Akeel M. Kadim
Ali K. Attia

Department of Medical Physics, College of Science, Al Karkh University of Science, Baghdad, IRAQ

Colloidal Synthesis of CdTe Nanocrystals by Laser Ablation and Fabrication of Hybrid Light Emitting Device

Cadmium telluride (CdTe) nanocrystals (NCs) have gained the interest of researchers as an electrode material in hybrid light emitting devices (HLEDs) due to their potential high ability. In this study, CdTe nanocrystals were synthesized applying a 600 mJ Nd: YAG laser with 150 pulses to create a light emitting device consisting of ITO/CdTe/TPD/Ni. The spectra of CdTe NCs have been measured using UV-VIS and photoluminescence. The energy gap (Eg) within cadmium telluride (CdTe) NCs described as the (PL) spectrum has been determined to be around 3.6 eV. Cadmium telluride (CdTe) NCs developed via laser ablation improve the performance of the HLEDs by enhancing the carrier's charge mobility and, as an additional reward, by increasing recombination reactions inside cadmium telluride (CdTe) NCs with TPD organic polymer. In addition to illumination at 3V, current-voltage (I-V) requirements determine the appropriate environment and formation.

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1. Introduction

The generation of electrical power from photovoltaic light conversion is gradually increasing. This may be ascribed to the development of novel renewable energy materials and low-cost production systems, which has resulted in a decrease in the cost of a watt-hour generated by photovoltaic means. Using polycrystalline semiconductor thin films is an intriguing approach to lower the cost of photovoltaic cells [1]. The covers of batteries are made up of several semiconductor and conductive organic polymer layers, including the absorber or active material. Cadmium tellurium (CdTe), silicon (Si), gallium arsenide (GaAs), N, N′-Bis(3-methylphenyl)-N,N′-diphenylbenzidine (TPD), and poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) [1,2] are now used in the industrial fabrication of high-efficiency light emitting devices [2].

For many years, researchers have been interested in the cadmium telluride (CdTe) semiconductor, which belongs to the II-VI family owing to their suitable band gaps and high absorption coefficients. Cadmium telluride (CdTe) has mostly been investigated in the last ten years as a polycrystalline thin film and as a nanocrystal [3], and a cadmium telluride (CdTe) has been identified as an interesting thin-film HLEDs material. It has been created as a thin film using laser ablation, electrodeposition, and spray pyrolysis, and it has mostly been employed as the absorber material of thin-film photovoltaic [3,4]. Recent cadmium telluride (CdTe) deposition techniques are based on dispersing cadmium telluride (CdTe) nanocrystals in water or organic solvents [4-6] and transforming them into cadmium telluride (CdTe) thin films utilizing simple and inexpensive deposition processes such as dip-coating or spin-coating and an annealing procedure. Many approaches have lately been studied in order to overcome the limitations of cadmium telluride (CdTe) nanocrystals-based cathode [5,6]. Furthermore, when already realized on a combination (CdTe nanocrystals and TPD organic polymer), all of these components should be as large as possible in order to set up a technique. A standard approach to generate transparent devices, as proved in nanocrystals and organic semiconductors, is working to components with low contrast sensitivity and high absorbance [6,7]. However, nanostructured cadmium telluride (CdTe) with a high surface area promotes electrolyte side reactions, resulting in irreversible capacity loss during the first cycle. Furthermore, this method is insufficient to increase cadmium telluride (CdTe) high electric conductivity altogether. To further overcome the constraints of the cadmium telluride (CdTe) cathode, nanostructured materials might be blended with a highly conductive and elastic matrix to form a nanocomposite structure [8,9]. One of the most important problems in this work is controlling the thickness of the layers while depositing them on the indium tin oxide (ITO) glass substrate. As the thickness of the layer's increases, it causes a disconnection in the electrical current passing through the device. Therefore, the deposition of the layers must be controlled, and the best solution for this is to deposit the layers separately from the others in a way chemical spraying and drying in oven. Laser ablation synthesis (LAS) in solution is a physical approach that may be used instead of chemicals. Typically, the methods most often

employed for the creation of nanoparticles involve the use of toxic substances as indicators as well as reducing or stability agents [9]. In addition, LAS has a low environmental effect since it does not require any preparations or reducing chemicals and may produce high purity colloids while producing no toxic waste [10]. Laser-ablation synthesis techniques have emerged as an effective and adjustable technique for nanomaterials synthesis [8-10], demonstrating the ability to be used for the synthesis of nanostructures using several starting materials in a variety of liquid environment.

