Plasma-prepared arsenic telluride films: relationship between physico-chemical properties on the parameters of the deposition process

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Abstract

Previously, we demonstrated the principal possibility to synthesize arsenic telluride films of different chemical and phase composition by PECVD when we directly use elemental arsenic and tellurium as the precursors. This paper presents the results of systematic study of physicochemical properties of As-Te films prepared in low-temperature non-equilibrium RF (40 MHz) argon plasma discharge at low pressure (0.1 Torr) as well. The surface morphology, structure and thermal crystallization behavior of the films obtained were studied in dependence on the plasma parameters of the deposition process. The characteristics of stationary and transitional photoconductivity of the films have been studied as well.

1. Introduction

Tellurium-based chalcogenide materials are supposed to be promising for application in IR optoelectronics and photonics [1–6], and, also, for fabrication of three-dimensional architecture of integrated optical elements of future quantum computer [7–9]. Despite the fact the effect of threshold switching was first found out for the telluride glasses by Northover and Pearson in 1960s [10, 11], the As-Te binary system has been serving as a clue model to figure out the phase-forming behavior of the whole family of tellurium-based materials so far [12–18].

Thermochemical, particularly, crystallization properties of As-Te bulk samples have been studied in detail and published in [18–22]. Structural properties of As-Te materials were studied and reported in [22–24], where the chalcogenide films were obtained by spin-coating technique from bulk samples and underwent annealing and quenching under different conditions. The authors of [24] have also suggested that the structural ordering of As-Te films is determined by two parallel processes of dissociation that occur during the formation of the glassy net structure. Physico-chemical properties of chalcogenide materials are largely determined by the method of their preparation, since the method of synthesis directly affects their structure and the state of defects in it. The validity of this statement is vividly confirmed when studying the properties of As-Te glasses obtained in different conditions. Thus, in [16], samples of As2Te3 and AsxTe100−x thin films were obtained under different quenching conditions and studied using Raman spectroscopy. It was found that AsTe and As2Te3 were the main elements of the structure. In addition, it was noted in [17–20] that, depending on the annealing modes, especially with fast cooling of the samples, the structural units of the AsTe and As2Te3 composition are present in the As-Te glass net. Mostly, thin films obtained using state-of-the-art deposition technologies do not have the same optical properties as the original bulk samples. The As-Te films obtained are chemically and structurally disordered.
Potential fluctuations due to disorder create small localized states near the allowed bands in the form of exponentially falling tails, which are characteristic of all amorphous semiconductors. According to [21], the tail width of the valence band can, as a first approximation, be estimated from the Urbach slope of the optical absorption curve. Since the holes are more mobile carriers in chalcogenides, it is also possible that this tail is probed by appropriate measurements of electric transport. In addition, the structural glassnet of any amorphous chalcogenide glass film contains a large number of defects such as ‘broken bond’. According to the model proposed in [22], in chalcogenide glasses, these defects are charged and have no unpaired electrons (D⁺ and D⁻ dangling bonds, with and without two spin-paired electrons, respectively). The neutral dangling bond D⁰ with one unpaired electron is energetically unfavorable and manifests itself only in the excited state. These defects are responsible for localized states located more deeply in the forbidden zone of amorphous material. Direct observation of these defects, for example, by measuring the optical absorption spectrum, is often difficult due to the lack of sensitivity in the case of thin layers of amorphous chalcogenide glasses. The antisite defects in glassy As–Te alloys are investigated by emission Mössbauer spectroscopy in [23]. Measurement of the photoconductivity of chalcogenide films, whose magnitude and temporal characteristics are determined by the density and type of defects responsible for the existence of deep localized states in the band gap (mobility gap) of an amorphous semiconductor, is one of the indirect methods of sensing (detecting) such defects in chalcogenide glasses. Vacuum evaporation and spin-coating are the most common methods for synthesizing of planar structures of the As–Te system. In [22–24, 26] we emphasize the advantages of using plasma chemical methods for the synthesis of chalcogenide glasses in the form of bulk samples and thin films. Compared to classical methods such as CVD, thermal vacuum evaporation or spin coating, plasma chemical vapor deposition (PECVD) provides much greater possibilities for controlling the deposition process and the formation of the final structure. At the same time, additional factors of influence are temperature and concentration of electrons in the plasma.

