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Fabrication of Cadmium Selenide (CdSe)–Porous Silicon (PSi) Solar Cell

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Chemical-bath deposition is used to prepare thin films of CdSe on *p*-type porous-silicon wafers at room temperature. Porous-silicon substrates are prepared using an electrochemical-etching method for etching time of 5 and 15 min. The energy gap of CdSe thin film is of 2.6 eV. Scanning electron microscope images and x-ray spectrum demonstrate that the films of the PSi–CdSe junction show that the films are crystalline with a small presence of the amorphous phase, and the grain size of CdSe compound is of about 38–41 nm.The junction shows I–V characteristics similar to that of ideal-diode and solar-cell characteristics.

Для приготування тонких плівок CdSe на пористих кремнійових пластинах *p*-типу за кімнатної температури використано метод хемічного осадження у ванні. Пористі кремнійові підкладинки виготовлено методом електрохемічного щавлення з часом щавлення у 5 і 15 хв. Енергетична заборонена зона для тонкої плівки CdSe становила 2,6 еВ. Зображення, одержані за допомогою сканівного електронного мікроскопа, та рентґенівський спектер демонструють, що плівки на переході PSi–CdSe були кристалічними з невеликою присутністю аморфної фази, а розмір зерен сполуки CdSe ≅ 38–41 нм. На переході показано вольт-амперні характеристики, подібні до характеристик ідеальних діод і сонячних елементів.

Key words: porous silicon, CdSe thin films, solar-cell characteristics, diode characteristics.

Ключові слова: пористий кремній, тонкі плівки CdSe, характеристики сонячних елементів, характеристики діод.

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1. INTRODUCTION

Thin film of cadmium-selenide material has good optical and structural properties for the application of solar cell [1]. CdSe is highly photosensitive and has suitable band gap (of 1.7 eV) that matches the maximum intensity in the visible range of the solar spectrum. Compared to bulk form, nanoparticles of CdSe have gained more attention of researchers because of their interesting characteristics as window layer in photovoltaic cell (PV cell) [2]. These properties making CdSe suitable for several application, including optoelectronic applications [3], solar-cell applications [4], field effect transistor [5], light emitting diode [6], biomedical imaging devices [7]. Several techniques have been used in the preparation and doping of CdSe such as pulsed laser deposition [8], thermal evaporation [9], chemical-bath deposition [10, 11], spray pyrolysis [12, 13], and electrodeposition [14–16].

In our study, thin films of CdSe have been deposited on *p*-type porous-silicon substrate. Scanning electron microscope, x-ray spectroscopy and UV–Visible spectrometer were used to measure structural properties of PSi–CdSe junction.

2. EXPERIMENTAL METHOD

The photoelectrochemical-etching technique of porous silicon (*p*-type) with an orientation (111) and resistivity of 1–10 Ω·cm was used. The sample of wafer silicon was dipped into an aqueous solution of HF (18 wt.%) and ethanol (99.9%) (1:1). The applied current was fixed at 15 mA/cm^2, and etching time was used of 5 and 15 min. Additionally, ethanol solution has a key role to increase the wet strength of the porous-silicon substrate that is important to enhance the lateral homogeneity of the PSi surface. Furthermore,

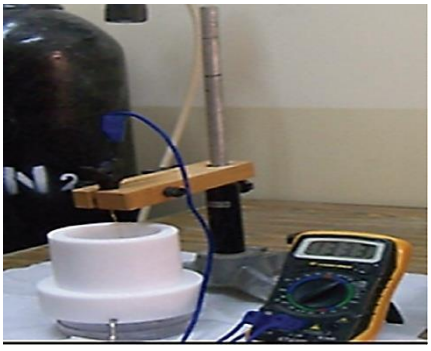

Fig. 1. Photoelectrical cell.

the etching cell was made of teflon connected with a rubber O-ring of 1.5 cm^2 diameter to permit it to touch the silicon wafer. The current was fixed by two electrodes; the first electrode is a stainless steel that was placed below the platinum-electrode electrolyte silicon. The cathode (second electrode) is a circular gold that is covered in the HF electrolyte; it is placed between the top part of an aluminium ring and the teflon (Fig. 1).

3. RESULTS AND DISCUSSION

Thin films of CdSe have been deposited on glass substrates and porous-silicon wafers.

The optical, structural, and electrical properties of CdSe thin films and PSi–CdSe junction have been investigated.

The optical properties of the CdSe thin films are shown in Figs. 2, 3; the transmittance and refractive index increase with incident wavelength over the visible wavelength, while the absorbance and extinction coefficient decrease with wavelength. The energy gap of CdSe thin films was of about 2.6 eV.

