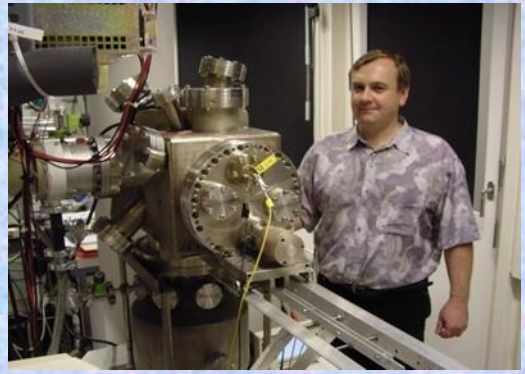
NATIONAL TECHNICAL UNIVERSITY
Kharkov, Ukraine

Thin film solar cells and photoenergy system

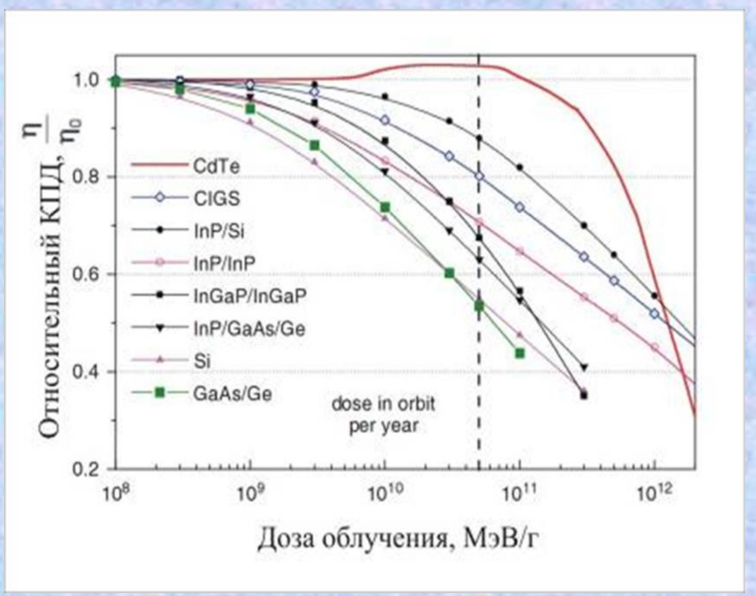
INTERNATIONAL ACTIVITIES DEPARTMENT ”MATERIALS FOR ELECTRONICS AND SOLAR CELLS”

The Department has been participating in various international projects for solar energy development for 15 years:

- INTAS Project. Co-ordinator: Stuttgart University (Dr.-Ing. H.W. Schock)
- International Partnership Program supported by Swiss National Science Foundation. Co-coordinator: Swiss Federal Institute of Technology (Prof. A.N. Tiwari)
- Tasis Project «Creation of a Center for Solar Energy Use in Odessa».
- STCU Project 4301 Collaborators: University of Verona (PhD in Physics A. Romeo)

