Structural Properties of Cadmium Arsenide Magnetron Films on Different Substrates

A.V. Kochura[1], Zaw Htet Aung[1], V.S. Zakhvalinsky[2], E.A. Pilyuk[2]

[1] South West State University, 50 years of October St, Kursk, 305040, Russia
[2] Belgorod State University, Belgorod, 308015, Russia
E-mail: alex_dop@mail.ru

Introduction, Topological materials currently attract wide interest related to the existence of Dirac nodes in their electron spectrum and related nontrivial topological characteristics of both bulk and surface states [1]. Theoretical and experimental studies have established that Cd_3As_2 belongs to a special class of topological insulators - Dirac semimetals, in which charge carriers - Dirac fermions have zero effective mass and obey relativistic laws of motion [2]. It has recently been discovered low-temperature superconductivity in cadmium arsenide films prepared by different methods. [3, 4]. The nature of this phenomenon is not completely clear and can have different reasons, for example, a sharp increase in the number of topologically protected states can occur, both due to an increase in internal stresses in polycrystalline films [3], and due to a weak, but sufficient for the appearance of the effect fine tuning of the band structure in the presence of a slight excess of cadmium and violation of stoichiometry [5]. This stimulates more detailed studies of the structure and composition of synthesized films. In this work, we study changes in the structural properties and morphology of cadmium arsenide films on various substrates, depending on the conditions for their production by reactive magnetron sputtering.

Experiment, Cadmium arsenide thin films were obtained by radio frequency magnetron sputtering in an argon atmosphere at a pressure of 8×10^{-3} mbar without heating the substrate. The sputtering rate at the supplied power of 10 W and the target substrate distance was about 1 nm/min. The powder target was made from pre-synthesized Cd_3As_2 single crystals. Monocrystalline polished oriented silicon p-Si (111), sapphire α-Al_2O_3 (001) and strontium titanate $SrTiO_3$ (100) were used as substrates. After deposition part of the film was annealed in an argon atmosphere at the temperature of 520 K. The structure and morphology of the thin films were studied by atomic force microscopy (AFM) (AIST Smart SPM, Horiba), Raman spectroscopy (RS) (OmegaScope, Horiba), electron microscopy (EM) (JEOL 6610LV) and X-Ray diffraction (XRD) (GBC EMMA) at the room temperature.

Results and discussions, The typical X-Ray diffraction patterns of the Cd_3As_2 magnetron films on different substrates with the crystal structures of α (sp. Gr. $I4_1cd$) and α' (sp. Gr. $P4_2/nbc$) polimorfic modifications found earlier in Ref. [3, 6]. XRD of As-growth films had complex structure with small amorfization. After annealing all obseved diffraction peaks we can correspond to the (112) family crystal planes (Fig. 1). This is typical because the (112) plane is the cleavage plane of cadmium arsenide.

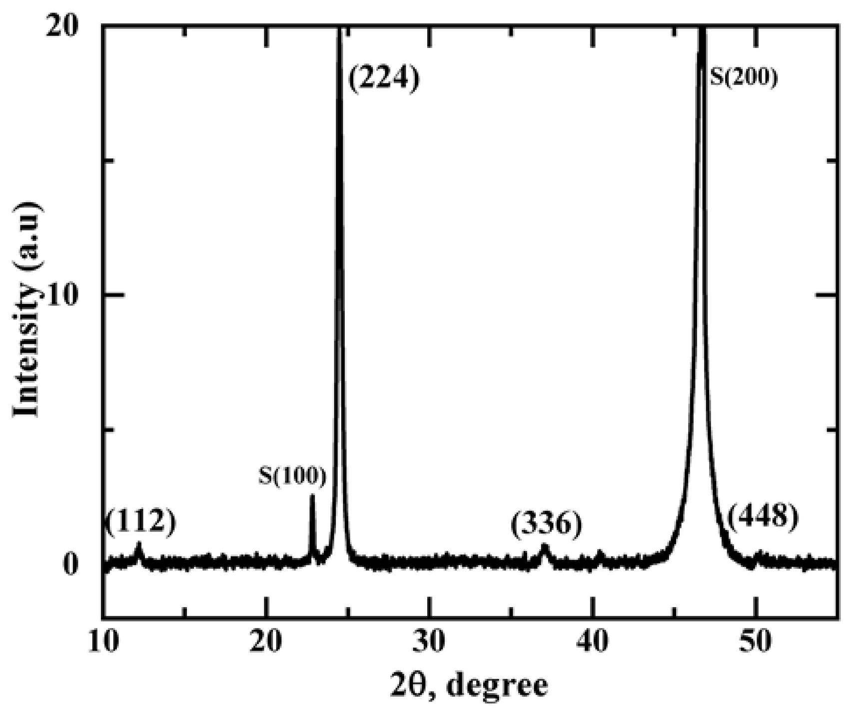

Fig. 1. X-ray diffraction patterns of annealed thin Cd_3As_2 film grown by magnetron sputtering on $SrTiO_3$ substrate (labeled by «S»).