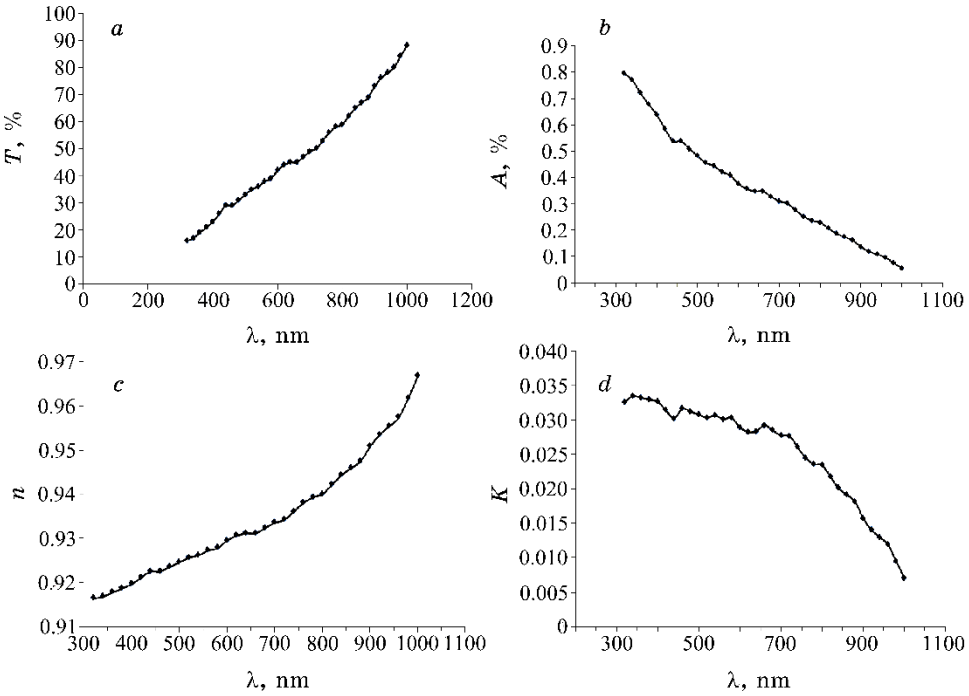

Fig. 2. The optical properties of CdSe thin film: (*a*) transmittance; (*b*) absorbance; (*c*) refractive index; (*d*) extinction coefficient.

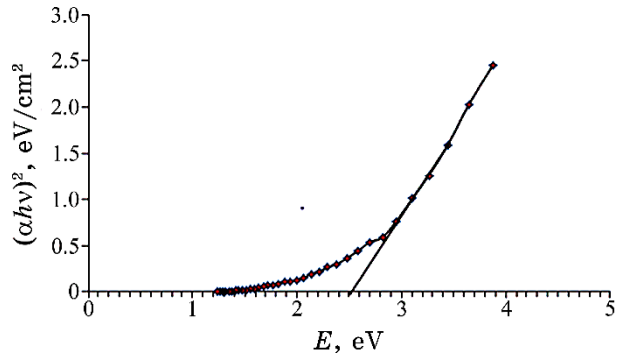

Fig. 3. The optical properties and energy gap of CdSe thin films.

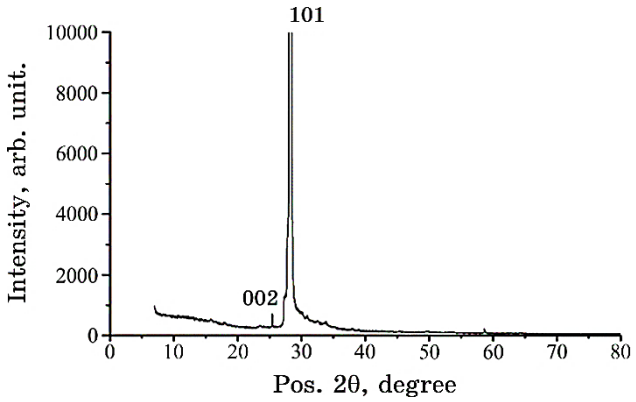

Fig. 4. XRD patterns of CdSe ('24 hrs–5 min' symbolically).

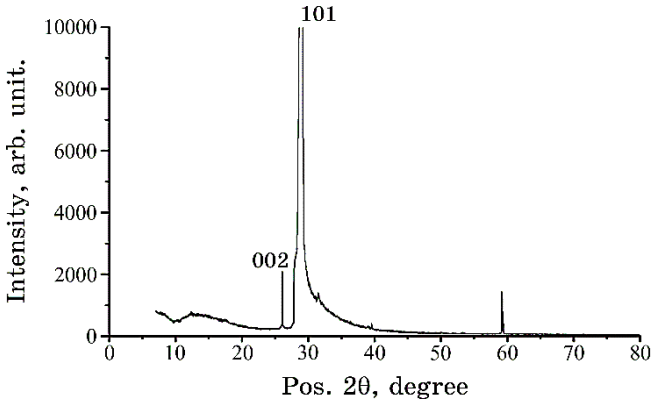

Fig. 5. XRD patterns of CdSe ('24 hrs–15 min' symbolically).