In the current assignment, a simple sustainable synthesis method for reconstructing colloidal cadmium telluride (CdTe) nanocrystals are used by laser ablation deposition with a TPD layer on the ITO surface to fabricate cadmium telluride (CdTe) hybrid light-emitting devices (CdTe-HLEDs), as well as to study the effectiveness of the resulting CdTe-HLEDs. The electrolayer that adds cadmium telluride (CdTe) nanocrystals to the surface of the TPD substrate allows more surface area to increase, demonstrates high specific capacity, great cycle stability, and distinguished rate performance. These features make cadmium telluride (CdTe) nanocrystals a remarkable fitting as emissive material in CdTe-HLEDs. Also makes the HLEDs environment friendly for the better reversible performance of the light emitting device environment.

2. Experimental Part

All of the main compounds were purchased from Fluka Company, which were employed without further purification. In the beginning 0.8 g of cadmium chloride ($CdCl_2$) and 0.3 g of sodium telluride (Na_2Te) were dissolved in 40 ml of deionized water. The Nd: YAG laser operating at (1064 nm) with energy up to 600 mJ/pulse was used to synthesis cadmium telluride (CdTe) nanocrystals (see Fig. 1).

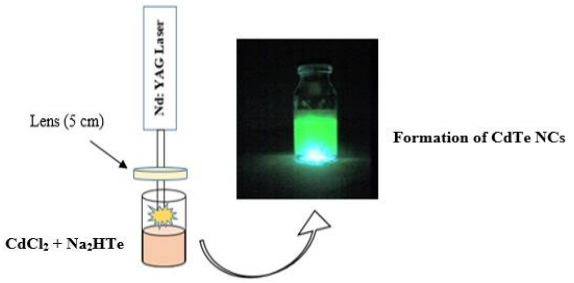


Fig. (1) Laser ablation technique used for prepare of cadmium telluride (CdTe) nanocrystals colloidal

The laser beams of a focal length of 20 cm focused on the mixed solution from a lens distance of 5 cm. A container was formed for generating homogenous nanocrystals and stirred for 2 hours before passing the nanocrystals solution with an increased pulse number of 150 pulses, allowing the color of the cadmium telluride (CdTe) nanocrystals solution change to light green. The cadmium telluride (CdTe) nanocrystals were then cleaned five times with deionized water before being completely vacuum packed.

The hybrid light emitting device was developed applying two layers of cadmium telluride (CdTe) nanocrystals and TPD. organic polymer provided by Sigma-Aldrich Chemie GmbH. Organic polymer coating dissolving 40 mg/ml in ethanol and injection by syringe on ITO glass substrate using covered spinning at 2000 r.p.m. in around 10 second for separate covered polymers. To avoid crashes, the first layer was 0.2 wt% cadmium telluride (CdTe) nanocrystals in the cover, the second layer was always layer TPD conductive polymer. Immediately after coating in a 40 °C oven for 10 minutes, the coating on each cover dries away. The thicknesses of the films have been measured by interference method (Tolansky method of thin film thickness measurement) while the thickness of TPD layer appear to be 30 nm, while a cadmium telluride (CdTe) nanocrystals cover appears to be 10 nm thick. Next that, a nickel (Ni) cathode is coated in system layer. Hybrid light emitting devices that process cadmium telluride (CdTe) nanocrystals covering TPD may increase the transport rates of cadmium telluride (CdTe) and TPD ions in HLEDs in response to light emitting device operations.

3. Results and discussion

Figures (2) and (3) illustrate the absorption and photoluminescence spectra of cadmium telluride (CdTe) nanocrystals at room temperature. The absorption spectrum in the UV-visible region of high-level cadmium telluride (CdTe) nanocrystals is shown. These findings have been obtained in an adequate setting when compared to the absorption spectra of previous studies [11-13].

