SUMMARY

Of the PhD Thesis on the Specialty 6D060400 – Physics Daurenbekov D.H.

Luminescence and mechanism of conversion solar radiation into synthesized semiconductor nanoparticles

Topicality of the research.

Currently, search for sources of renewable energy and ways to enhance their effectiveness is very urgent problem of modern physics and technology. Converting solar energy into electrical energy, it is traditionally carried out by semiconductor photovoltaic cells (solar cells). Maximum efficiency of such conversion of light energy into electrical energy for polycrystalline silicon is 12-18%, which is considerably inferior to traditional energy sources. This fact forces the researchers to look for new technical solutions to improve the efficiency of solar cells. One of these solutions is the use of fluorescent solar converters (FSC). In general, the FSC is a plate of translucent material with embedded luminescent substances with a broad absorption band in the visible and ultraviolet region of the spectrum. A typical semiconductor solar cell can not operate at maximum efficiency in the entire spectral range of solar radiation. An essential condition for the functioning of the FSC is a luminescent conversion of short-wave part of the solar light to longer wavelengths. In this case, the FSC can convert some of the energy from the near ultraviolet and blue region to the red region of the spectrum, in which the majority of semiconductor photovoltaic cells has the best response.

Currently, semiconductor nanostructures such as quantum dots (QDs), quantum wells et al., shows physical properties distinguishing from the bulk materials due to quantum size effects. Great practical interest in quantum dots which stabilized by organic molecules called colloidal quantum dots.

Physico-chemical properties such as absorption and luminescence of QDs depend on the size, shape and condition of nanocrystals synthesis. Colloidal quantum dots are interesting for the development of lasers, LEDs, optoelectronic converters, markers, including for biological objects. Due to the high variability of methods of synthesis can be obtained QD in a broad spectral range of luminescence, depending on the reagents used QDs can be dissolved in various solvents and implemented in various matrices so depending on a variety of tasks.

For the energy industry is of great interest in the use of clean energy. At the moment, a large widespread third generation solar cells. To such solar cells (SC) directly implemented nanoscale materials. Quantum dots, nanotubes, fullerenes and dyes incorporated into the structure of the solar cells can improve their performance. When SC creations based on the polymer-fullerene can get efficiency up to ~ 10%, but fullerenes are unstable and rapidly degraded. It is also very important for the creation of type SC Grettselya cells where as a base layer of nanostructured TiO_2 or ZnO, is used as a coating a sensitizing dye. Dyes much inferior to QDs in the optical properties, and photostability. The conversion efficiency of solar energy in such elements is 12%. Also one of the most promising directions in the formation of the new SC involves the use of semiconductor QDs,

obtained by the methods of the colloidal synthesis. at a maximum efficiency of such elements 6-6,2%. Nevertheless, the use of QDs in direct designing SC easy to embed in liquid-phase technology to build solar panels

Converting solar energy into electricity, traditionally carried out by semiconductor photovoltaic cells (solar cells) based on polycrystalline, monocrystalline, amorphous silicon and hydrogenated. Semiconductor components can not operate at maximum efficiency over the entire spectral range of solar radiation. "Work" spectral range of solar radiation for solar cells is determined by the band gap (Eg) of the semiconductor. This area starts at the red edge (fundamental absorption) semiconductor photoelectric effect. Thus, the energy range used solar cells to convert solar energy into electricity is 30% of the incident solar radiation on Earth. The rest of the solar radiation energy spent on unwanted heating of photoelectric converts (PEC) material. To protect against heat, PEC surface covered with a special reflective film. The efficiency of such solar cells in open atmospheric conditions is 10-12%.

To increase the efficiency of solar cells developed various technologies for conversion of the remaining part of the solar spectrum in the red luminescence and the infrared (IR) illumination to further the creation of electron-hole pairs in the photovoltaic cells, which are converted into electrical energy. In this regard, various technologies are developed converting solar radiation spectrum in the red spectrum or direct use of the ultraviolet and visible spectrum. For example, the luminescent converter (LC) in the form of a thin film placed on the surface of the PEC can more efficiently absorb ultraviolet and visible part of the solar spectrum and emit radiation in the orange-red range that is falling on the solar cells making more electron-hole pairs. The radiator in such matrices can be specially introduced impurities - rare-earth ions, quantum dots (CdSe, PbS, CdTe, etc.). The basic matrix can be organic polymers, porous oxides or other compounds.

In recent years, is to increase the current efficiency of silicon photovoltaic cells used luminescent nanoparticles of silicon or QDs applied as a thin coating on the surface of the PEC. For example, the size of silicon nanoparticles 2.85 nanometers when excited by UV or visible light emits a red glow. Voltage taken from such elements is significantly higher compared with conventional multicrystalline silicon solar cells.

The aim of the research and scientific outcomes

Research of intrinsic and extrinsic luminescence of semiconductor quantum dots CdSe, CdTe, ZnSe, CdSe-Cu, CdSe/ZnS and SiO_2-Eu^{3+}, Tb^{3+} which used in fluorescent coatings in industrial solar cells to increase efficiency.

In accordance with the purpose of the dissertation following scientific results were obtained for the first time:

1. Based on the kinetics measurements of growth quantum dots CdSe and CdTe by in-situ methods experimentally established the dependence of the shift of the luminescence band with linear dimension of synthetic QDs in a wide temperature range from 170 to 270 ^{0}C,

2. It is shown that in LMCS particles doped with Eu^3 + and Tb^{3+} detected excitation spectra of impurity emission band which coincide in position with the

excitation band of their own matrix. On the basis of experimental studies suggest that energy self-radiation of LMCS particles effectively transferred to impurities

3. The observed emission band with a maximum at 780 nm in a doped QDs CdSe-Cu associated with the exciton emission near copper impurities which are located on the surface of QDs.