The purpose of this work is a systematic study of the physicochemical properties of amorphous As–Te films of different composition, obtained by plasma chemical deposition from the gas phase under low-temperature argon plasma under reduced pressure.

2. Experimental

The samples of chalcogenide films were obtained at the facility, the schematic diagram of which is given in [24]. The layers were deposited on high-pure fused quartz substrates with a thickness of 0.5 mm and crystalline NaCl; the substrate temperature was about 40 °C. In order to avoid thermal crystallization of amorphous films, flat slit electrodes with aluminium contacts (distance between contacts was 0.5 mm, contact width was 10 mm) for measurements of dark and photoconductivity were made on a fused silica substrate before deposition of As–Te films.

The study of chemical composition of the obtained samples was carried out by x-ray microanalysis on a JSM IT-300LV scanning electron microscope (JEOL) with an energy dispersive attachment for elemental analysis of X-MaxN 20 (Oxford Instruments) under high vacuum and accelerating voltage of 20 kV. The Raman spectra were studied on a NTEGRA Spectra Raman spectroscopy complex (NT-MDT) using a HeNe laser with the wavelength of 632.8 nm. The study of the Raman spectra was carried out in the scheme of reflection. All spectra were recorded at the room temperature. The thickness of As–Te films was estimated by Atomic Force Microscopy according to the step formed in the process of obtaining samples. It was from 5 to 8 μm. To measure the photoconductivity, a semiconductor continuous-wave laser with the power of 40 mW and the wavelength of 785 nm was used as the light source, the light intensity was controlled by calibrated filters with neutral density. A shutter with a constant time of about 10⁻³ s was used to turn on/off the light. Photoconductivity relaxation was recorded using a SourceMeter® KEITHLEY series 2420 device with a time constant of not more than 0.02 s. The temperature of the test samples was set using a vacuum thermal bench Linkam Scientif Instruments THMS350V with an accuracy 0.1 °C. The electric field applied to the test sample did not exceed 200 V cm⁻¹. The spectral distribution of the stationary photoconductivity was obtained using a MDR-204 monochromator with the 100 W halogen lamp as the light source.

3. Results and discussion

3.1. Study of the process of plasma deposition

The study of the plasma-chemical process consisted of two stages. The first stage included the optical emission diagnostics of the chemically active plasma, which allows determining what kind of active particles is formed in the plasma and offer possible mechanisms for the plasma-chemical reactions. The second stage included
mass-spectroscopy of exhausted gas mixtures to determine the degree of conversion of the precursors as well as the impurities in the plasma discharge.

3.1.1. OMS of the plasma discharge

The optical emission spectra of the inductively-coupled plasma discharge of high-pure argon (for comparison), and mixtures of (Ar + As) and (Ar+Te) at different values of energy input were studied in the range of 180 ÷ 1100 nm. The power supplied into the plasma discharge changed in the range of 30–50 W, the total pressure in the system was constantly maintained 0.1 Torr. Individual emission spectra of As and Te in argon discharge are presented in figure 1.

