System for effective harvesting of solar electric energy on flexible supercapacitor basis.

Solar cells with microtextured surface and Au nanoparticles
Research directions:

- The growth processes of $A^IIB^VI$ single crystals, films of semiconductor materials and electronic device fabrication on their basis;
- Solar cells with microtextured surface and Au nanoparticles;
- System for effective harvesting of solar electric energy;
- Development of technology of highly efficient ultracapacitors

Our group collaborates with:

Institute of Physics, Polish Academy of Sciences
Silesian University of Technology
Kaunas University of Technology
The technology of obtaining an effective nanocarbon electrode material for supercapacitors was developed.

The carbon electrode material for supercapacitors with enhanced functional characteristics and significant lower cost was received.

<table>
<thead>
<tr>
<th>Functional parameters of supercapacitors carbon materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific capacitance, F / g</td>
</tr>
<tr>
<td>Specific capacitance, F / g</td>
</tr>
<tr>
<td>Specific internal resistance, Ohm/ cm²</td>
</tr>
</tbody>
</table>

The benefits of development:
- natural carbon materials;
- low cost;
- better technical and functional parameters:
  - capacitance;
  - power;
  - working time;
- manufacturing process located in Ukraine.

Journal of Surface Physics and Engineering. Vol 12., No. 3, 412 (2014);
Material Science. Vol. 51., No.2, 188 (2015);
Patent №77786, UA;
Patent №96174 UA.
Developments for Taiwan "Supercapacitor"

The experimental samples of flexible supercapacitors for use in the harvesting of electrical energy from solar cells and flexible supercapacitors - solar cell hybrid system were developed.

“Fully flexible fabric supercapacitor” was among the winners of the prestigious competition “100 best research and development of the world” (known as “Oscar among inventions”) in 2011 by famous American magazine “Research and development”

The invention of the «flexible supercapacitor» was performed together with Taiwanese Textile Research Institute

Patents
EP 2323146 A1
JP 2011103430
US 8379366
Development «System of autonomous power supply»

- Power of SB is enough for charging of Mob
- Energy excess is accumulated in Bat
- If Mob is not connected then the Bat is charging
- If power from SB is not enough for charging of Mob then shortage is covered by Bat
- In the evening and at night a Mob is charged by using the energy previously accumulated in Bat

**System Manager** provides:
- redistribution of energy flows according to the environmental conditions;
- work of **Solar Battery** in point of maximum power;
- effective energy harvesting even in scattered light due to the fact that SC can be charged by small currents and discharged by large ones

SB – Solar Battery,
SC – SuperCapacitor,
MS – Manager System,
Bat – Rechargeable Battery,
Mob – Mobile phone
Systems for take off electricity from solar battery on flexible supercapacitor basis

Functional scheme of the device
SB – Solar Battery,
SC – SuperCapacitor,
MS – Manager System,
Bat – Rechargeable Battery,
RL – Loading

Conversion process for electrical power in the device
System for effective harvesting of solar electric energy

The photoconversion system for mobile phone autonomous power supply was developed.

- It was found that using the SC improves the efficiency of electric energy harvesting by 4 times in low insolation levels (less than 20%), and by 1.3 - 2.0 times in average insolation levels (20 to 60%).
Solar cells with micro textured surface

**Aim of the project:** the development of fabrication technology basis of the CdS/CdTe heterojunction three-dimensional thin-film solar cells;

1. The microtextured surface modeling for three-dimensional (3D) substrates;

2. The materials selection and 3D substrates fabrication methods analysis

The trajectories of the incident, reflected and refracted light rays in 3D solar cell

The polymer/ZnO/CdS/CdTe structure transmittance on the light incident angle dependence
Solar cells with micro textured surface

The morphology of the single-crystal silicon wafer surface after the microtexture formation

The morphology of the CdS films deposited on different microtextured substrates
Solar cells with micro textured surface

The morphology of the CdTe films on different microtextured substrates

<table>
<thead>
<tr>
<th>Structure type</th>
<th>$R_p$, $\Omega$</th>
<th>$R_{sh}$, $\Omega$</th>
<th>$U_{oc}$, V</th>
<th>$J_{sc}$, mA/cm$^2$</th>
<th>ff</th>
<th>$\eta$, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>7,18</td>
<td>141</td>
<td>0,61</td>
<td>18,6</td>
<td>0,51</td>
<td>7,03</td>
</tr>
<tr>
<td>Textured</td>
<td>2,28</td>
<td>204</td>
<td>0,64</td>
<td>17,5</td>
<td>0,68</td>
<td>8,96</td>
</tr>
</tbody>
</table>

Table 1. The basic photoelectric parameters of best flat and textured solar cells CdS/CdTe.

- Inorganic materials. 50, No. 8. 762 (2014)
- Inorganic materials. 50, No. 6. 605 (2014)
- Inorganic materials. 49, No. 4. 341 (2013)
- Inorganic materials. 49, No. 3. 239 (2013)
- Semiconductors. Vol. 44, Iss. 3. 318 (2010)
Fabrication and physical properties of the Au nanoparticle arrays for solar cell application

The efficiency of the thin-film solar cells can be greatly improved by deposition of metal nanoparticles on the top of photoactive layer. The improvement is caused by increase of light absorption in thin-film layer due to light scattering and absorption on metal NP, and electromagnetic field amplification by means of SP excitation in active layer.

Optical absorption spectra of Au films as deposited (a) and annealed (b). Nominal thickness are shown in graphs. The results of model simulations are shown by solid line.

Surface morphology of gold film at glass substrates before (a) and after (b) thermal annealing. Film mass thickness 25 nm.

Photocurrent spectral dependencies of heterostructures: ITO/n-CdS/p-CdTe/Ni (1), ITO/n-CdS: Au/p-CdTe/Ni (2)
Fabrication of the Au nanoparticle arrays by ultrathin gold film annealing

Typical SEM image for gold nanoparticle array fabricated by ultrathin gold film annealing

Typical size distribution for nanoparticle array

Absorption spectra for gold nanoparticle array deposited at glass substrate for different initial ultrathin gold thicknesses (from 0.5 nm to 3 nm)

Int. Conf. ICPTTFN-XV, p. 163.
Thank you for attention!