In addition, AFM results demonstrates (Fig. 2) that the films are continuous with a granular structure with an average granule size within 20 - 40 nm for annealed samples. Their thickness was about 50 nm – 60 nm.

(Al_2O_3)

(Si)

($SrTiO_3$)

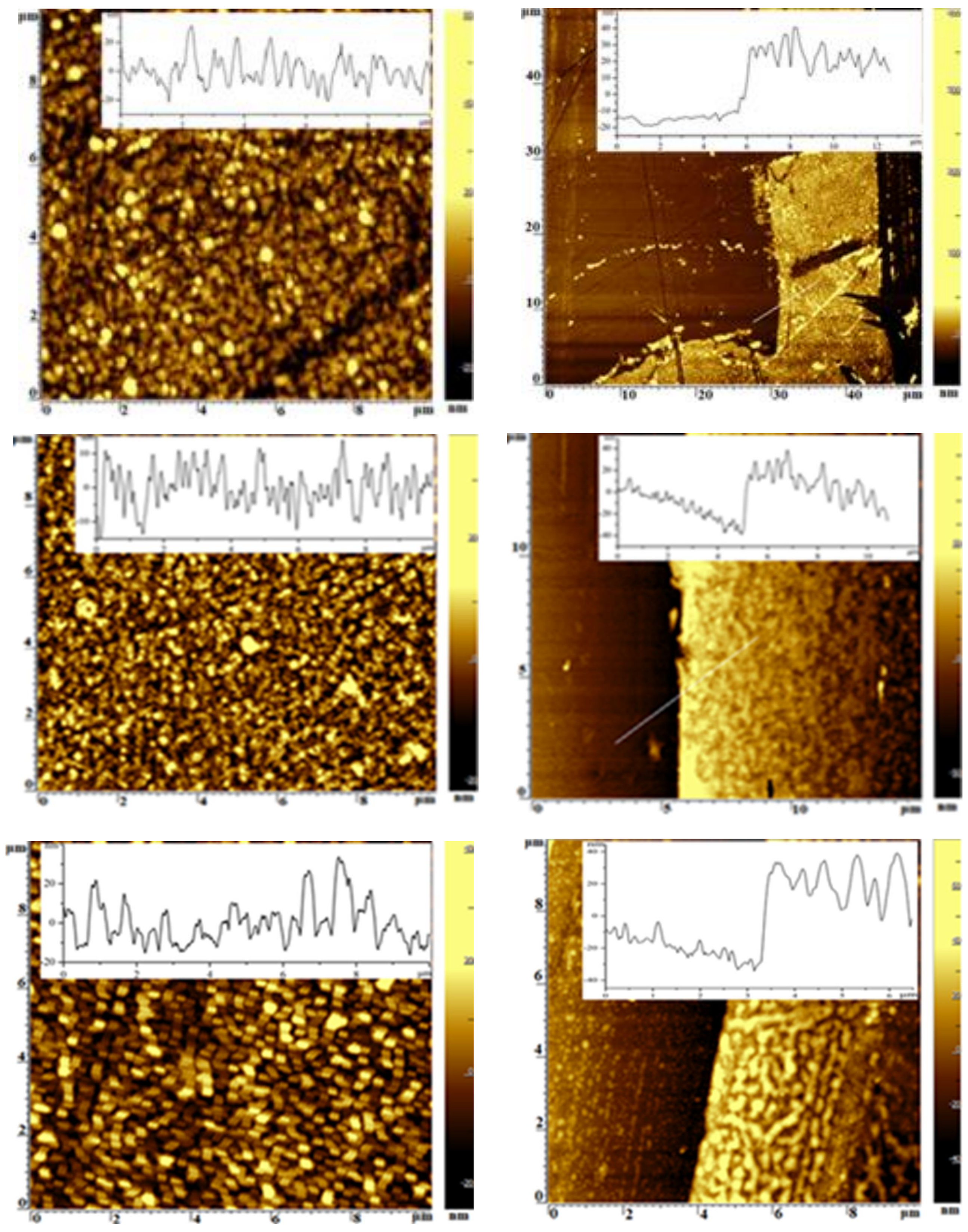

Fig. 2. AFM images with profiling of annealed Cd_3As_2 film on Si, Al_2O_3 and $SrTiO_3$ substrates in the center (on left) and near edge (on right).

The study of thin films using RS in the far IR region confirms that the films are formed from cadmium arsenide. Two broad peaks with a position of about at 193.2 and 247.7 cm^{-1}, whose nature is not associated with the classical mechanism of inelastic light scattering, are often used to characterize nanostructures containing Cd_3As_2 single crystals and films. Figure 3 shows the Raman spectra measured in individual regions of the crystal for the sample. For the α-Cd_3As_2 crystal structure, the experimental Raman spectra in the region above 100 cm^{-1} contained only three strong vibrational modes located near 140, 195 and 250 cm^{-1}.