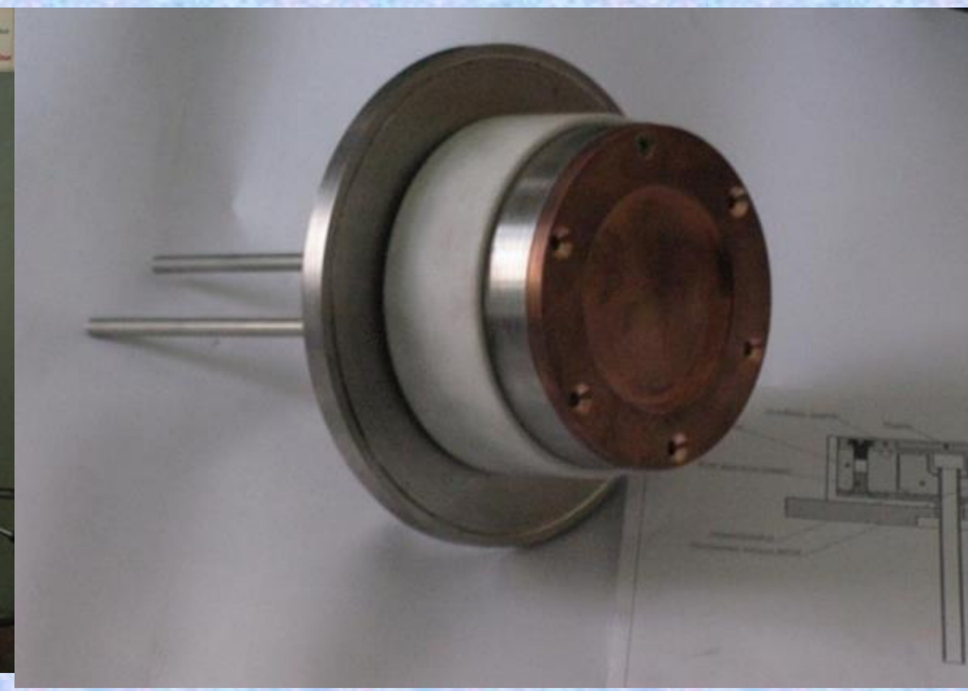


FLEXIBLE SOLAR CELLS ON CdS/CdTe BASE



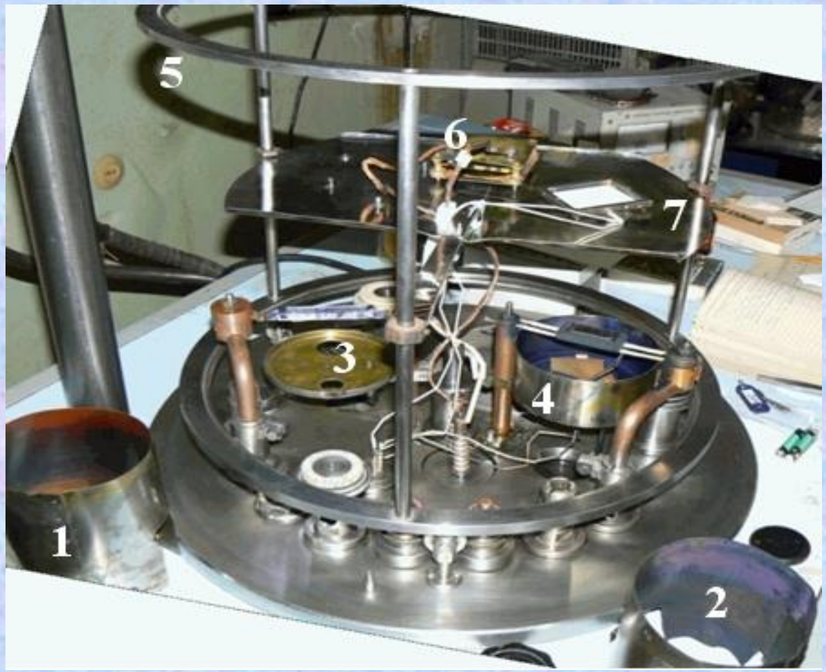
CdTe/CdS solar cells is one the most importance photovoltaic devices for cost-efficiency and clean generation of solar electricity for terrestrial and space application. Development of flexible and lightweight CdTe solar cells together with highly stable performance and low cost production make them interesting for low-cost and easily deployable solar power generation in the space.

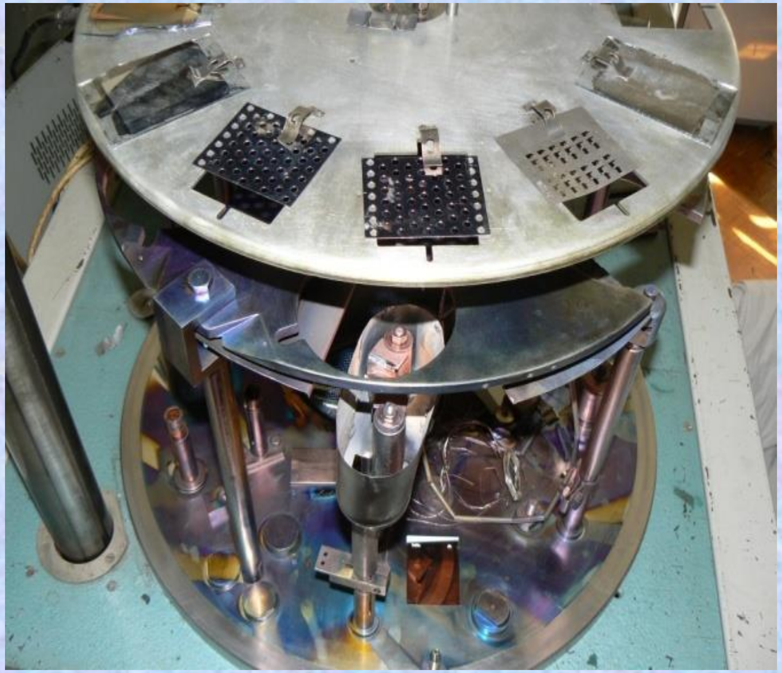
CdTe FLEXIBLE SOLAR CELLS TECHNOLOGY (stage 1)



ITO layers are deposited on Upilex polyimide foils by commercial magnetron sputtering equipment

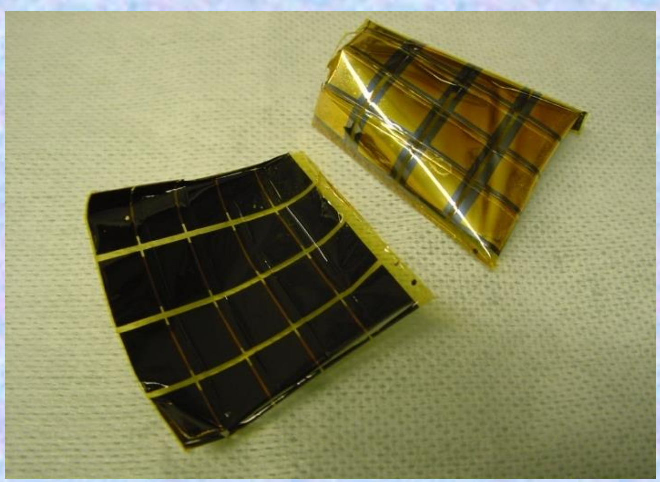
CdTe FLEXIBLE SOLAR CELLS TECHNOLOGY
(stage 2)

