Наносистеми, наноматеріали, нанотехнології
Nanosistemi, Nanomateriali, Nanotehnologii
2026, т. 24, № 1, сс. 97–103
https://doi.org/10.15407/nnn.24.01.0097

PACS numbers: 42.70.Qs, 72.40.+w, 78.40.Fy, 78.67.-n, 84.60.Jt, 88.40.hj

Solar-Cell Properties of Porous Silicon/Cadmium Telluride Junction

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PSi–CdTe junction is prepared using spray pyrolysis and photoelectrochemical etching methods; the deposition method of thin CdTe films is performed at 90°C; thin CdTe films are completely crystalline with energy gap of 2.4 eV. The grain sizes are investigated using SEM and x-ray spectroscopy; both measurement techniques show that the grain sizes are within the nanoscale. The junction show *I–V* characteristics similar to the diode in both forward and reverse bias; the junction also show solar-cell characteristics with fill factor of 0.594.

Перехід PSi–CdTe одержано методами розпорошувальної піролізи та фотоелектрохемічного щавлення; метод осадження тонких плівок CdTe виконано за температури у 90°C; тонкі плівки CdTe є повністю кристалічними із забороненою енергетичною зоною у 2,4 еВ. Розміри зерен досліджено за допомогою сканівної електронної мікроскопії та рентґенівської спектроскопії; обидва методи міряння показують, що розміри зерен знаходяться в наномасштабі. Перехід демонструє вольт-амперні характеристики, подібні до діоди, як у прямому, так і у зворотньому зміщенні; перехід також демонструє характеристики сонячного елемента з коефіцієнтом заповнення у 0,594.

Key words: porous silicon, cadmium telluride, thin films, semiconductors, optical properties of semiconducting thin films, diode characteristics, solar-cell characteristics.

Ключові слова: поруватий кремній, телурид Кадмію, тонкі плівки, напівпровідники, оптичні властивості напівпровідникових тонких плівок,

характеристики діоди, характеристики сонячних елементів.

(Received 7 September, 2024; in revised form, 8 October, 2024)

1. INTRODUCTION

Cadmium telluride CdTe is one of the II–VI group semiconductors; cadmium telluride has unique properties, which enable it to enter into many applications, including gamma-ray detection [1], fuel cells [2], photocatalytic hydrogen production [3], sensors [4, 5], laser materials [6], and solar panels [7]. It is a *p*-type semiconductor and can be converted to *n*-type by heat treatment [8], has a band-to-band energy gap of about 1.4–1.5 eV [9–12], high absorption coefficient of 10^4 cm^{-1} [13, 14]. Cadmium telluride can be deposited *via* different easy methods including chemical bath deposition [15–17], flash evaporation [18], close spaced sublimation [19], spray method [20], thermal evaporation [21, 22], and electrodeposition [23].

In our work, thin CdTe films have been deposited on porous silicon to fabricate PSi–CdTe solar cell; the optical, structural, and electrical properties were measured for thin CdTe films and PSi–CdTe junction.

2. EXPERIMENTAL METHOD

n-type silicon wafer was used as a substrate to construct PSi–CdTe solar cell. The silicon wafer was etched to obtain the porous silicon using photoelectrochemical-etching technique; the method was performed with etching current of 15 mA/cm^2, etching period of 10 min with 18 wt.% HF and ethanol (99.9%) (1:1) aqueous solution [24].

Tellurium oxide TeO_2 was dissolved in 25 ml distilled water in-

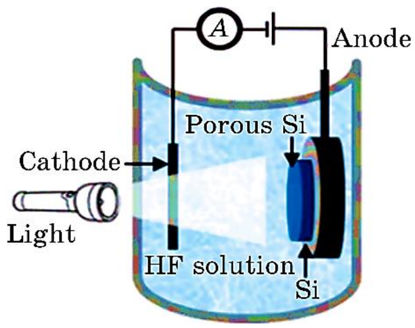


Fig. 1. Experimental setup for the fabrication of porous silicon by electrochemical etching of silicon wafers [25].

cluded 5 ml HCl, while $ZnCl_2$ was dissolved in 25 ml of distilled water; both solutions were mixed for 1 hr at 90°C using magnetic stirrer. Finally, the deposition of the mixture was performed using spray-pyrolysis method with deposition temperature of 100°C, 20 sprays, nozzle distance of 30 cm, and air pressure of 7.5 kg/cm^2.