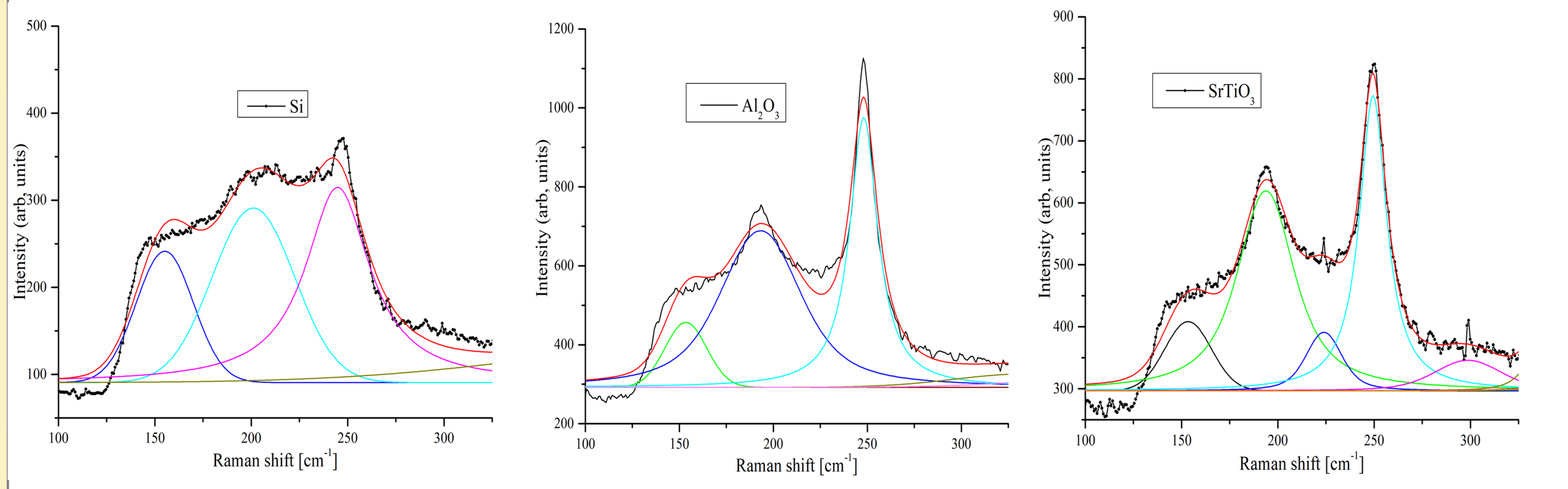

Fig. 3. Raman spectra of the annealed Cd_3As_2 film grown on Si, Al_2O_3 and $SrTiO_3$ substrates.

It is clearly seen that the film demonstrates growth according to Stranski -Karstanov, with the initial deposition of a homogeneous thin layer and subsequent growth with intensive nucleation .The composition of the film corresponded to stoichiometric within the measurement error and was uniform, as observed on the distribution maps of Cd and As atoms by SEM (Fig. 4).

(Si) (Al_2O_3) ($SrTiO_3$)