The excited states of As (I) atoms at 228.81, 234.98, 238.12, 245.65, 278.02 nm and As (II) atoms at 283.08, 299 and 311.51 nm [24–27] may be identified in the spectra. Besides, the emission spectrum of Ar–As plasma includes the picks responsible for exiting of As2 molecules at 248.74, 289.03, 298.9, 302.65, 305.8 nm [27]. With increase of the energy input into the plasma discharge the intensity of the molecular bands decreases, but the intensity of the atom lines increases. It is established that in the vapour phase arsenic exists in the forms of As4 and As2 agglomerates. [28]. Under the influence of electron impact, the agglomerates dissociate by the following reactions:

\[
\text{As}_4 + \epsilon^* \rightarrow 2\text{As}_2 + \epsilon
\]

(1)

\[
\text{As}_2 + \epsilon^* \rightarrow 2\text{As}^* + \epsilon
\]

(2)

The lines of the exited states of Te (I) atoms appear at 201.4, 217.1, 218.0, 222.3, 239.8, 253.6, 280.1, and 318.3 nm. The Te (II) exited state bands locate at 292.3, 298.4, and 299.6 nm. Without plasma initiation, tellurium is presented in the vapor phase in the form of Te2 molecules [29]. In the plasma discharge the reaction of dissociation of the tellurium molecules takes place as in the case with arsenic:

\[
\text{Te}_2 + \epsilon^* \rightarrow 2\text{Te}^* + \epsilon
\]

(3)

In comparison with the spectra of the initial substances, in the plasma emission spectrum of Ar–As–Te mixture (figure 2) does not include the molecular bands of both—tellurium and arsenic agglomerates, the intensity of tellurium lines in the range of 227–340 nm significantly diminishes, atomic arsenic lines almost disappear (203.98, 207.48, 216.42, 537.15, 891.89, 900.20, 903.86 nm) [30], while the intensity of the argon lines in the range of 690–850 nm remains almost unchanged (do not shown in the spectra).

As a result of this initiation by plasma, we get our precursors in the atomic excited state in the gas phase. Judging by the fact that As–Te molecular lines are absent in the spectra, we can assume that the reaction of formation of the As–Te solid phase occurs on the substrate simultaneously with the quenching process. We may also assume that the atomization of the initial clusters in plasma discharge seems to be the reason of deposition of the arsenic telluride materials with the more structurally and chemically uniform surface. Since the dissociation energy of As4, As2, and Te2 is different, this also affects the content of As and Te in the final chalcogenide thin films deposited.
3.1.2. Chromate-mass-spectrometry of the exhausted gas mixtures

The investigation of the exhausted gas mixtures is of a special interest due to, on the one hand, it allows determining the degree of conversion of the precursors, on the other hand, it makes possible to clarify behavior of some volatile impurities, especially if they are of a carbon nature. The exhausted gas mixtures after each process were accumulated in the traps, cooled by liquid nitrogen and analyzed by chromate-mass-spectrometry. The data are shown in table 1.

The quantity of water vapor traces traditionally rises with growing of the power input into the plasma discharge [25, 27]. One of the reasons may be that plasma enhances outgassing of the water traces from the walls of the plasma-chemical chamber.

Both commercial precursors—arsenic and tellurium—include heterophase inclusions of the carbon nature. In plasma discharge their intensive conversion takes place. It may be interaction with the traces of oxygen and water with formation of CO₂ or carbon derivatives of different molecular masses, which may be partly removed during the process of deposition. With increase of the plasma power the concentration of carbon-containing gas-forming impurities increases in the exhausted gas mixture.

3.2. Study of the materials obtained

3.2.1. Dependence of chemical composition of the AsₓTe₁₀₀₋ₓ films on the energy input into the plasma discharge. EDX and SEM studies of the samples

In order to study the effect of plasma power on the chemical composition, structure and properties of AsₓTe₁₀₀₋ₓ films, first of all, the sample with composition As₂₀Te₈₀ was obtained with a minimum generator power — 10 W. Then, at the same ratio of the precursors in the gas phase, samples of the films of different compositions were obtained, while the plasma power varied in the range from 10 to 65 W. The composition of the films was investigated by x-ray microanalysis (EDX). The data are presented in table 2.

As follows from the data presented in table 3, with increase of the energy input from 10 to 64 W, the arsenic content increases from 20 to 80 at%.

