

## IMPACT OF SUBSTRATE MATERIAL ON THE CdTe FILMS STRUCTURAL PROPERTIES

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Cadmium telluride (CdTe) has remained one of the most popular thin-film semiconductor materials for creating economical and efficient device structures, particularly thin-film solar cells for terrestrial applications. This is attributed to its optimal bandgap for photoelectric conversion under terrestrial conditions, high optical absorption coefficient enabling the use of thick absorber layers of a few micrometers, and the availability of material- and energy-efficient CdTe film deposition technologies. The world leader in industrial production of the most efficient CdS/CdTe solar modules is the company First Solar (USA). In 2020, the total electrical capacity of First Solar's manufactured solar modules reached 2.4 GW. In recent years, there has been a growing number of studies focusing on the application of cadmium telluride in device structures for purposes other than solar cells. In particular, the rapid switching effect between high and low conductivity states in CdTe has been discovered and actively researched. This effect can be utilized to create memory devices based on cadmium telluride. Additionally, there is potential for investigating the possibility of creating electronic device protection elements against electromagnetic pulses by exploiting the rapid switching effect in structures based on cadmium telluride. Commercial prospects have intensified scientific research in developing the physical and technical foundations of industrial technologies for obtaining device structures based on CdTe. Since the operation principle of these device structures is based on kinetic charge carrier transport processes, and the crystalline structure of the thin film directly influences the charge carrier parameters, the study of the influence of substrate materials on the structural properties of thin cadmium telluride films is a relevant task in thin-film materials science.

The investigation focuses on the influence of the substrate material on which thin films of cadmium telluride (CdTe) are deposited on their structural properties.

In the upgraded vacuum system UVN-74, layers of cadmium telluride (CdTe) were implemented and fabricated using the thermal vacuum evaporation method at various technological parameters of the substrate temperature ranging from 100 to 300 °C. The initial vacuum level in the vacuum chamber was maintained at  $10^{-5}$  Pa. The thickness of the obtained samples and the deposition rate were monitored using optical methods after the deposition process. The deposition of CdTe layers took place on glass substrates without a transparent conductive oxide sublayer to investigate the thickness and deposition rate of the layers, and with a sublayer of conductive oxide to study the influence of the substrate material on the structural parameters of the test samples.

Figures 1 depict the diffraction patterns example of the CdTe film obtained on a glass substrate. Tables 1 present the results of the diffraction analysis (intensity  $I$ , integral intensity  $I_{\text{int}}$ , lattice parameter  $d$ , full width at half maximum FWHM). Calculations of lattice parameters, coherent scattering domain (CSD) sizes, and film texture coefficients are provided in Table 2. As indicated by the results presented in Table 1, for this sample obtained on a glass substrate at a substrate temperature of 100 °C, only one phase can confidently be identified. This phase is denoted in the table as H1, and identified as the hexagonal phase of CdTe, which, according

to the JSPDC-19-0193 table, has a P63mc (186) structure with tabulated lattice parameter values  $a = 4.58 \text{ \AA}$ ,  $c = 7.50 \text{ \AA}$ .

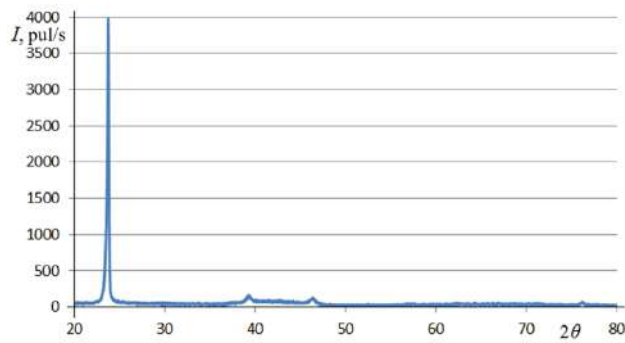


Fig. 1 – Diffraction pattern of the CdTe film obtained on a glass substrate at a substrate temperature of 100 °C.

Table 1 – Results of the diffraction analysis of the CdTe film obtained on a glass substrate at a substrate temperature of 100°C.

CdTe	2θ, deg	I, pulse	d, Å	I <sub>int</sub> , pulse	FWHM, deg
H1 (002)	23.7068 8	2715.06	3.7498 6	707.0 6	0.26487
H1 (110)	39.2007	42.33	2.2961 3	33.16	0.78327
galo	39.5 - 46				
C (311)	46.3054 6	40.16	1.9590 2	30.2	0.74778
H1 (006)	76.0661 2	17.22	1.2501 8	11.07	0.64201

On the diffraction pattern, there is also an observed peak at an angle of 46.305°, which may correspond to the cubic phase of CdTe, indicated in the table by the letter *c* and, according to the tables JSPDC-15-0770, 65-0440, 65-0880, 65-1081, 65-1082, 65-1085, 65-8395, has an F43m (216) structure with tabulated lattice parameter values of  $a = 6.48 - 6.483 \text{ \AA}$ . However, based on a single peak, it is not possible to definitively identify the presence of the phase; nevertheless, from the analysis of subsequent samples, it can be inferred that the cubic phase may indeed be present in this sample.

Table 2 – Lattice parameters, CSD sizes and stresses for the identified phases in CdTe films obtained on a glass substrate.

H1: $a = 4.58 \text{ \AA}$ , $c = 7.50 \text{ \AA}$							C: $a = 6.48 - 6.483 \text{ \AA}$		
T <sub>sb</sub> , °C	c, Å	a, Å	L, nm		ε		G	G	a, Å
			min	max	min	max			
100	7.501	4.593	1.84	2.33	-0.0651	-0.2555	1.08		6.497
200	7.503	4.593	3.37	3.54	0.0087	0.0358	1.63	0.47	6.495
300	7.505	4.588	5.09	5.43	-0.0046	-0.0294	1.26		
Cubic phase 300 °C			4.54	4.68	-0.0065	-0.0295		1.33	6.493

For the sample obtained on a glass substrate with a layer of transparent conductive oxide ITO at a substrate temperature of 200 °C, the presence of two hexagonal phases, H1 and H2, and a cubic phase C. was identified. Similar to samples obtained on purely glass substrates, it was found that the coherent scattering domain sizes increase with the temperature growth. Regardless of the film's phase composition, the main H1 phase exhibits texture for samples obtained at all temperatures. With an increase in temperature from 100 to 200 °C, the texturing of the H1 phase slightly decreases, but with further temperature increase to 300 °C, it significantly increases. The absolute value of stresses decreases by a factor of two as the substrate temperature increases from 100 to 200 °C, and with further temperature increase, the sign of stresses changes from "+" to "-" and decreases by two orders of magnitude.

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