The x-ray spectrum of PSi–CdSe junction (24-hrs deposition time of CdSe film and 5-min etching time of silicon) shows two peaks; one of them was a distinctive high-intensity peaks at $2\theta = 28.8°$ (b.c.c. structure) with orientation (101); the second low-intensity peak appears at $2\theta = 26.2°$ with orientation (002) (Fig. 4). The x-ray spectrum of the other PSi–CdSe junction (24-hrs deposition time of CdSe film and 15-min etching time of silicon) shows a distinctive single high-intensity peaks at $2\theta = 29.8°$ with (b.c.c. structure) orientation (101). The other low-intensity peaks appear at $2\theta = 27.67°$ reflecting different structures with orientations (002) (Fig. 5).

The scanning electron microscope images of the samples prepared during 24-hrs deposition time of CdSe and 5-min etching time of silicon are shown in Fig. 6; they show inhomogeneous distribution of nanoparticles of CdSe compound covering the sample surface; the images also showed that the average grain size was within the range near 41.9075 that agree with XRD results. In Figure 7, the scanning electron microscope images of the samples prepared during 24-hrs

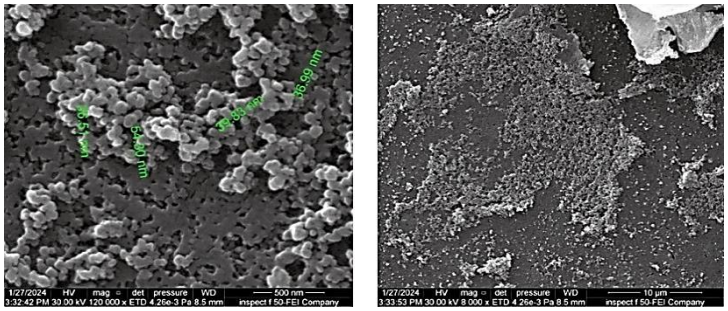

Fig. 6. Field-emission scanning electron microscopy (FESEM) picture of PSi–CdSe with CdSe deposition time of 24 hrs and silicon etching time of 5 min.

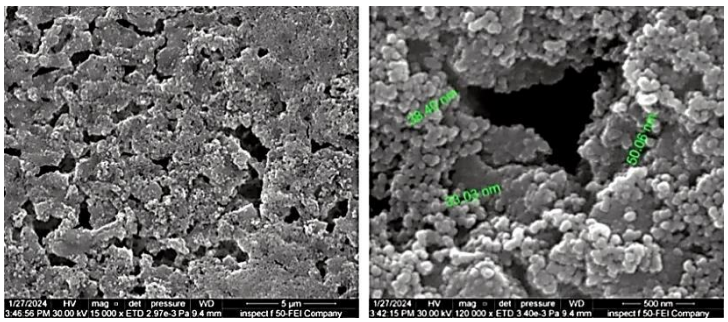

Fig. 7. FESEM picture of PSi–CdSe with CdSe deposition time of 24 hrs and silicon etching time of 15 min.

TABLE 1. Average grain size of PSi–CdSe junction.

Sample	Pos. 2θ, °	*FWHM* left, 2θ, °	*D*, nm	Average grain size, nm
Deposition time of CdSe—24 hrs. Etching time of silicon—15 min	7.2419	3.2168	2.474851	40.19941084
	12.5785	3.775	2.117426	
	15.3728	1.8086	4.432812	
	26.0562	0.0635	128.424	
	28.5163	0.767	10.68772	
	28.8293	0.3533	23.2188	
	28.8646	0.0753	108.9489	
	28.9302	0.8015	10.23713	
	29.2693	0.6624	12.39638	
	30.5024	1.8478	4.456624	
	38.8264	0.3838	21.94805	
	59.2158	0.0597	153.0503	
Deposition time of CdSe—24 hrs. Etching time of silicon—5 min	14.3183	1.5622	5.125841	38.05298087
	18.002	0.2127	37.81938	
	23.5521	0.0586	138.496	
	25.3949	0.1153	70.63481	
	27.4487	0.4005	20.42072	
	27.7909	0.1845	44.36041	
	28.2043	0.1235	66.33079	
	29.5605	1.0648	7.716785	
	31.1957	1.5861	5.200614	
	32.8832	2.5677	3.226081	
	33.8205	1.9111	4.345094	
	37.9183	0.3665	22.92084	
	38.8808	0.0727	115.8882	
	45.3173	0.1635	52.65465	
	49.6394	1.089	8.037551	
	53.5337	1.3898	6.402139	
	58.6366	0.1232	73.95355	
	63.7559	6.5868	1.420229	

deposition time of CdSe and 15-min etching time of silicon are shown; the images show the formation of CdSe nanotubes with various orientations covering the entire sample surface with presence of some clusters. The average grain size of CdSe was of about 40.497 nm, and this agrees with XRD results (Table 1) too.