Table 1. The composition of the exhausted gas mixture

| Compound | m/z | 10 (W) | 65 (W) |
|----------|-----|--------|--------|
| H₂O      | 18  | 5.3    | 8.6    |
| CO₂      | 44  | 3.5    | 7.4    |
| CₙHₘ (iC₄H₁₀, nC₄H₁₀, nC₆H₁₄, hexane, nC₇H₁₄, heptane, C₇H₈, toluene, nC₈H₁₈, octane) | 0.3 | 3.1 |

Figure 2. Emission spectra of Ar-As-Te mixture at different energy input.
The SEM images of the AsxTe100−x are presented in figure 3.

Judging by the photos obtained the As20Te80 sample has a specific crystalline structure due to the sufficient excess of tellurium, the As40Te60 film looks like a two-phase one and the samples As50Te50 and As80Te20 are, presumably, one-phase, but formed by different structural units. The activation energies of photoconductivity of the AsxTe100−x films are presented in the Table 4.

3.2.2. The XRD patterns of the As-Te plasma prepared films

The XRD measurements have been done for the films deposited on the crystal NaCl substrates at the substrate temperature 40 °C. All the prepared samples are of amorphous matter (figure 4(a)), except for the sample the chemical composition As40Te60 (figure 4(b)) [17] and corresponding curves illustrating the dependence of the signal intensity from the double angle 2θ, include only several broad and structureless bands.

Table 2. The AsxTe100−x composition in dependence on the energy input.

| Composition, at% | Energy input, W |
|-----------------|-----------------|
| As 20 ± 1       | Te 80 ± 1       | 10 ± 3           |
| As 40 ± 1       | Te 60 ± 1       | 22 ± 3           |
| As 50 ± 1       | Te 50 ± 1       | 38 ± 4           |
| As 80 ± 1       | Te 20 ± 1       | 64 ± 4           |

Table 3. Activation energies of dark conductivity of the AsxTe100−x films

| Composition    | ΔE1, eV | σ01, 1/(Ωm · cm) | ΔE2, eV | σ02, 1/(Ωm · cm) |
|----------------|--------|-----------------|--------|-----------------|
| As40Te60       | 0.179  | 6.1 × 10−02      | 0.015  | 4.7 × 10−04      |
| As50Te50       | 0.210  | 6.3 × 10−03      | 0.018  | 1.0 × 10−03      |
| As80Te20       | 0.297  | 5.8 × 10−02      | 0.026  | 2.9 × 10−06      |

Table 4. Activation energies of photoconductivity of the AsxTe100−x films

| Composition    | ΔE1, eV | σ01, 1/(Ωm · cm) |
|----------------|--------|-----------------|
| As40Te60       | 0.03   | 2.1 × 10−07      |
| As50Te50       | 0.11   | 4.2 × 10−05      |
| As80Te20       | 0.10   | 8.7 × 10−05      |

The SEM images of the AsxTe100−x are presented in figure 3.

Judging by the photos obtained the As20Te80 sample has a specific crystalline structure due to the sufficient excess of tellurium, the As40Te60 film looks like a two-phase one and the samples As50Te50 and As80Te20 are, presumably, one-phase, but formed by different structural units. The activation energies of photoconductivity of the AsxTe100x films are presented in the Table 4.

3.2.2. The XRD patterns of the As-Te plasma prepared films

The XRD measurements have been done for the films deposited on the crystal NaCl substrates at the substrate temperature 40 °C. All the prepared samples are of amorphous matter (figure 4(a)), except for the sample the chemical composition As40Te60 (figure 4(b)) [17] and corresponding curves illustrating the dependence of the signal intensity from the double angle 2θ, include only several broad and structureless bands.

