Solid state dewetting application for In/ (0001) Sb_2Te_3 2D layered semiconductor nanosystem formation

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

Faculty of Electronics and Computer Technologies

Instytut Fizyki Doświadczalnej

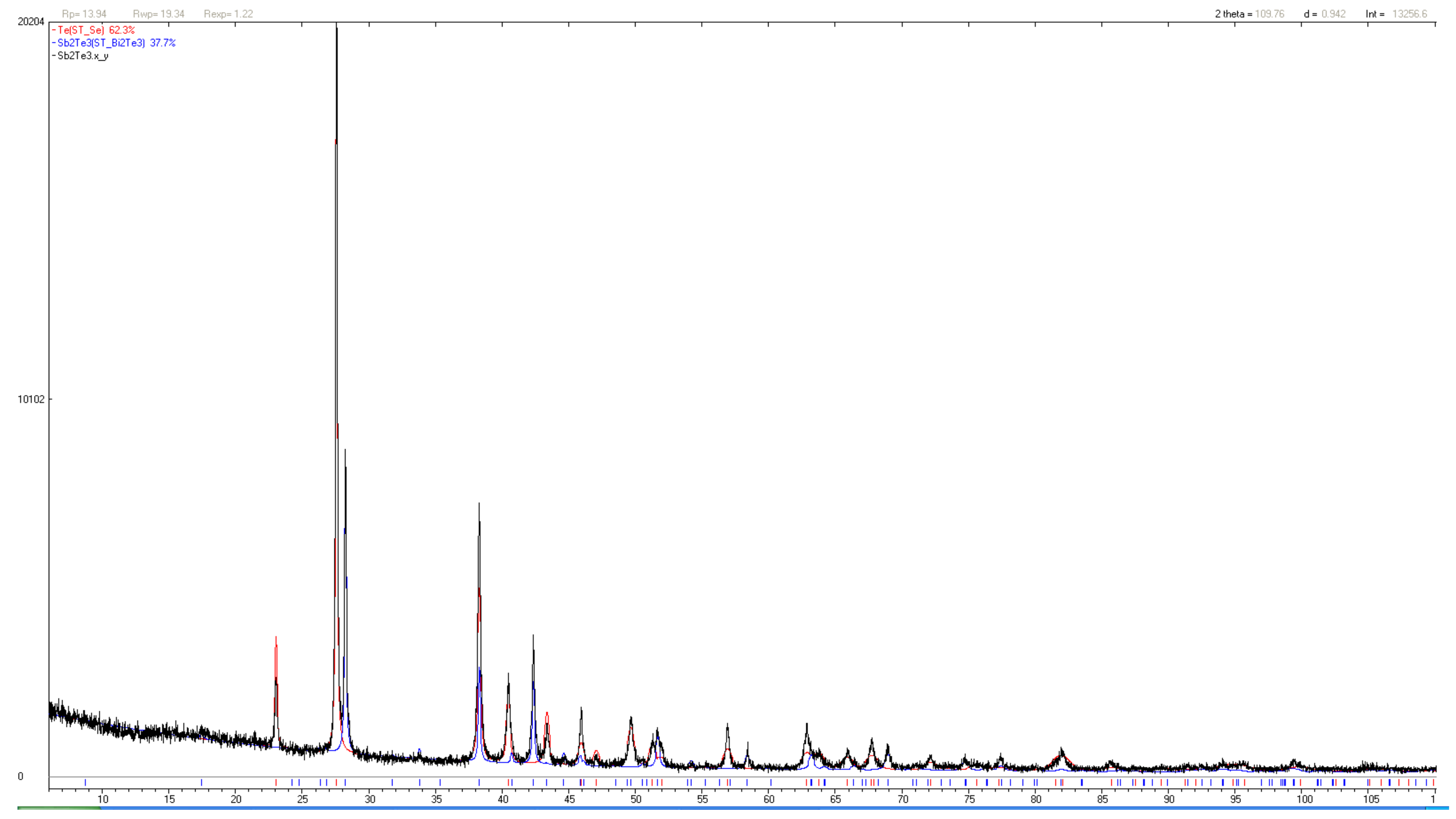
Uniwersytet Wrocławski

Introduction

Self-assembled indium deposition induced nanostuctures formation on the (0001) UHV cleaved surface of Sb_2Te_3 layered semiconductor crystals has been studied by scanning tunneling microscopy/spectroscopy (STM/STS). Previously, we reported on In/ (100)In_4Se_3 [1] and In/(0001)InSe [2] nanosystems formation.

