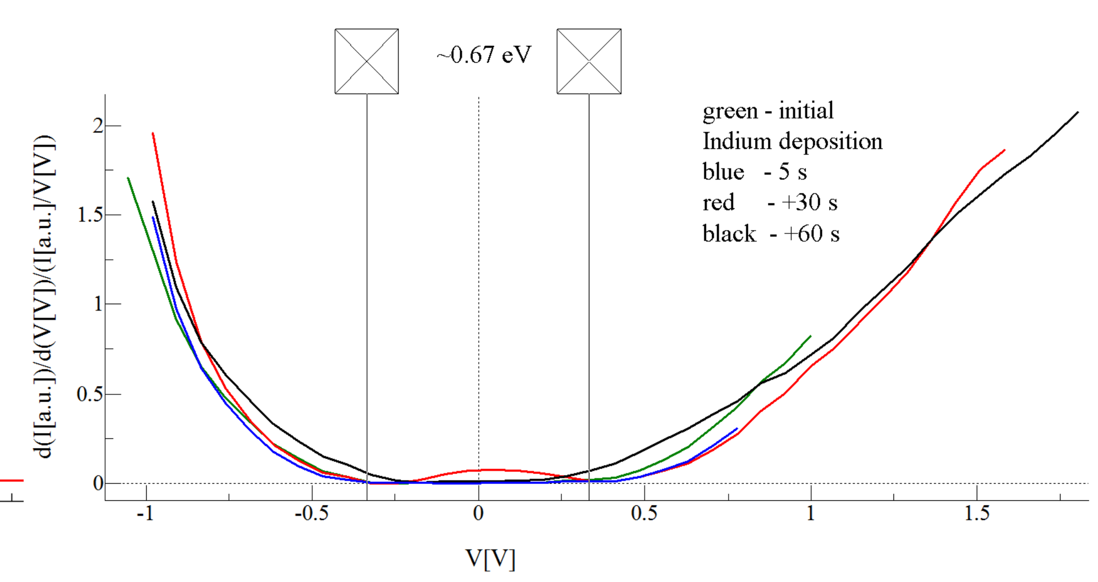
LEED pattern of the as-cleaved sample of InTe, acquired at a primary electron energy of 58 eV