3. RESULTS AND DISCUSSION

Thin films of CdTe on porous silicon were deposited; the optical, structural, and electrical properties of the CdTe film and the junction have been discovered.

The film show a high transmittance, which increases with wavelength, where the maximum transmittance was of 97.3. The absorbance spectrum has a peak at wavelength of 540 nm, which belong to the CdTe nanotubes (Fig. 2).

The energy gap of the cadmium-telluride films was calculated using Scherrer equation; it was of about 2.4 eV (Fig. 3).

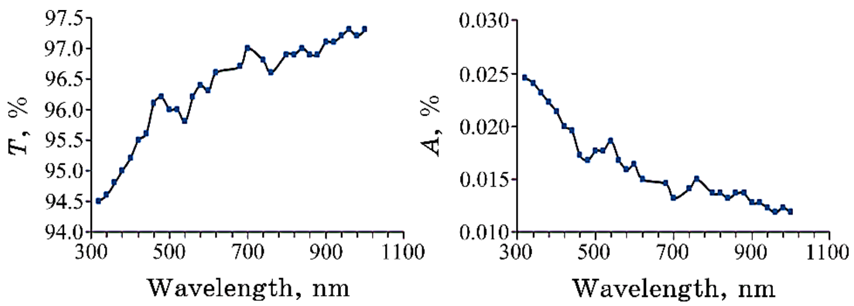


Fig. 2. The transmittance and absorbance of thin CdTe films.

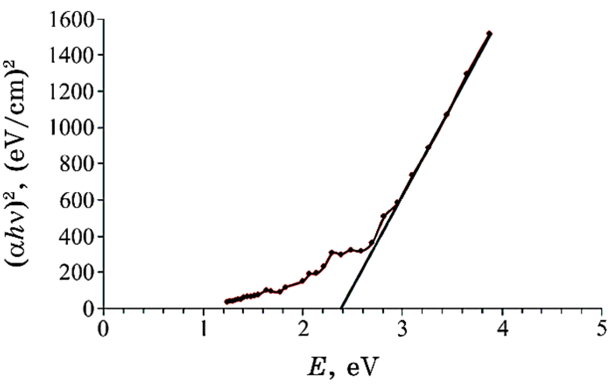
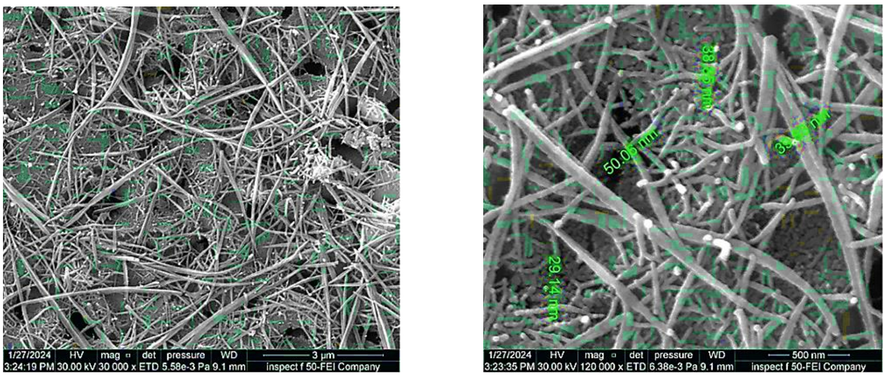


Fig. 3. Energy gap of thin CdTe films.