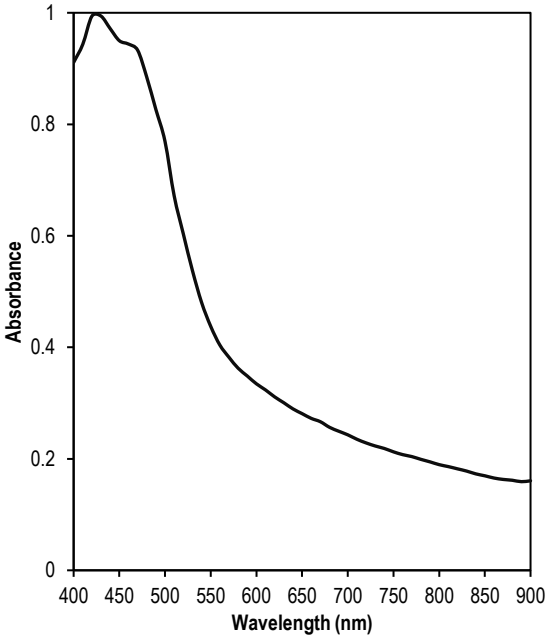


Fig. (2) Absorption spectrum of cadmium telluride (CdTe) nanocrystals

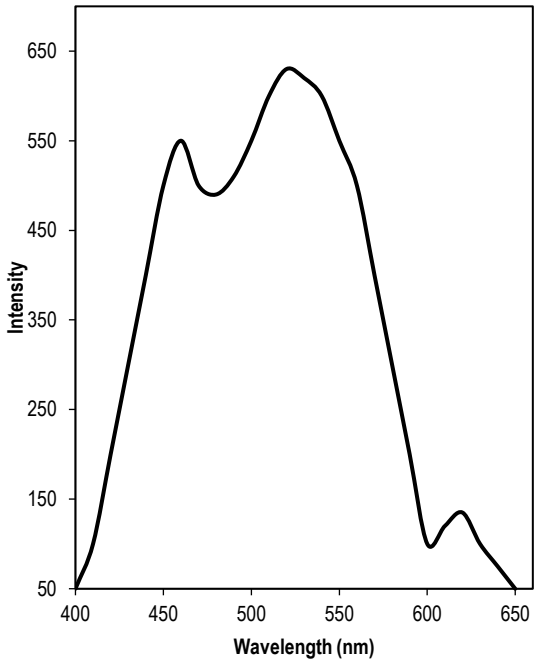


Fig. (3) Photoluminescence spectrum of cadmium telluride (CdTe) nanocrystals

Figure (3) exhibits the photoluminescence of cadmium telluride (CdTe) nanocrystals, which suggests that a specific energy band conduction occurs at 530 nm. Excessive fluorescence occurs as a result of the emission of the near-band edge of cadmium telluride (CdTe) nanocrystals, with additional highlights at 460 and 620 nm caused by free excitons recombination. These broad emissions are linked to deep-level leaks, which can be caused by defects in structure [12]. According to that circumstance, the presence of the relevant defect identified as a beyond observer, an emission associated with nanocrystalline defects cadmium telluride (CdTe) nanocrystals might be due to Cd or Te vacant seats [14-18]. The energy-gap in cadmium telluride (CdTe) nanocrystals must have been established formulated at essentially 3.6 eV.

As shown in Fig. (4), the surface morphology of the grown cadmium telluride (CdTe) nanocrystals has been imaged using SEM at 50 KX magnification. The nanocrystals covering's SEM properties serve as an acceptable notice for the formation of cadmium telluride (CdTe) nanocrystals. The average grain size was found to be around 10 nm Figure 4 depicts spherical morphology with low aggregation of nanocrystals generated at 100 nm scale.

The electrically charged cadmium telluride (CdTe) nanocrystals that perform in Hall Effect assignments of magnitude are described. Developed and introduced a semiconductor electrical characterization technique called differential Hall effect metrology (DHEM). HEM provides depth profiles of critical electrical properties through semiconductor layers at nanometer-level depth resolution. HEM is based on the differential Hall effect (DHE) method, which makes successive sheet resistance and mobility measurements on a layer using Hall effect and Van der Pauw techniques as the thickness of the layer is reduced through successive processing steps, typically involving chemical or electrochemical etching or oxidation. The data obtained as a function of thickness removed can then be used to determine the depth profiles of carrier concentration, resistivity and mobility. Thin films with thicknesses of 10, 20, and 30nm exhibit semiconductor activity and n-type conductivity. Table (1) summarizes the Hall Effect.