Experimental

The initial surface before deposition, so-called, template was characterised by X-ray photoelectron spectroscopy and low energy electron diffraction (LEED) and 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 of Sb_2Te_3 as determined by XPS. The 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.



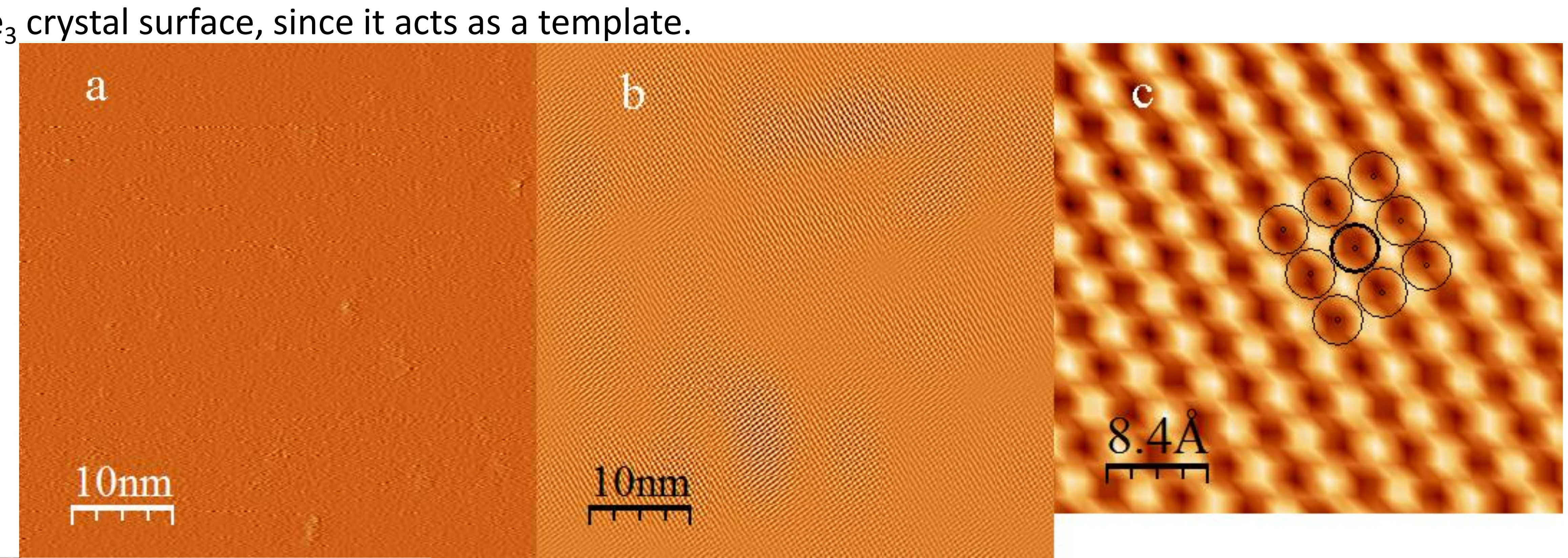
Experimental results

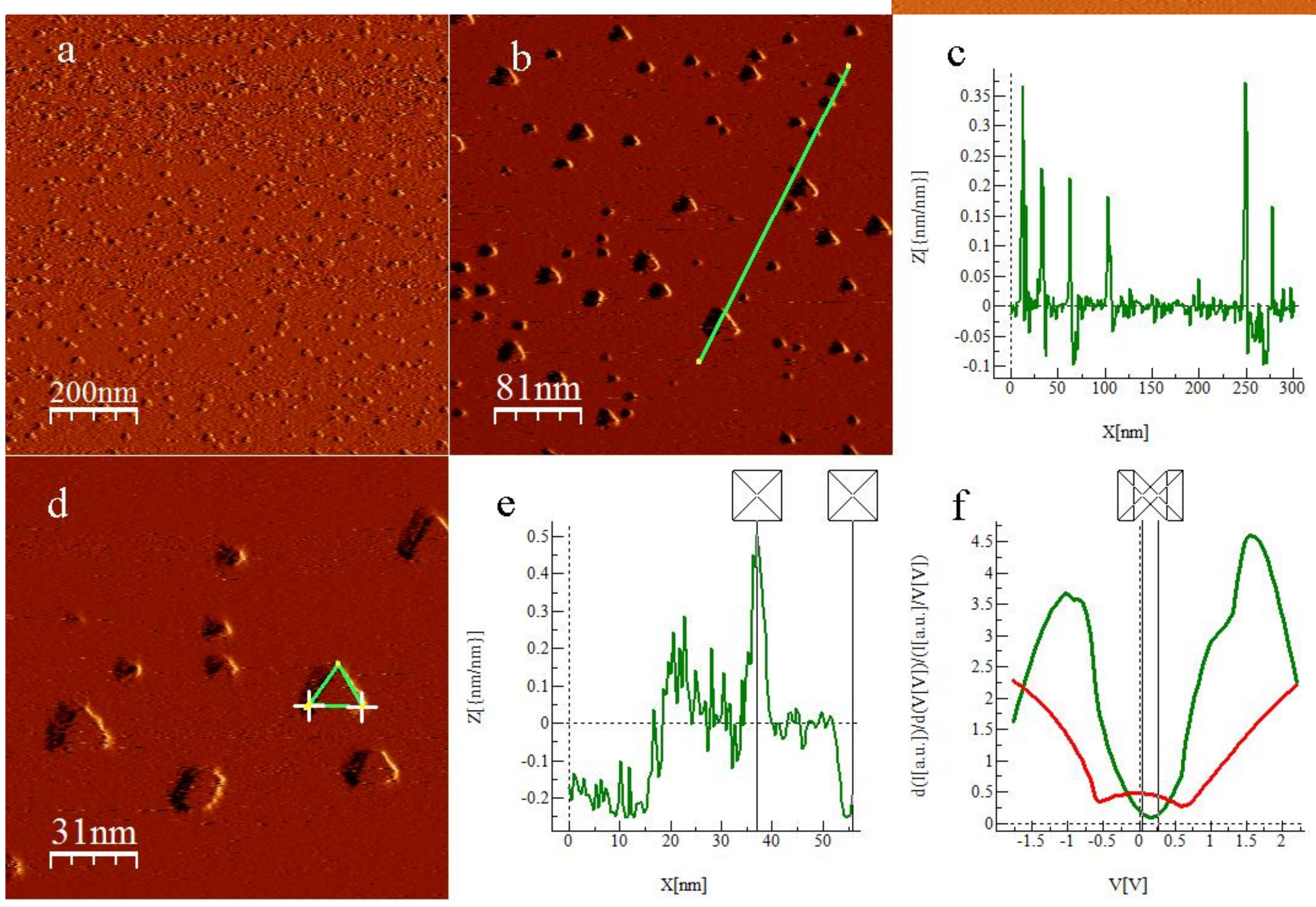
XRD study (STOE STADI P, CuKα1) shows rhombohedral crystal structure (R3m space group, lattice parameters a = 4.2654(8), c = 30.435(2) Å).

The study of indium Sb_2Te_3 (0001) substrate sub- and monolayer nanosystem's formation was 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 bias range corresponding to 0.21 eV energy gap of Sb_2Te_3. We analyzed the array of studied surface areas with 50x50 nm² dimensions to obtain reliable conclusions about metal - semiconductor hetero nano system formation (In/ Sb_2Te_3 (0001)).

The growth of 0D metallic nano objects quantity on the semiconductor surface depending on indium deposition time powered by consequent thermal annealing conducted after deposition cycle was observed. These formed nano structures have a characteristic triangular shape that agrees well with the corresponding surface structure inherent in the Sb_2Te_3 crystal surface, since it acts as a template.