Field-emission scanning electron microscope has been used in the examining of thin CdTe films (Fig. 2); the images show the for-



a *b*

Fig. 4. FE–SEM images of thin CdTe films on porous silicon substrate: (*a*) magnification ×30000, (*b*) magnification ×120000.

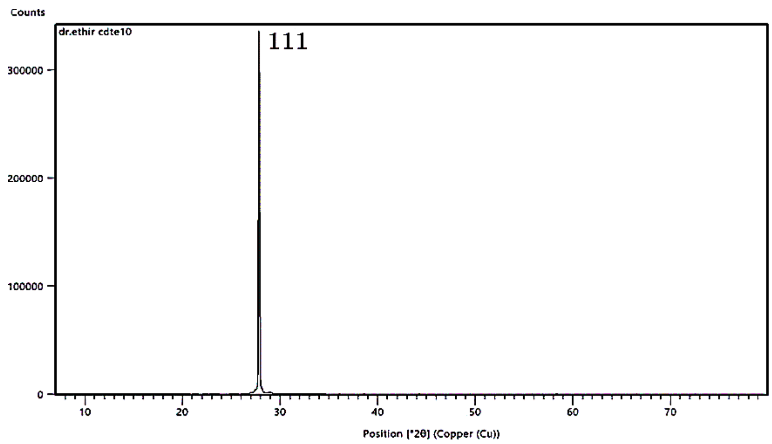


Fig. 5. XRD spectrum of thin CdTe films on porous silicon substrate.

TABLE 1. The average grain size of thin CdTe film.

2-theta, θ	*FWHM* [2Th.]	*D*, nm	Average grain size, nm
27.0091	0.4489	18.20207032	
27.7446	0.5628	14.54100846	
27.832	0.0858	95.39885917	37.07802849
27.9339	0.1667	49.1123415	
28.8395	1.0083	8.135862994	

mation of the CdTe nanotube in different orientations and diameters; the average nanotube diameters was of about 39.47 nm.

XRD spectrum of the CdTe shows that the film was completely crystalline, where a single significant peak appear at $2\theta = 27.82°$ with the (111) orientation. The average grain size was calculated using Scherrer equation; it was equal to 37.07802849 nm (Fig. 5 and Table 1); this result agrees with the FE–SEM image.

The electrical properties of PSi–CdTe junction were investigated; the junction show *I–V* characteristics similar to diode characteristics in both forward and reverse bias as shown in Fig. 6. PSi–CdTe junction also show solar-cell characteristics with short circuit current density of 9.362 mA/cm^2, open circuit voltage of 0.730 V, fill factor of 0.594, and efficiency of 4.061% (see Fig. 7 and Table 2).

4. CONCLUSIONS

Thin films of CdTe have been deposited *via* spray-pyrolysis method

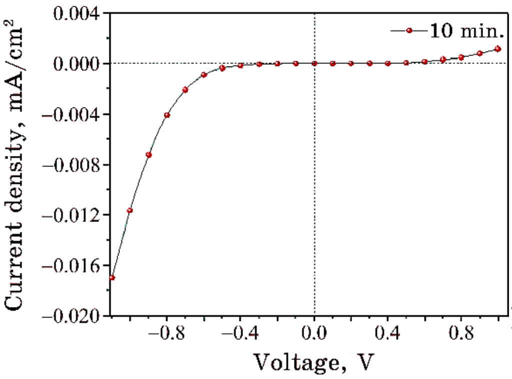


Fig. 6. *I–V* diode characteristics of PSi–CdTe junction.

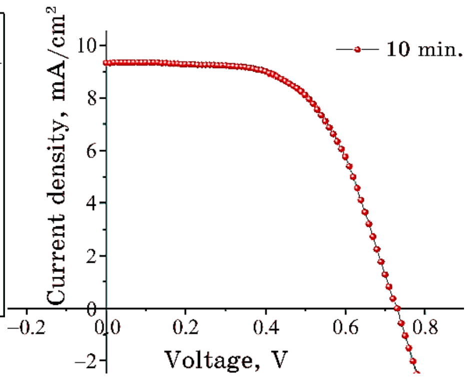


Fig. 7. Solar-cell characteristics of PSi–CdTe junction.