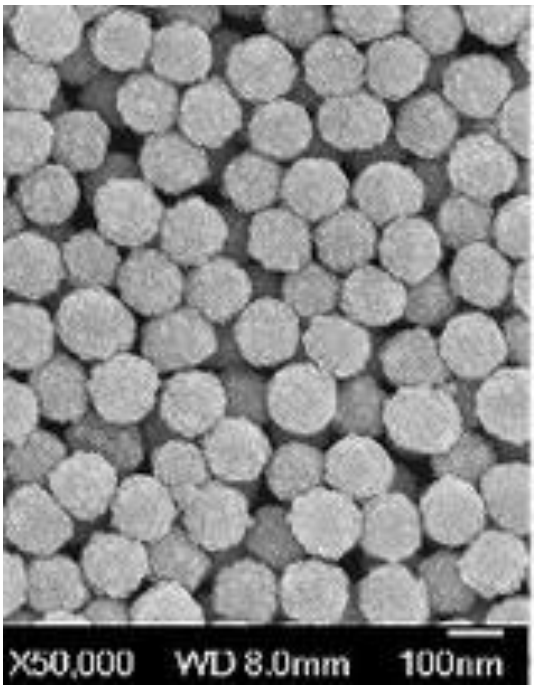


Fig. (4) Scanning electron microscope (SEM) image of the cadmium telluride (CdTe) nanocrystals prepared in this work

Table (1) Overview of cadmium telluride (CdTe) nanocrystals Hall Effect measurements with varying thickness

Sample	Thickness (nm)	Conductivity $(\Omega.cm)^{-1}$	Mobility (cm^2/Vs)	Hall Coefficient (cm^2/C)
CdTe	10	2.56	48.5	-1.23×10^{8}
	20	1.48	16	-1.27×10^{8}
	30	1.34	13.5	-1.31×10^{8}

When compared to other cadmium telluride (CdTe) nanocrystals thicknesses, it was suggested that cadmium telluride (CdTe) nanocrystals had strong conductivity at 10 nm thickness. In addition, the mobility of cadmium telluride (CdTe) nanocrystals at 10 nm thickness is greater than that of cadmium telluride (CdTe) nanocrystals at 20 and 30 nm thicknesses, implying that the cadmium telluride (CdTe) are impacted by a decrease in the resistance of the cadmium telluride (CdTe) nanocrystals, which suggests that, amid substantial increases in the nanocrystals, the growth of recombination extremely emerged a cadmium telluride (CdTe) battery device

and induced charges, which governed. In the light of the improved electron confinement in cadmium telluride (CdTe) nanocrystals, mobility in a carrier increases as dimensions' decrease.

This feature separates batteries from commercial batteries, which operate at higher voltages and have lower efficiency [19,20]. Figure (5) explains the I-V combinations of the CdTe-HLEDs achieved with the ITO/CdTe/TPD/Ni performance. The figure shows the capacity to rearrange with a general conversion voltage of 3 voltage bias and a current of just under 0.01-0.44 mA.

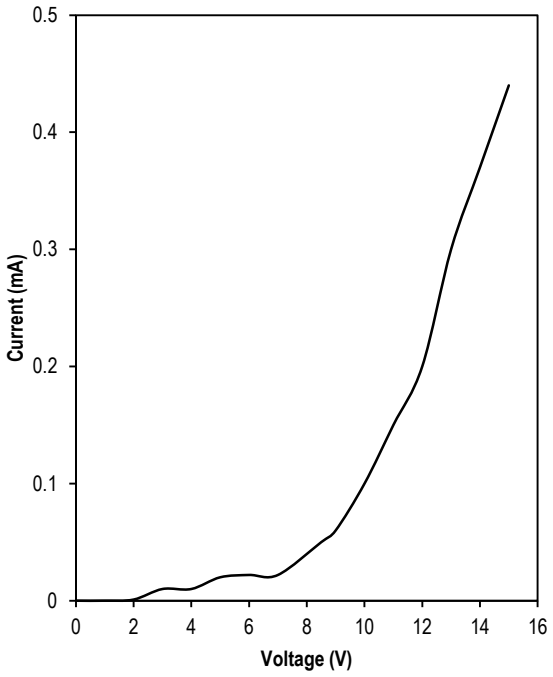
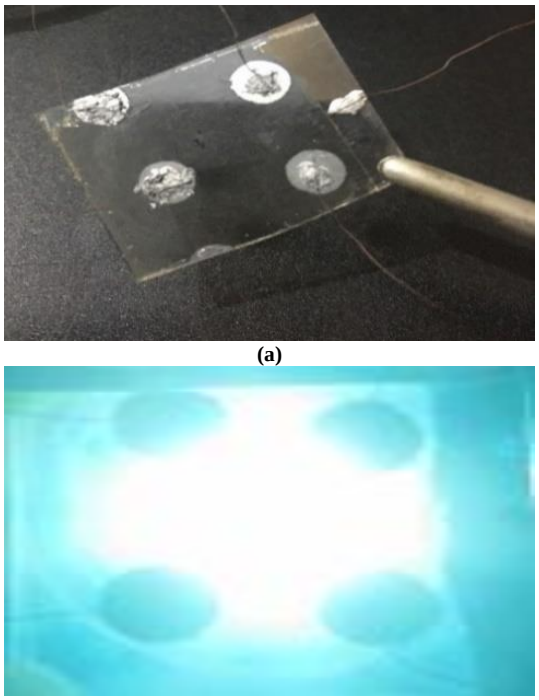