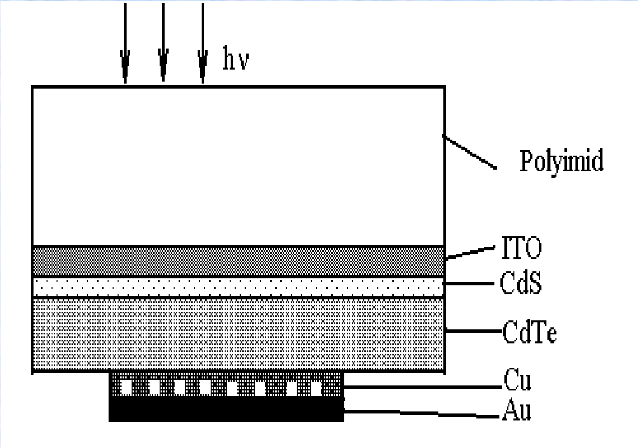


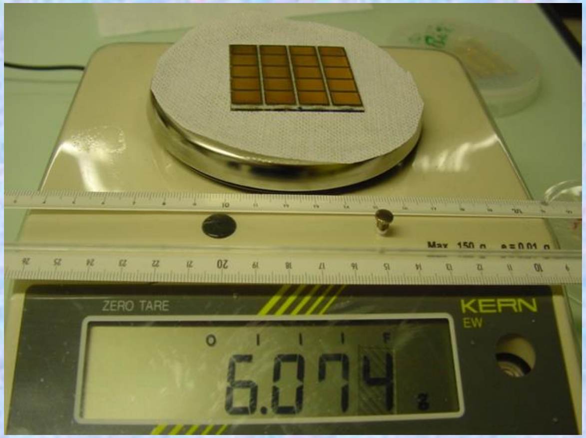


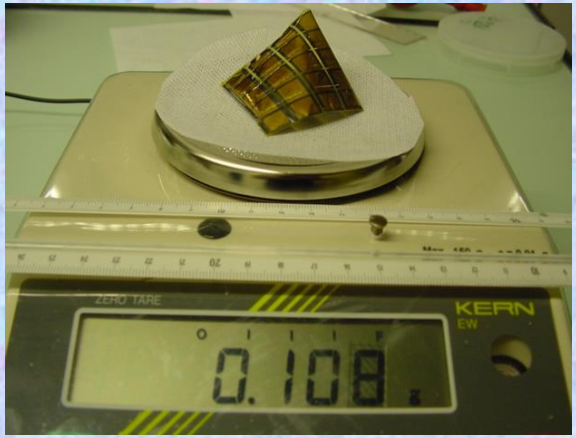
CdS/CdTe layers for flexible solar cells are deposited on Poly/ITO substrate by physical vapor deposition (CdS and CdTe) in a vacuum chamber

CdTe FLEXIBLE SOLAR CELLS DESIGN







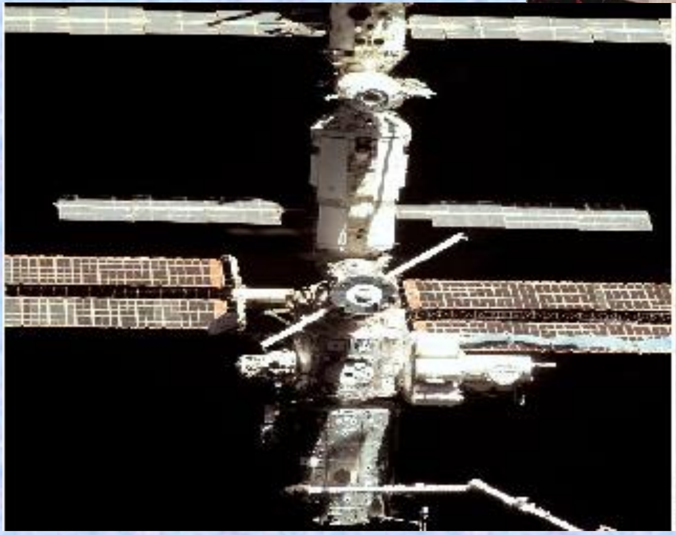


Flexible Poly/ITO/CdS/CdTe/Cu/Au solar cells have total thickness ≈15 μm and surface density of 0.48 mg/cm^2 and word record efficiency 11,4%

(Khrypunov G., Romeo A., Kurtzesau F., Batzner D.L., Zogg H. and Tiwari A.N. Recent developments in evaporated CdTe solar cells // Solar Energy Materials & Solar Cells.- 2006.- V.90, №6.- P. 664-677.)