The curve for the sample As40Te60 consists of reflexes corresponding to the As2Te3 crystal phase (figure 4(b) in insertion) and reflexes corresponding to the AsTe crystal phase. Due to similarity of the x-ray diffraction patterns of the samples in the figure 4 is represented only one pattern corresponding to the As50Te50 sample.
3.2.3. DSC measurements of the As–Te samples

In order to investigate the phase composition of the \( \text{As}_x\text{Te}_{100-x} \) plasma-prepared materials in the range from 310 to 620 K, the Differential Scanning Calorimeter (model: DSC 204 F1 Phoenix, Netzsch Gerätebau, Germany) was used. The calorimeter was calibrated and tested against melting of \( n \)-heptane, mercury, tin, lead, bismuth, and zinc. The temperatures and the enthalpies of transitions were evaluated according to the standard Netzsch Software Proteus procedure. The technique for determining of transition values according to the data of DSC measurements is described in detail in \([31]\) and the Netzsch Software Proteus. The heating rate and cooling rate were 5 K min\(^{-1}\). The measurement was carried out in argon atmosphere, 0.025 g of the compound under study was put in the aluminum crucible. The data of the measurements are illustrated in the figure 5. The SEM images are additionally given for each film in the insertion to illustrate the phase composition.

\( \text{As}_30\text{Te}_{80} \) sample has three exothermic crystallisation reactions at 415.8 K, 482.1 K and 514.9 K and one endothermic glass transition 373 K. In the previous paper \([20]\) the authors Titus and Asokan, reported only one crystallization pick at 415 K and one endothermic glass transition at 373 K for the \( \text{As}_x\text{Te}_{100-x} \) bulk samples with the arsenic content below 40 at%. But we know that the structure or, in our case, phase composition of the chalcogenide materials strongly depends on the method of their preparation.

The \( \text{Tg} \) at 373 K was explained in \([20]\) by the transition ’virgin glass (Tg) \( \rightarrow \) super cooled melt’ and the \( \text{Tc}_1 \) at 415 K was referred to the process of formation of hexagonal Te phase. The change in the phase state was proved by x-ray diffraction patterns of two glasses, \( \text{As}_{30}\text{Te}_{70} \) and \( \text{As}_{30}\text{Te}_{80} \), representing the region of 25–40 at% of arsenic. In the case of the plasma prepared \( \text{As}_{30}\text{Te}_{80} \) we can see two additional crystallization processes referred to formation of fss As–Te and monoclinic \( \text{As}_2\text{Te}_3 \) crystal phases at 482.1 K (\( \text{Tc}_2 \)) and 514.9 K (\( \text{Tc}_3 \)) K, respectively, that have not been observed previously in \([20]\). The identification of fss As–Te and monoclinic \( \text{As}_2\text{Te}_3 \) crystal

![Figure 4. The XRD data of the As\(_{30}\)Te\(_{80}\) (a) XRD and As\(_{30}\)Te\(_{80}\) (b).](image-url)
phases was done in [20] on the analysis x-ray diffraction patterns of As$_{40}$Te$_{60}$ glass annealed in a sealed evacuated (10 Torr) ampoule.

The sample As$_{40}$Te$_{60}$ possesses barely noticeable transition addressing to formation of hexagonal Te at 415 K, and one endothermic glass transition ‘virgin glass (Tg) → super cooled melt’ at 518.6 K, followed by two crystallisation picks at 524.4 and 553.5 K due to appearance of fss As-Te and monoclinic As$_2$Te$_3$ crystal phases [20]. The sample As$_{50}$Te$_{50}$ has one Tg of the transition ‘virgin glass (Tg) → super cooled melt’ at 473 K and one Tc at 520 K corresponding to formation of As-Te crystal phase.

And, finally, As$_{80}$Te$_{20}$ sample has two crystallization temperatures at 544 and 574.1 K referring to fss As-Te and monoclinic As$_2$Te$_3$ crystal phases [20]. The excess of arsenic, which is usually in the form of an amorphous phase, has not manifested itself from the point of view of phase transitions in the measured temperature range.