Fig. (5) I-V characters of the ITO/CdTe/TPD/Ni HLEDs

A hybrid light emitting device product performed current-voltage reveals an overall increase concerning current induced beside a decrease during the depletion-edge layer's size. The propagation band barrier will decrease in the forward bias owing to dramatic increase dispersion of ions (CdTe and TPD) inside the valence and conduction band [20]. Because allowed towards charge besides discharging processes shifted significantly across one cycle to another remained when the stream is steady for the duration of the cycle [21,22]. The number of charging and discharging cycles that a CdTe-HLEDs may go through before it stops operating is referred to as its life-cycle. The discharge depth has a significant impact on the life of CdTe-HLEDs. The depths of discharge describe how much of a battery's storage is consumed. As a result of the rechargeable batteries provide ions (TPD) to (cadmium telluride (CdTe) nanocrystals) owing to system discharges, recombination would increase the forward bias's current flow [23]. At this point, these processes emerge as a result of multiple techniques that influence the production of batteries.

One particular technique stands out, as it does not seem to be directly controlled by another synthesis. Insufficient results have an influence on success, as is shown in a band gap the semi-conductors that is operating even more devices for generating current [22-24]. These devices in the gap charge domain can be classified as surface imperfections, barrier annealing, output recombination, and boundary configurations [24]. Figure (6) illustrates a view of an ITO/CdTe/TPD/Ni displays the light emitted by this component.



(a)

(b)

Fig. (6) (a) A picture of the ITO/CdTe/TPD/Ni HLEDs (b) Light illumination produced by ITO/CdTe/TPD/Ni HLEDs

4. Conclusion

In summary, composition analysis confirms of the controlled size of cadmium telluride (CdTe) nanocrystals using laser ablation technique, which has been highly useful because the size reduced as the number of laser pulses increased. Cadmium telluride (CdTe) nanocrystals raised more the ability of the HLEDs by improving the carrier's charge mobility as well as the interactions between cadmium telluride (CdTe) nanocrystals and TPD organic conductive polymer. The (I-V) characteristics are completely matched with the needed voltage, which produces critical features for the functioning of the light emitting system. A progressive interaction development in the HLEDs including cadmium telluride (CdTe) nanocrystals and TPD organic polymer ions may give forward current flow bias in order to use a few volts and create positive effects for light output.

References

[1] A. Tze-Zhang et al., "A Comprehensive Study of Renewable Energy Sources: Classifications, Challenges and Suggestions", *Ener. Strat. Rev.*, 43(2022) 1-27.

[2] M.K. Akeel, "Fabrication of nano battery from CdS quantum dots and organic polymer", *Kuwait J. Sci*., 49(1) (2022) 1-9.

[3] M.K. Akeel and M.S. Amjed, "Enhanced White Light Emitting Device Based on ZnTe Nanocrystals and Conductive Organic Polymer by Surface Excitons", *Chalcog. Lett.*, 18(6) (2021) 289-295.

[4] A.P. Antonio et al., "Study and Application of Colloidal Systems for Obtaining CdTe+Te Thin Films by Spray Pyrolysis", *J. Anal. Appl. Pyrol.*, 124 (2017) 285-289.

[5] S. Sudeshna et al., "A new Route for Preparing CdTe Thin Films by Chemical Bath Deposition", *Mater. Today: Proc.*, 44(1) (2021)1463-1467.