ADVANTAGES OF CdTe FLEXIBLE SC

- Low cost of flexible thin film SC on CdTe base if produced in large volumes
- Simple deposition “roll to roll” technology makes it very promising for industrial application
- Considerable weight reduction due to use of only a few micrometers thick film layers on lightweight flexible substrate compared to glass substrate which represents over 98% of the total weight of solar cells
- CdTe SC have the highest stability under space irradiation compared to Si and GaAS photovoltaic devices, which makes CdTe cells very prospective for space application.
- Facilities of mounting on the surface of any forms.
- Creating a small autonomous power sources (including for emergencies)



EXPERINENTAL RESULTS

Comparison of conventional SC on glass substrate and flexible SC on polyimide

SC parameters	Glass	Polyimide
Open circuit voltage Voc, mV	793	765
Shot current density Jsc, mA/cm2	19,9	20,9
Fill factor FF	0,71	0,71
Efficiency η, %	11,2	11,4*
Specific power, kW/kg	0,025	2,5*

*Romeo A., **Khrypunov G.,** Kurtzesau F., Arnold M., Batzner D.L., Zogg H. and Tiwari A.N. High-efficiency flexible CdTe solar cells on polymer substrates // Solar Energy Materials&Solar Cells.- 2006.- V.90, №18-19.- P.3407-3415.

COMPETITION

First Solar (USA): the best industrial technology for production of CdTe SC on glass substrate.

But: high substrate temperatures (>550^{o}C) and high deposition speed cause thickness' heterogeneity of base layer in large SC). High substrate t^{o} of SC does not allow using polyimide films for creation of flexible SC on CdTe base.

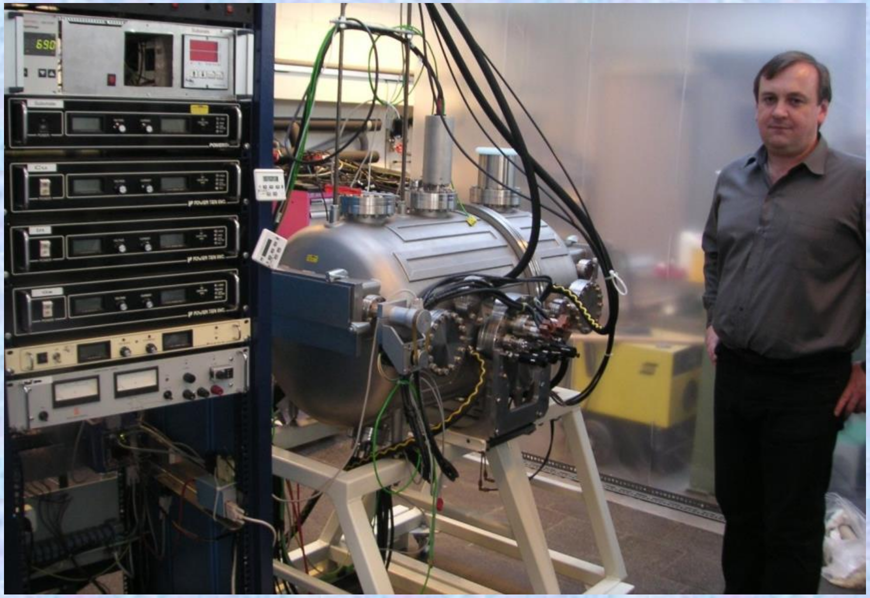
Proposed technology: use of lower t^{o} (400^{o}C) and vacuum vapor deposition method which allows obtaining homogeneity of base layer in large areas polyimide films.

Flisom (Switzerland): produces laboratory samples of flexible SC (on the basis of polyimide films) with all-time high efficiency.

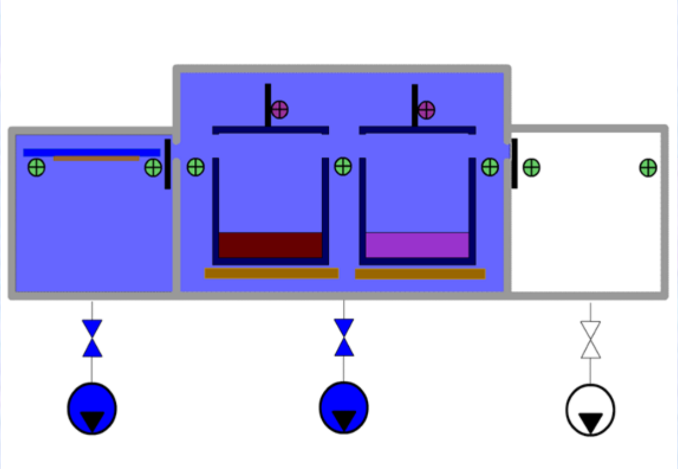
But: complicated technology of $CuIn_{1-x}Ga_xSe_2$ SC, namely using mass-spectrometer vapor flow control, increases the costs.