As intermediate conclusions we can formulate the following statements:

1. we once again confirmed the fact that the phase composition of chalcogenide materials significantly depends on the method of their preparation,
2. plasma-chemical method allows varying the phase composition, if necessary, by changing the quenching parameters on the substrate.

### 3.3. Raman spectroscopy of the As$_x$Te$_{100-x}$ plasma-prepared samples

Raman spectra of the As$_x$Te$_{100-x}$ plasma-prepared films are shown in figure 6. All the spectra consist of three broad picks referring to the vibration of structural fragments containing Te-Te at □160 cm$^{-1}$, As-Te at □197 cm$^{-1}$ and As-As bonds at □234 cm$^{-1}$. The sample As$_{20}$Te$_{80}$ containing excess of tellurium has the most intense peak at 160 cm$^{-1}$ attributed to vibrations of tellurium chains or their fragments in the As-Te glass net [24]. The Raman spectra of the As$_{40}$Te$_{60}$ and As$_{50}$Te$_{50}$ samples seem approximately symmetrical with a dominant band at 197 cm$^{-1}$—the vibration mode of the As$_{3}$Te$_{5/2}$ trigonal pyramid.

In the sample with composition As$_{80}$Te$_{20}$, amorphous arsenic exhibits a broad maximum at a frequency of 235 cm$^{-1}$; it is characteristic of glasses enriched with arsenic [22]. In paper [23] it was suggested that the structural ordering of As$_x$Te$_{100-x}$ films depends on two parallel reactions of dissociation that take place during the formation of the glass structure:

$$\text{As}_3\text{Te}_3 \equiv 2\text{As} + 3\text{Te} \quad (4)$$
This assumption is in a good agreement with our data obtained.

3.4. Mass-spectrometry of the arsenic telluride materials

Preliminary, the films were deposited on the soluble substrate (high-pure NaCl) and separated in deionized double distilled water. In order to get the mass-spectra of arsenic telluride films we exploited the standard analytical procedure, when 3–5 micrograms of the film were placed into a microreservoir of direct injection setup of QMS and entered via a vacuum gate directly into an ion source of the mass-spectrometer. The quartz glass microreservoir was gradually heated up from 35 to 500 °C at the rate of 50 °C/min. The mass-spectra of arsenic telluride materials deposited at various conditions were fixed in the mass number range 30–650 at an ionization energy of the electrons −75 eV. The spectra of two samples—As_{40}Te_{60} and As_{50}Te_{50} are presented in figure 7.

Both mass-spectra obtained include the structural units of the original films - As, Te, As₂, As₃, Te₂, As₄, AsTe₂, and As₂Te₂. The species of AsTe₂ are likely the pieces of As₂Te₃ phase and the fragments of As₂Te₂ look like the representatives of the As-Te phase. It looks logically, that with increase of arsenic content the concentration of the As-Te structural fragments increases. The presented spectra once again confirm the previously stated theory that the structure of the films is determined by the flow of two parallel reactions: As₂Te₃ ⇌ 2As + 3Te and AsTe ⇌ As + Te.

The obtained mass-spectra together with analysis of the exhausted gas mixtures allow us to talk about conversion of carbon-containing impurities during the process of plasma-chemical synthesis. Commercial high-pure precursors always include carbon in the form of nanoparticles due to two reasons. First of all, carbon is non-limiting impurity in terms of semiconductors. Secondly, there is a lack of appropriate methods of deep purification of arsenic and tellurium from nanoparticles of different nature. That is why in both mass-spectra, besides the main lines related to the structural fragments of the glass net, a large number of impurity lines of carbon derivatives are observed. With increase of the energy input the quantity of carbon-containing impurities with the masses less than 400 decreases, partly due to removing into trap and partly due to polymerization.
3.5. Transparency of As$_x$Te$_{100-x}$ films in the range of 2–25 microns

IR transparency of the plasma-prepared As$_x$Te$_{100-x}$ films was studied in the range of 2.0 to 25 µm. For this aim the films were synthesized on NaCl substrate of high purity. The results are presented in figure 8.