TABLE 2. Solar-cell parameters' values of PSi–CdTe junction.

Area	cm^2	10 min
P_{in}	mW/cm^2	100
J_{sc}	mA/cm^2	9.362
V_{oc}	V	0.730
J_{max}	mA/cm^2	8.122
V_{max}	V	0.500
FF		0.594
PCE	%	4.061

on porous silicon, which has already been prepared using photoelectrochemical etching technique. The energy gap of thin CdTe films was of 2.4 eV. The grain sizes were measured using SEM images and x-ray spectrum; they were of about 39.47 nm and 37.07 nm, respectively. The x-ray spectrum shows also that the film was completely crystalline. The PSi–CdTe junction show diode and solar-cell characteristics with fill factor of 0.594 and efficiency of 4.061%.

ACKNOWLEDGMENTS

We would like to thank our college and university for the assistance they provided in completing our research.

REFERENCES

1. S. C. Ray and K. Mallick, *International Journal of Chemical Engineering and Applications*, **4**, Iss. 4: 183 (2013); doi:10.7763/IJCEA.2013.V4.290
2. X. Ai, S. Yan, Y. Chen, S. Chen, Y. Jiang, X. Song, and X. Wu, *Journal of Luminescence*, **252**: 119372 (2022); https://doi.org/10.1016/j.jlumin.2022.119372
3. Z. Fan, W. Weng, J. Zhou, D. Gu, and W. Xiao, *Journal of Energy Chemistry*, **58**: 415 (2021); https://doi.org/10.1016/j.jechem.2020.10.049
4. Azqa F. Butt, M. Azhar, Hassan Yousaf, K. M. Batoo, Dilbar Khan, M. Noman, Mujeeb U. Chaudhry, Shahzad Naseem, and Saira Riaz, **10**, Iss. 3: 24492 (2024); https://doi.org/10.1016/j.heliyon.2024.e24492
5. A. U. Yimamu, M. A. Afrassa, B. F. Dejene, O. K. Echendu, K. G. Tshabalala, J. J. Terblans, and S. J. Motloung, *Materials Research Express*, **10**, No. 5: 056403 (2023); doi:10.1088/2053-1591/acd322
6. Subhash Chander, A. Purohit, C. Lal, and M. S. Dhaka, *Materials Chemistry and Physics*, **185**: 202 (2017); https://doi.org/10.1016/j.matchemphys.2016.10.024
7. H. I. Salim, V. Patel, A. Abbas, J. M. Walls, and I. M. Dharmadasa, *Journal of Materials Science: Materials in Electronics*, **26**: 3119 (2015); https://doi.org/10.1007/s10854-015-2805-x
8. Antonio Arce-Plaza, Fernando Sánchez-Rodriguez, Maykel Courel-Piedrahita, Osvaldo Vigil Galán, Viviana Hernandez-Calderon, Sergio Ramirez-Velasco, and Mauricio Ortega Lypez, *Coatings and Thin-Film Technologies*: *CdTe Thin Films: Deposition Techniques and Applications* (Eds. Jaime Andres Perez-Taborda and Alba G. Avila Bernal) (Intechopen: 2018), p. 131; doi:10.5772/intechopen.79578
9. B. A. Ahmed, I. H.Shallal, and F. I. Mustafa Al-Attar, *Journal of Physics: Conference Series*, **1032**, No. 1: 012022 (2018); doi:10.1088/1742-6596/1032/1/012022
10. G. S. Sanyal, A. Mondal, K. C. Mandal, B. Ghosh, H. Saha, and M. K. Mukherjee, *Solar Energy Materials*, **20**, Iss. 5–6: 395 (1990); https://doi.org/10.1016/0165-1633(90)90031-U
11. A. Bosio, G. Rosa, and N. Romeo, *Solar Energy*, **175**: 31 (2018);