Proposed technology: production of CdTe flexible SC by thermal vacuuming evaporation technology (using our know-how) is considerably simpler and cheaper.

CREATION OF THE VACUUM MODULE



Development of industrial technology for production of flexible CdTe solar cells by thermal vacuuming evaporation which surpass single crystal silicon and gallium arsenide solar cells technologies for terrestrial and space application due to combination of technical and economical characteristics.



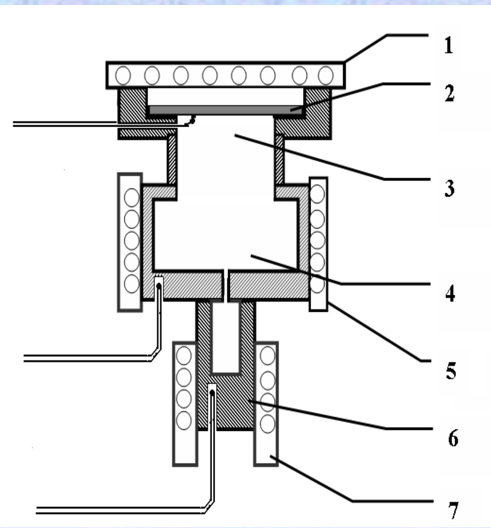
Market value of technology: 5-8 mln $ USA*

Goal: to find an investor for pilot project for the following Stages:

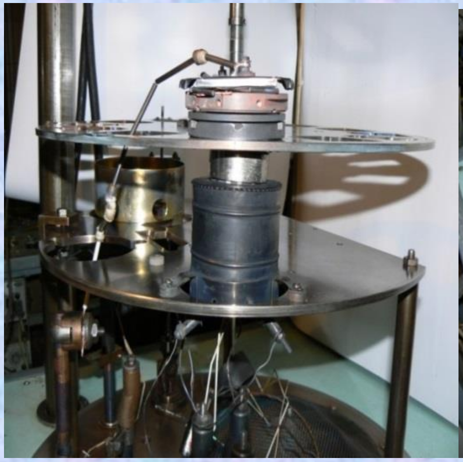
Stage 1: modernization of vacuum equipment (300.000 $ USA, 1 years)

Stage 2: optimization of technology of flexible CdS/CdTe SC (200.000$ USA, 1 years).

CLOSE BOX DEPOSITION (CBD)TECNOLOGY OF CIS FILMS FOR FLEXIBLE SOLAR CELLS



1- condensation zone heater,
2- substrate,
3-condensation zone,
4-vapour preparation zone,
5- vapor preparation zone heater,
6-Se evaporation zone,
7- Se evaporation zone heater



Innovative Aspects and Main Advantages of CBD technique

•The film deposition is fulfilled on conditions same to thermodynamic equilibrium that allow to obtain polycrystalline CIS films with perfect crystalline structure.

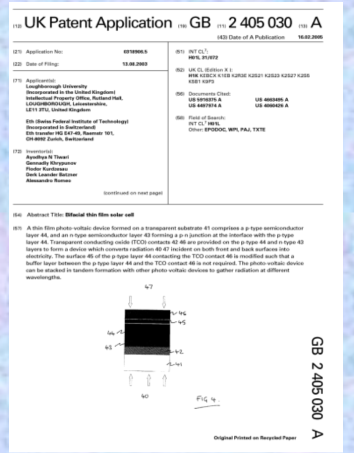
• The design of Se-crucible allows varying Se pressure in the chamber within large interval.

•Material - and energy saving technology:

-using of CD technique for preparation of In_2Se_3 by evaporation of elemental In and Se allows to decrease the In- source temperature to 500-580^{o}C, the substrate temperature to 350-400^{o}C. Se-source temperature was 400-470^{o}C;

- the reaction of Cu thin film with Se vapour in CD chamber allows to obtain Cu_2Se compounds at Cu film temperatures 320-470^{o}C (the Se source temperature was 330-350^{o}C);

BIFACIAL CdS/CdTe SC


(12) UK Patent Application (19) GB (11) 2 405 030 (13) A

(43) Date of A Publication 16.02.2005

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(22) Date of Filing: 13.08.2003

(71) Applicant(s):
Loughborough University
(Incorporated in the United Kingdom)
Intellectual Property Office, Rutland Hall,
LOUGHBOROUGH, Leicestershire,
LE11 3TU, United Kingdom

Eth (Swiss Federal Institute of Technology)
(Incorporated in Switzerland)
Eth transfer HG E47-49, Raemstr 101,
CH-8092 Zurich, Switzerland

(72) Inventor(s):
Ayodhya N Tiwari
Gennadiy Khrypunov
Fiodor Kurdzesau
Derk Leander Batzner
Alessandro Romeo

(continued on next page)

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(56) Documents Cited:
US 5916375 A
US 4497974 A
US 4663495 A
US 4090426 A