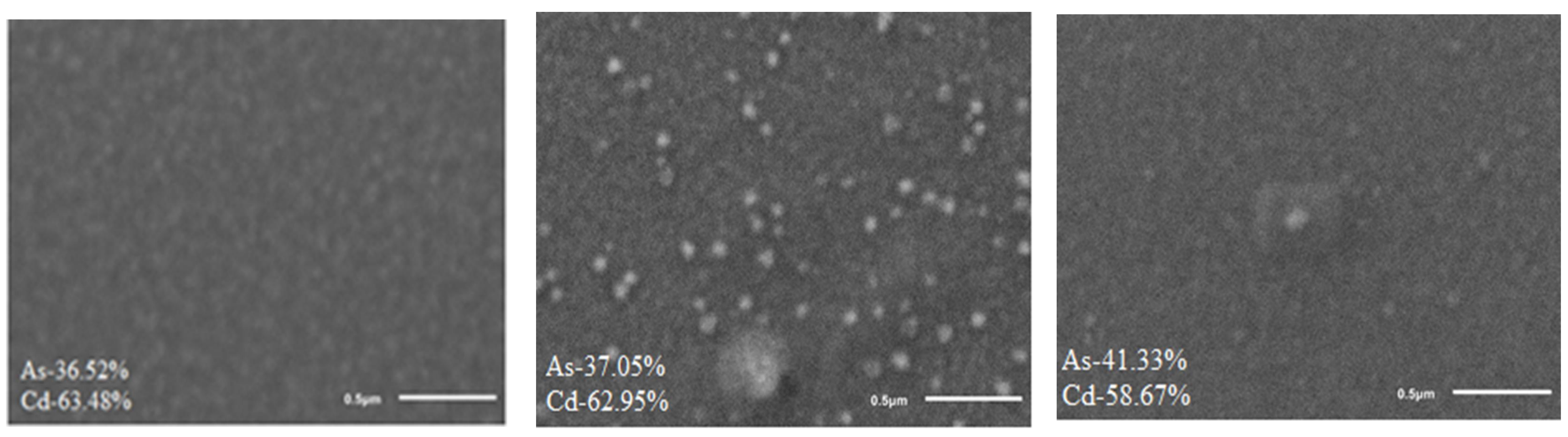

Fig. 4. SEM images of the annealed Cd_3As_2 film grown on Si, Al_2O_3 and $SrTiO_3$ substrates.

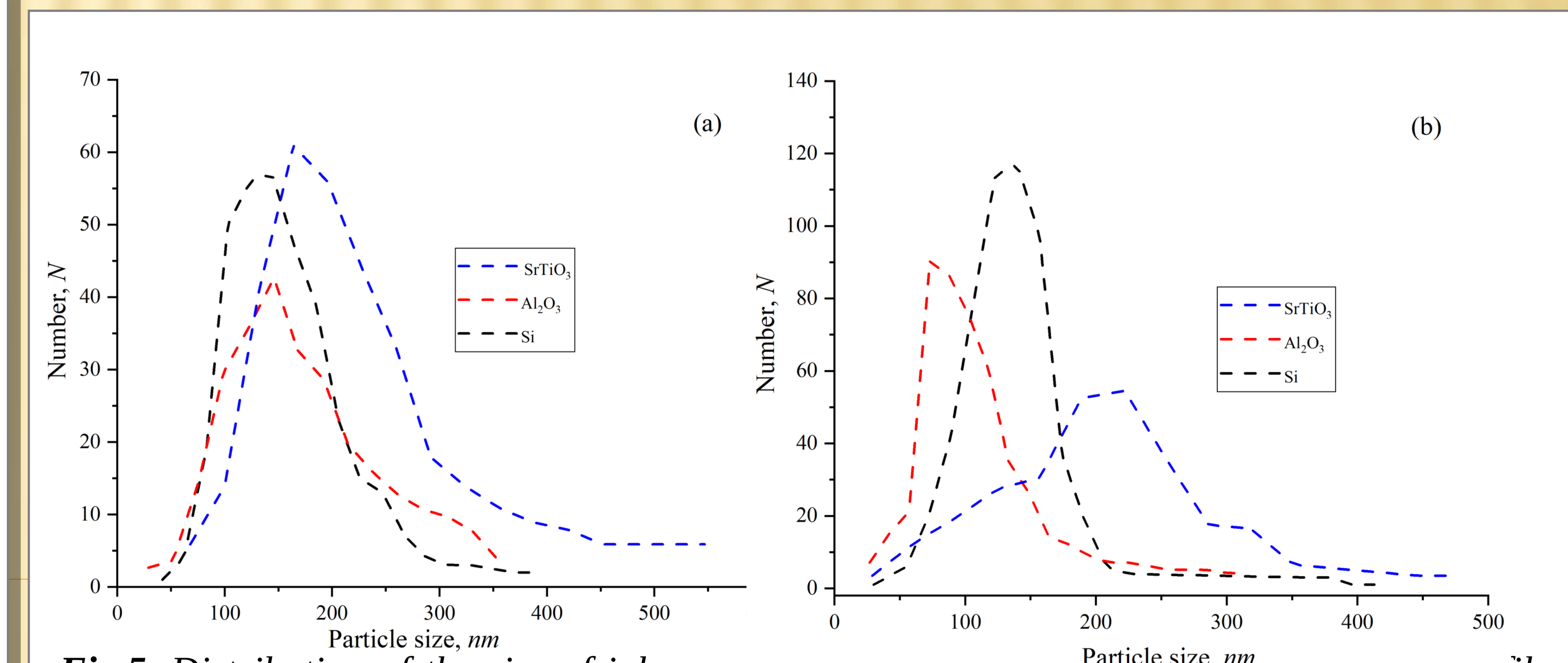

Fig.5. Distribution of the size of inhomogeneities of a) annealed and b) non-annealed films Cd_3As_2

Conclusions, Cadmium arsenide films were grown by RF magnetron sputtering on different substrates. The composition and structural properties of this nanostructured films have been studied by X-ray analysis, scanning electron microscopy combined with energy-dispersive analysis, and Raman spectroscopy. The films are continuous with stoichiometric content and had a granular structure. After annealing they After the films are annealed, their crystallinity increases and they become textured with the (112) texture axis.

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