doi:10.1016/j.solener.2018.01.018
12. D. G. Diso, T. S. Bichi, M. A. Y. Hotoro, I. A. Faragai, and A. O. Musa, *Bayero Journal of Pure and Applied Sciences*, **8**, Iss. 2: 58 (2015); doi:10.4314/bajopas.v8i2.11
13. R. S. Kapadnis, S. B. Bansode, A. T. Supekar, P. K. Bhujbal, S. S. Kale, S. R. Jadkar, and H. M. Pathan, *ES Energy & Environment*, **10**: 3 (2020); https://dx.doi.org/10.30919/esee8c706
14. Kazi Sajedur Rahman, Muhammad Najib Harif, Hasrul Nisham Rosly, Mohamad Ibrahim Bin Kamaruzzaman, Md. Akhtaruzzaman, Mohammad Alghoul, Halina Misran, and Nowshad Amin, *Results in Physics*, **14**: 102371 (2019); https://doi.org/10.1016/j.rinp.2019.102371
15. M. Mahendar, A. K. Chaudhary, Ganesh Damarla, and Vinay Gupta, *2019 Workshop on Recent Advances in Photonics (WRAP) (13–14 December, 2019)* (Guwahati, India: IEEE: 2019); doi:10.1109/WRAP47485.2019.9013662
16. M. Soliman, A. B. Kashyout, M. Shabana, and M. Elgamal, *Renewable Energy*, **23**, Iss. 3–4: 471 (2001); https://doi.org/10.1016/S0960-1481(00)00153-1
17. S. Surabhi, S. Rajpal, and S. R. Kumar, *Materials Today: Proceedings*, **44**: 1463 (2021); https://doi.org/10.1016/j.matpr.2020.11.635
18. S. H. Ibraheem, *Journal of the College of Basic Education*, **21**, Iss. 88: 117 (2015); https://doi.org/10.35950/cbej.v21i88.9957
19. Todd A. Schneider, Jason A. Vaughn, Kenneth H. Wright, and Brandon S. Phillips, *IEEE 42nd Photovoltaic Specialist Conference (PVSC) (14–19 June, 2015, New Orleans, LA, USA)*; doi:10.1109/PVSC.2015.7355909
20. V. M. Nikale, S. S. Shinde, C. H. Bhosale, and K. Y. Rajpure, *Journal of Semiconductors*, **32**, Iss. 3: 033001 (2011); doi:10.1088/1674-4926/32/3/033001
21. S. A. Fadaam, M. H. Mustafa, A. H. Abd AlRazaK, and A. A. Shihab, *Energy Procedia*, **157**: 635 (2019); https://doi.org/10.1016/j.egypro.2018.11.229
22. H. M. Ali and M. H. Mustafa, *Chalcogenide Letters*, **20**, Iss. 6: 431 (2023); https://doi.org/10.15251/CL.2023.206.431
23. A. U. Yimamu, M. A. Afrassa, B. F. Dejene, O. K. Echendu, K. G. Tshabalala, J. J. Terblans, and S. J. Motloung, *Materials Research Express*, **10**, Iss. 5: 056403 (2023); https://doi.org/10.1016/j.rinp.2019.102371
24. I. A. Younus, A. M. Ezzat, and M. M. Uonis, *Nanocomposites*, **6**, Iss. 4: 165 (2020); doi:10.1080/20550324.2020.1865712
25. Gonzalo Recio-Sánchez, Ramyn J. Peláez, and Raúl J. Martín-Palma, *Porous Silicon: An Attractive Material for Biomedical Uses. Inorganic Frameworks as Smart Nanomedicines* (William Andrew Publishing: 2018), Ch. 3, p. 93–135; https://doi.org/10.1016/B978-0-12-813661-4.00003-1