[6] M. Tetiana, M. Myroslav and H. Marian, "Surface-Barrier CdTe Diodes for Photovoltaics", *J. Nano- Electron. Phys.*, 15(2) (2023)1-5.

[7] I.G. Orletskyi et al., "Electrical Properties of the n-NiS2/n-CdTe Isotype Heterojunction Fabricated by Spray Pyrolysis", *Proc. 50th Int. School Conf. Phys. Semicond.*, Szczyrk, Poland (2022).

[8] M.K. Akeel, "Zinc Selenide Quantum Dots Light Emitting Devices (ZnSe QDs-LEDs) with Different Organic Polymers", *Nano Hybr. Compos.*, 18 (2017) 11-19.

[9] Z. Ghassan et al., "Concept Development and Techno-Economic Assessment for A Solar Home System Using Lithium-Ion Battery for Developing Regions to Provide Electricity for Lighting and Electronic Devices", *Ener. Conver. Manag.*, 122 (2016) 439-448.

[10] E. Al-Bermany et al., "Effect of Green Synthesis Bimetallic Ag@SiO_2 Core–Shell Nanoparticles on Absorption Behavior and Electrical Properties of PVA-PEO Nanocomposites for Optoelectronic Applications", *Silicon*, 15 (2023) 4095-4107.

[11] B. Anugop et al., "Nanoparticle Production via Laser Ablation Synthesis in Solution Method and Printed Electronic Application - A Brief Review", *Resul in Eng.*, 16 (2022) 1-14.

[12] R. Grover, R. Srivastava and K. Saxena, "Luminescence studies in cadmium telluride nanocrystals grown on glass substrates", *RSC Adv.*, 12 (2022) 26596-26602.

[13] M.K. Akeel "Fabrication of Quantum Dots Light Emitting Device by Using CdTe Quantum Dots and Organic Polymer", *J. Nano Res.*, 50 (2017) 48-56.

[14] M.K. Akeel, "Hybrid White Light Emitting Devices (HWLEDs) From Organic Polymer and PbS Nanocrystals by Multiple Excitons", *Mater. Sci. Poland*, (2020)1-6.

[15] L. Guangmin et al., "Fluorescence and Optical Activity of Chiral CdTe Quantum Dots in their Interaction with Amino Acids", *ACS Nano*, 14(4) (2020) 4196-4205.

[16] Q. Guillermo, S. Hugo and R. Jesus, "Characterization of CdTe Thin Films Using Orthogonal Double-Pulse Laser-Induced Breakdown Spectroscopy", *Chemosensors*, 11(1) (2023).

[17] A.I. Omar, M.K. Akeel and R.S. Wasan "White Light Generation from Electroluminescence Devices Using TPD:PMMA/QDs/Alq_3", *Nano Hybr. Compos.*, 15 (2017) 10-20.

[18] M.K. Akeel, A.I. Omar and R.S. Wasan, "Electroluminescence Devices from Quantum Dots with TPD Polymer White Light Generation", *J. Nano Res.*, 48 (2017)104-113.

[19] S. Meng-Yao, L. Xin-Yuan and Z. Jia-Tao, "Telluride Semiconductor Nanocrystals: Progress on their Liquid-Phase Synthesis and Applications", *Rare Met.*, 41 (2022), 2527-2551.

[20] G.U. Fehmi and A. Adisa "Environmental Impacts of Small-Scale Hybrid Energy Systems: Coupling Solar Photovoltaics and Lithium-Ion Batteries", *Sci. Total Enviro.*, 643 (2018) 1579-1589.

[21] M.J. Simon and A.M. Brian, "Battery and Energy Metals: Future Drivers of the Minerals Industry", *SEG Discovery*, 127 (2021)11-18.

[22] Y. Xiutao et al., "Investigation of the Surface and Interfacial Properties of Polycrystalline CdTe/Monocrystalline Si Structure", *J. Electron. Mater.*, 51 (2022) 4378-4387.

[23] X. Yiqiu et al., "Advances in the Applications of Graphene-Based Nanocomposites in Clean Energy Materials", *Crystals*, 11(47) (2021)1-26.

[24] Z. Yue et al., "A Durable Lithium–Tellurium Battery: Effects of Carbon Pore Structure and Tellurium Content", *Carbon*, 173 (2021)11-21.