STM/STS study of initial Sb_2Te_3 (0001) substrate:
a) STM image 51.2x51.2 nm² (tunneling current 124 pA, bias +1.6 V); b) 2D FFT image; c) zoomed fragment of 2D FFT image 4,2x3,8 nm² with characteristic lattice size of 4.26 Å.





STM/STS study of Sb_2Te_3 (0001) substrate after indium deposition and subsequent annealing at 100°C:
a) STM image 1x1 μm² (tunneling current 124 pA, bias +1.0 V) with indium triangular shaped nanostructures;
b) STM image 402.5 x402.5 nm² (tunneling current 124 pA, bias +1.0 V) with subsequent profile on (c) indicating height of induced nanostructures; d) STM image 155x155 nm² (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).

Conclusions

Both, STM and STS data give evidence that In deposited nanostuctures' growths has island like, localized nature with next thermal-activated surface migration. Integral STS data over the analyzed area show on formation of indium metal phase on Sb_2Te_3 (0001) surface at high deposition times and subsequent annealing.

References

[1] P.V. Galiy, P. Mazur, A. Ciszewski, T.M. Nenchuk, I.R. Yarovets', The European Physical Journal Plus 134, 70 (2019).
[2] P.V. Galiy, T.M. Nenchuk, P. Mazur, A. Ciszewski, Ya.M. Buzhuk, O.V. Tsvetkova, Applied Nanoscience 10, 4629 (2020).