The *I–V* characteristics of the PSi–CdSe have been measured for both samples (Fig. 8). The junctions show ideal characteristics of the diode in both forward and revers bias. The solar-cell characteristics of the PSi–CdSe also have been measured for both samples (Fig. 9). The junctions show ideal solar-cell characteristics, where the out power, efficiency and fill factor increase with etching time of silicon as shown in Fig. 8 and Table 2.

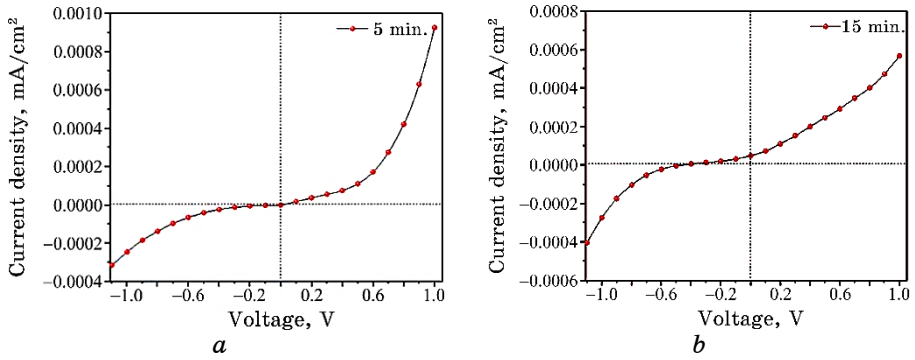

Fig. 8. *I–V* characteristics of the PSi–CdSe junction: (*a*) 24-hrs deposition time of CdSe and 5-min etching time of silicon; (*b*) 24-hrs deposition time of CdSe and 15-min etching time of silicon.

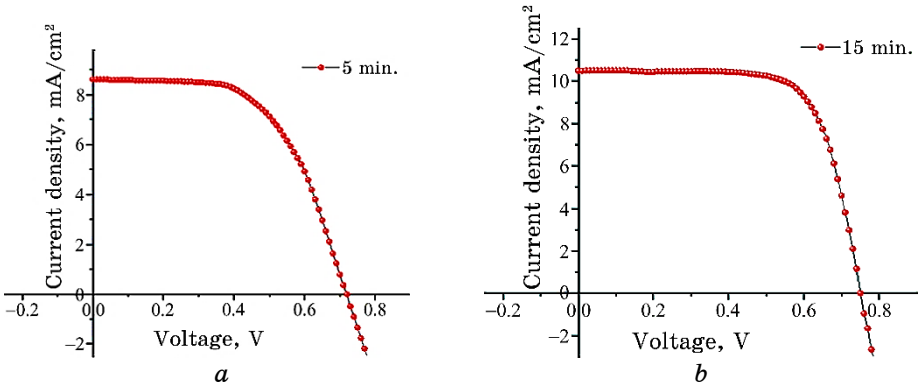

Fig. 9. Solar-cell characteristics of the PSi–CdSe junction: (*a*) 24-hrs deposition time of CdSe and 5-min etching time of silicon; (*b*) 24-hrs deposition time of CdSe and 15-min etching time of silicon.

TABLE 2. Out power, efficiency, and fill factor of PSi–CdSe solar cell.

Parameters	Unite	Deposition time—24 hrs, etching time—5 min	Deposition time—24 hrs, etching time—15 min
Area	Cm^2	1	1
P_{in}	Mw/cm^2	100	100
J_{sc}	mA/cm^2	2.385	2.507
V_{oc}	V	0.330	0.360
J_{max}	mA/cm^2	2.021	2.203
V_{max}	V	0.250	0.270
FF		0.642	0.659
PCE	%	0.505	0.595

4. CONCLUSIONS

Thin films of CdSe have been deposited for 24-hrs deposition time; the film was deposited on porous silicon prepared during 5-min and 15-min etching periods. The energy gap of CdSe thin films was of 2.6 eV. The grain size of both junctions was of about 38–41 nm. The junctions show ideal characteristics of diode and solar cell. The fill factor and efficiency was of 0.642, 0.505 for 5-min etching time junction and 0.659, 0.595 for the 15-min etching time junction, respectively.

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