The sample with composition As$_{50}$Te$_{50}$ possesses the widest transparency window from 2.0 to, at least, 26 µm. The other films includes substantial quantity of As$_2$Te$_3$ phase and sharp decline near 22 µm. This feature appears, presumably, because of the fact that As$_{50}$Te$_{50}$ includes different structural fragments than the As$_2$Te$_3$, and these units do not manifest the bands of intrinsic absorption at 22 µm. This assumption correlates with the data of structural investigations reported in [24].

3.6. Investigation of photoconductivity of As$_x$Te$_{100-x}$ samples obtained at various plasma powers

The electrical conductivity of AsTe films was studied as follows. Two aluminum contacts 10 mm long with a distance of 0.5 mm between them were deposited in vacuum on clean glass substrates by magnetron sputtering. Then, over the contacts, the AsTe film of certain compositions were formed by plasma-chemical deposition. Measurement of electrical conductivity was carried out in vacuum at the temperatures from +60 to –100 °C, placing the samples in a thermostatic transparent cuvette. Temperature dependences of the dark current in AsTe films of different composition are shown in figure 9.

The temperature dependences of the photocurrent in AsTe films of different composition when irradiated with light from the wavelength of 795 nm at the intensity of 40 mW cm$^{-2}$ are presented in figure 10.

The electrical conductivity of the films increases with increase in the content of tellurium, while decrease in photosensitivity is observed. The temperature dependences of the dark and photoconductivity are of the activation character (figures 9, 10).
The dependences of the dark current on temperature are described by two exponents, which indicates two mechanisms of conductivity. Both mechanisms possess low activation energies and low values of the preexponential factor, which indicates the hopping mechanism of conduction over localized states in the forbidden zone of the amorphous semiconductor. Theoretical models of the mechanisms of conductivity in chalcogenide semiconductors have been repeatedly discussed in the works of other authors. In our case, the model of charged own defects \[32\] probably fits. Defects of this type arise due to the violation of the ground state of the chemical bond, and are charged dangling bonds \(D^+\) and \(D^-\) \[33–37\].

4. Conclusions

The \(\text{As}_x\text{Te}_{100-x}\) films of different chemical and phase composition have been prepared by changing of the energy input into the plasma discharge. As a result of this initiation by plasma, we get our precursors in the atomic excited state in the gas phase. Judging by the fact that As-Te molecular lines are absent in the spectra, we can assume that the reaction of formation of the As-Te solid phase occurs on the substrate simultaneously with the quenching process. We may also assume that the atomization of the initial clusters in plasma discharge seems to be the reason of deposition of the arsenic telluride materials with the more structurally and chemically uniform
The exhausted gas mixtures after each process were accumulated in the traps, cooled by liquid nitrogen and analyzed by chromate-mass-spectrometry. Both commercial precursors—arsenic and tellurium—include heterophase inclusions of the carbon nature. In plasma discharge their intensive conversion takes place. Judging by the Raman and mass-spectra obtained the structural ordering of As\textsubscript{x}Te\textsubscript{100-x} films depends on two parallel reactions of dissociation that take place during the formation of the glass structure: As\textsubscript{2}Te\textsubscript{3} \rightleftharpoons 2As + 3Te and AsTe \rightleftharpoons As + Te. The electrical conductivity of the films increases with increase in the content of tellurium, while decrease in photosensitivity is observed. The dependences of the dark current on temperature are described by two exponents, which indicates two mechanisms of conductivity. Both mechanisms possess low activation energies and low values of the preexponential factor, which indicates the hopping mechanism of conduction over localized states in the forbidden zone of the amorphous semiconductor.

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