4. On the basis of analysis of experimental data identified the optimal process parameters for «CdSe / ZnS + polymer" for use as luminescent coating for solar cells. To investigate the effect of efficiency oh fluorescent coatings on industrial solar cells.

5. The use of thin films of the type «CdSe / ZnS + polymer» and «CdTe + polymer", as a luminescent coating for solar cells increases the efficiency of solar cells from 5 to 6% , compared to basic samples.

The object of the research is – semiconductor quantum dots CdSe, CdTe, SiO_2-Eu^{3+},Tb^{3+}, CdSe-Cu, CdSe/ZnS.

The subject of the research is – study of the nature of the emission and excitation spectra of colloidal quantum dots embedded in solution and a polymer matrix upon excitation with UV and visible light. Measuring the growth kinetics of nanoparticles by in-situ method for establishing dependence of the position of the luminescence band and the size of the quantum dots CdSe and CdTe. The doping of CdSe quantum dots by copper.. The study mechanisms of electron excitation energy transfer from LMCS particles to rare earth ions impurities. Establishing the optimal technological parameters of the luminescent coating for solar cells. The use of fluorescent films based on QDs CdSe/ZnS and CdTe as a coating to increase the efficiency of solar cells.

The scientific novelty

– By method in-situ established the parameters of the long-wavelength shift of the luminescence, depending on the size of the quantum dots CdSe and CdTe.

– Own energy radiation particles LMCS effectively transferred to impurities.

– Emission band with a maximum at 780 nm in a doped CdSe-Cu QDs associated with the exciton radiation near the copper impurities, on the surface of QDs

– Set the optimal technological parameters of the system «CdSe / ZnS + polymer" for use as a fluorescent coating of solar cells.

– Suggested luminescent coating «CdSe / ZnS + polymer» and «CdTe + polymer" increases the solar cell efficiency by 5-6% compare uncoated solar cells

Research objectives: The main objectives of the thesis are as follows:

1. Investigate the nature of the emission and excitation spectrum, kinetics of growth and dependence of the position of the luminescence spectrum with size of QDs CdSe and CdTe;

2. Investigate the emission, excitation spectrum of LMCS particles activated by Eu^{3+}, Tb^{3+} impurities and transfer of electronic excitation energy of its own matrix to impurities;

3. Examine the emission spectra and excitation doped CdSe QDs copper;

4. To study the luminescence quantum yield in CdSe/ZnS system, depending on the parameters of shell capacity;

5. To investigate the effect of the fluorescent coating on the efficiency of the industrial solar cells;

Statements for the defense

1. Growth kinetics of nanoparticles showing the optimal increase in the size of the quantum dots to produce long-wavelength luminescence band.
2. Nature of the luminescence band with a maximum at 780 nm in a QDs CdSe-Cu associated with the exciton radiation near the copper impurities on the surface of QDs.
3. Optimal parameters of quantum dots CdSe/ZnS introduced into polymer matrices, serving as luminescent coatings for solar cells.
4. The use of fluorescent films based on CdSe/ZnS and CdTe results in increase efficiency of solar cells by 5-6% compared with uncoated cells

Practical significance of the research outcomes

The thesis is carried out in accordance with the plan of scientific research work within the framework of grant funding of MES RK, under budget program 055 "Scientific and / or scientific and technical activities " within the framework of the project on « Development of technology for the new luminescent material to increase the efficiency of photovoltaic cells based on silicon» (State Reg 0112PK02285, 2012-2014.)

Due to the ability of the solar spectrum transformation of high-energy radiation to radiation in the orange-red range, fluorescent film based on quantum dots can be used as coatings for solar cells, to increase their efficiency. The obtained fluorescent coatings were tested on a commercially produced solar cells of domestic production

Personal contribution of the PhD student

Doctoral candidate was personally directly involved in the synthesis and experimental research of semiconductor nanoparticles, showed constant commitment and dedication. The research results and their interpretation were discussed together with the scientific consultants. In the course of a doctoral thesis he studied the spectroscopic investigation methods, he has mastered in the technology of synthesis of QDs and received skills on modern research facilities and instruments of Research Institute «Energy and Functional Materials» ENU L.N. Gumilyov, MSU M.V Lomonosov and Bashkir state university, Ufa.

Approbation of the thesis outcomes

The study, conducted in the framework of the thesis, reported and discussed at:

- 17th International conference on luminescence and optical spectroscopy of condensed matter. Poland, Wroclaw. - 13-18 July 2014.
- The 4th International conference on the physics of optical materials and devices ICOM 2015. – Montenegro, Budva. – 2015.
- II All-Russian Scientific Youth Conference "Actual problems of nano- and microelectronics," Russia, Ufa. 2014.

- 9 International Conference "Efficient use of resources and environmental protection - the key issues of the development of mining and metallurgical complex" and 12 International Scientific Conference "Advanced technologies, equipment and analytical systems for materials and nanomaterials». – Ust-Kamenogorsk. – 20-23 Мая 2015.

- 13 International scientific conference "Solid State Physics".– Astana. –2016.

Publications

According to the results of the thesis published 11 publications, including 1 - article in foreign journals with high impact factor, 5 article - in periodicals of the Republic of Kazakhstan, recommended by the Committee on control and attestation in education and science MES, 2 thesis - in materials of international conferences in foreign countries (not CIS), article 3 - in the materials of international conferences (CIS).

Volume and structure o the thesis. The thesis work consists of an introduction, three chapters, conclusion and list of references. The volume of theses is 110 pages, including 79 figures, 15 tables and a list of references, including 162 references