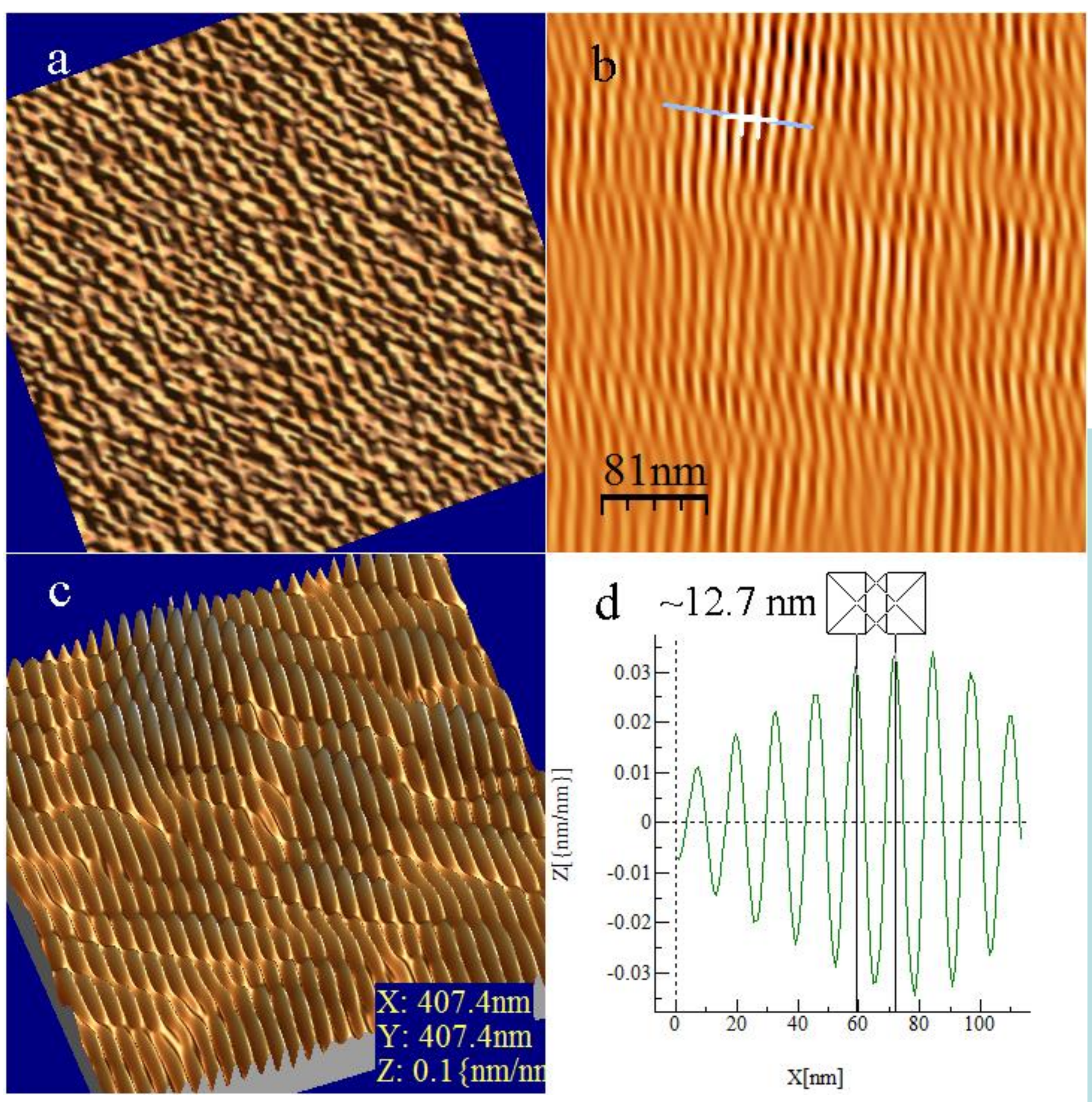
Results



Height distribution of pixels for 150x150 nm^2 STM images on (001) InTe surface before and after In deposition: 1 - initial, 2 -5 s deposition, 3 –annealed (125 °C), 4 – annealed (200 °C),



STS data averaged over 50x50 nm^2 area on (001) InTe surface before and after In deposition/



STM study of In/(001)InTe nanosystem surface after 950 s 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.

AFM study of initial InTe (001) surface : a) 3D 21.8x21.8 nm^2 image, 0.459 nN constant force mode; b) 9.1x9.2 nm^2 zoomed area from (a); c) 3D visualization of 2D FFT filtered image (b) with profile indicated and shown on d). Periodicity of ~8.45 Å derived from topographical profile corresponds well with InTe (001) surface lattice parameter.

Conclusions

Surface of two-dimensional InTe layered semiconductor crystal was applied as template for directed assembly of indium nanostructures. Our work revealed the ability to organize the directed assembly process for a given lattice texture of (001) InSe cleavage surface. In fact the approach of templated dewetting leads to formation of deposited indium nanostructures the shape and arrangement of which are powered by lattice symmetry of surface lattice. We observed the formation of nanosized 1D linear structures in a result of the solid state dewetting process by surface heating above the indium melting point. The STS spectra analyses show good correlation between SSD and increase in the peak of the density of states within the band gap of InTe corresponding to metallic phase with increasing degree of indium coverage.
In our opinion, the choice of experimental conditions which are successful for the formations of as shown nanostructures depends on the rate of indium deposition, and consequently, the degree of surface coating by deposit, as well as the choice of heating conditions to activate the dewetting process, is another factor important for the successful formation of indium nanostructures on 2D surfaces of a layered crystal.