(58) Field of Search:
INT CL7 H01L
Other: EPODOC, WPI, PAJ, TXTE

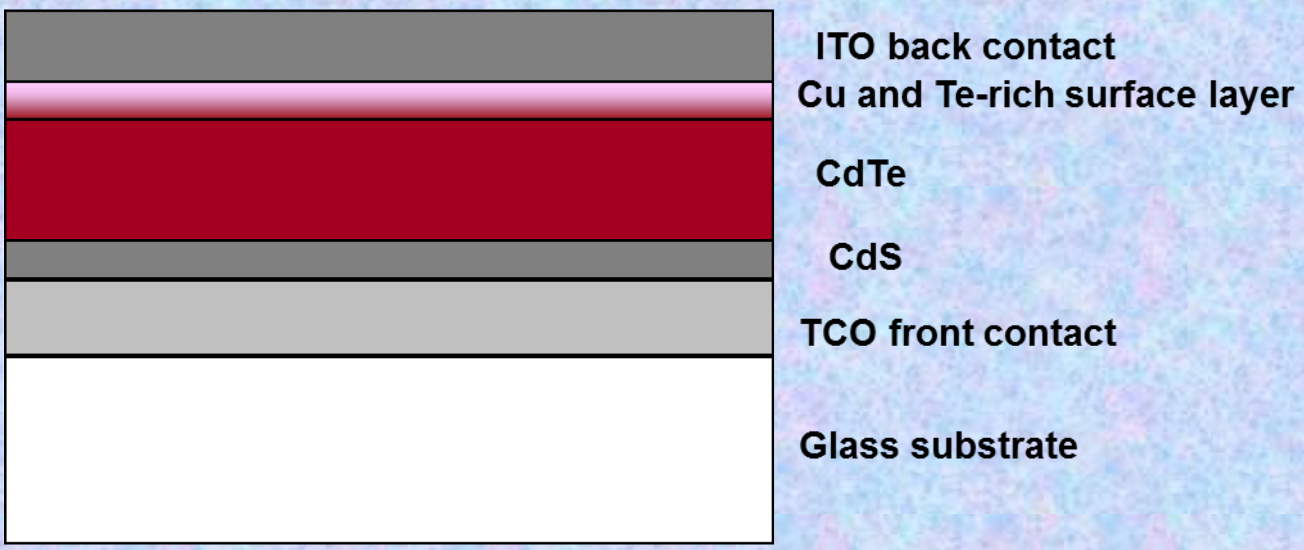
(54) Abstract Title: Bifacial thin film solar cell

(57) A thin film photo-voltaic device formed on a transparent substrate 41 comprises a p-type semiconductor layer 44, and an n-type semiconductor layer 43 forming a p-n junction at the interface with the p-type layer 44. Transparent conducting oxide (TCO) contacts 42 46 are provided on the p-type 44 and n-type 43 layers to form a device which converts radiation 40 47 incident on both front and back surfaces into electricity. The surface 45 of the p-type layer 44 contacting the TCO contact 46 is modified such that a buffer layer between the p-type layer 44 and the TCO contact 46 is not required. The photo-voltaic device can be stacked in tandem formation with other photo-voltaic devices to gather radiation at different wavelengths.

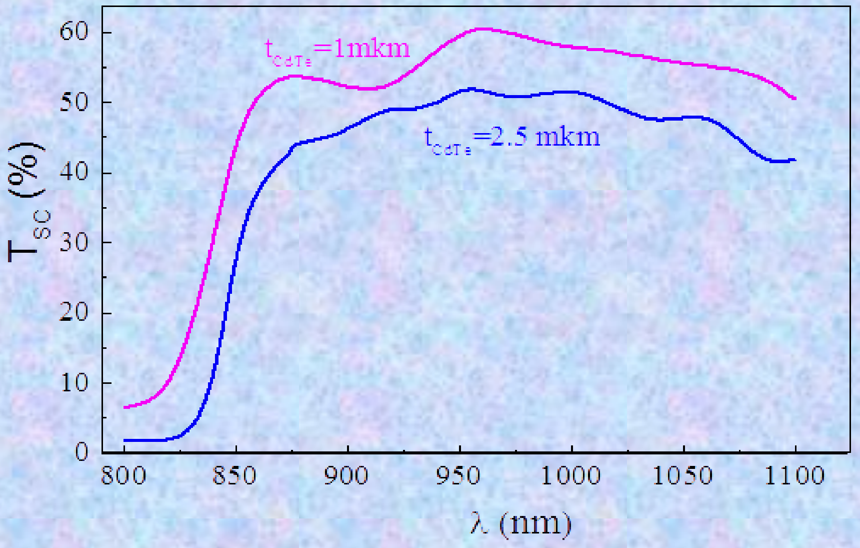
FIG 4.

GB 2 405 030 A

Original Printed on Recycled Paper



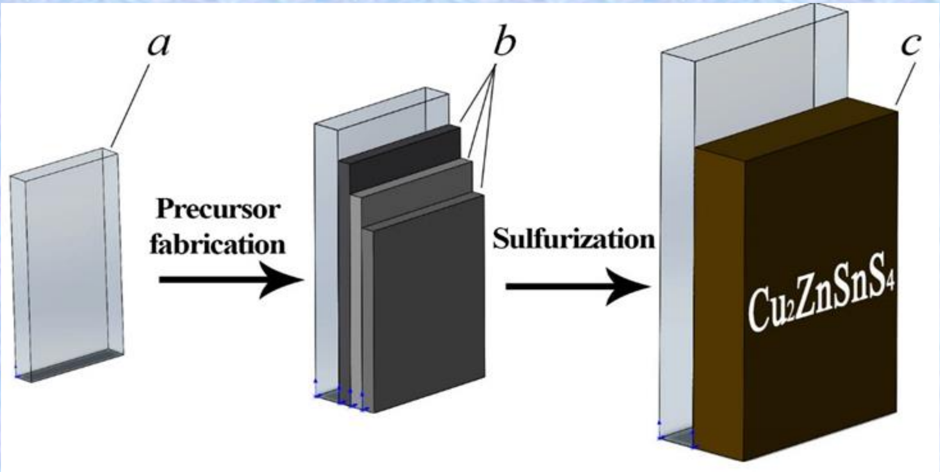
Sharing possibility of bifacial film solar cells on the base of CdTe and CuInSe2 in tandem structures is experimentally proved. It is established that for use in a tandem structure the optimum thickness of the base CdTe layer in bifacial solar cells is 1 µm. The prize of efficiency in investigated tandem structures in comparison with that of one solar cell on the CuInSe2 makes 1.8% at consecutive connection of solar elements and 1.3% at parallel connection.



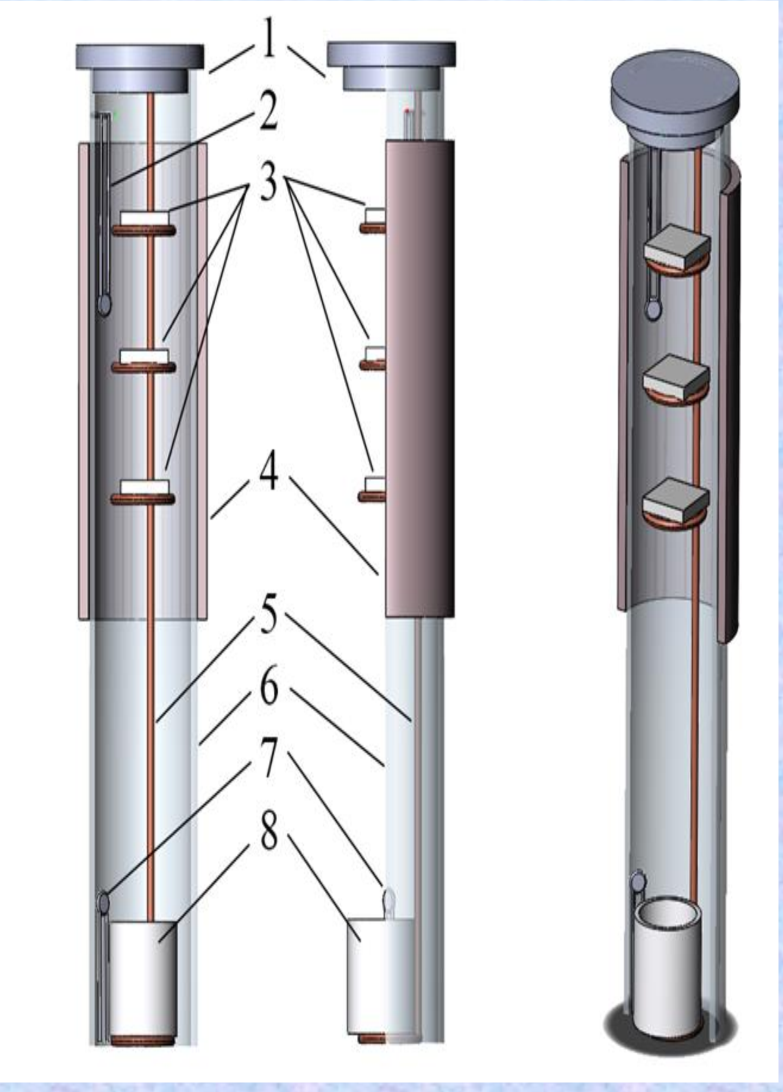
Infrared transmission glass/FTO/CdS/CdTe/Cu/ITO SC

TWO-STEP SYNTHESIS OF KESTERITE THIN FILM

electrodeposition



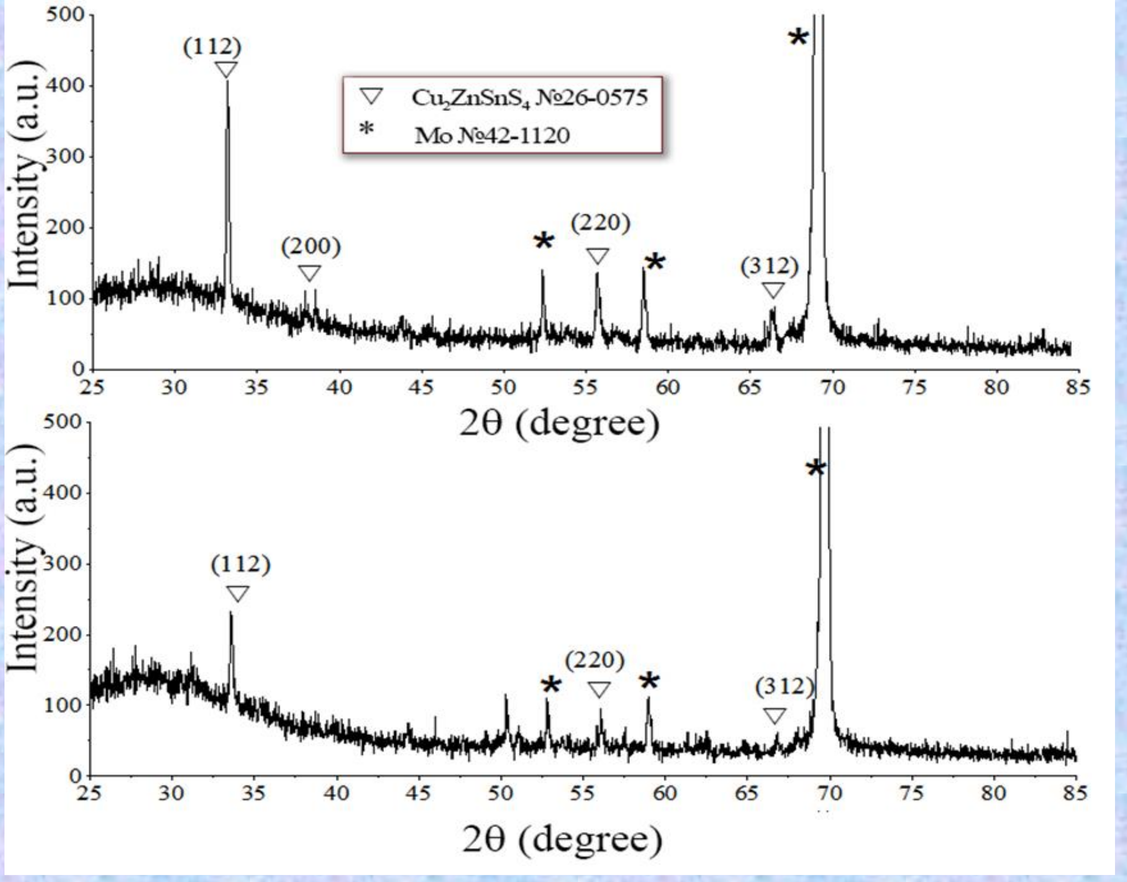
sulfurization

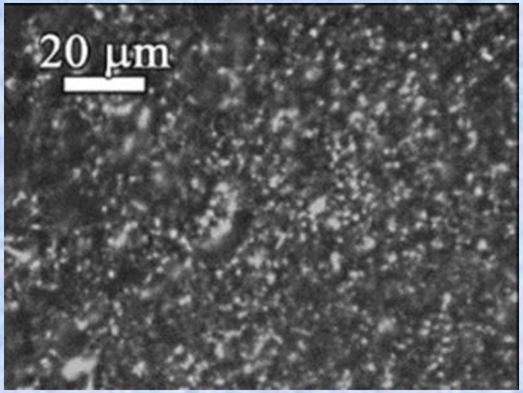


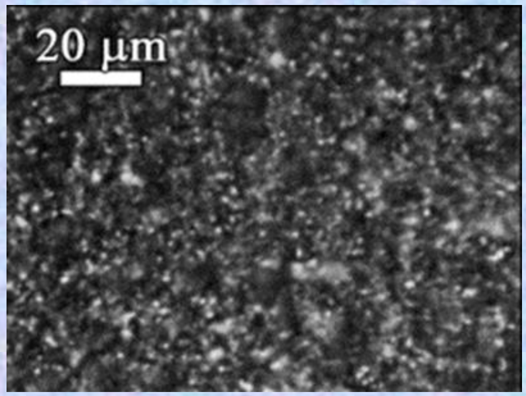
Process steps: a- substrate; b - electrochemically deposited layers of copper, tin and zinc in different sequences; c - synthesized kesterite

Design of reactor for precursors sulfurization: 1 - valve; 2, 7 - type K thermocouples; 3 - substrate; 4 - resistive heater; 5 - holder; 6 - quartz tube; 8 - cell with sulfur

STRUCTURAL PROPERIES OF KESTERITE THIN FILMS

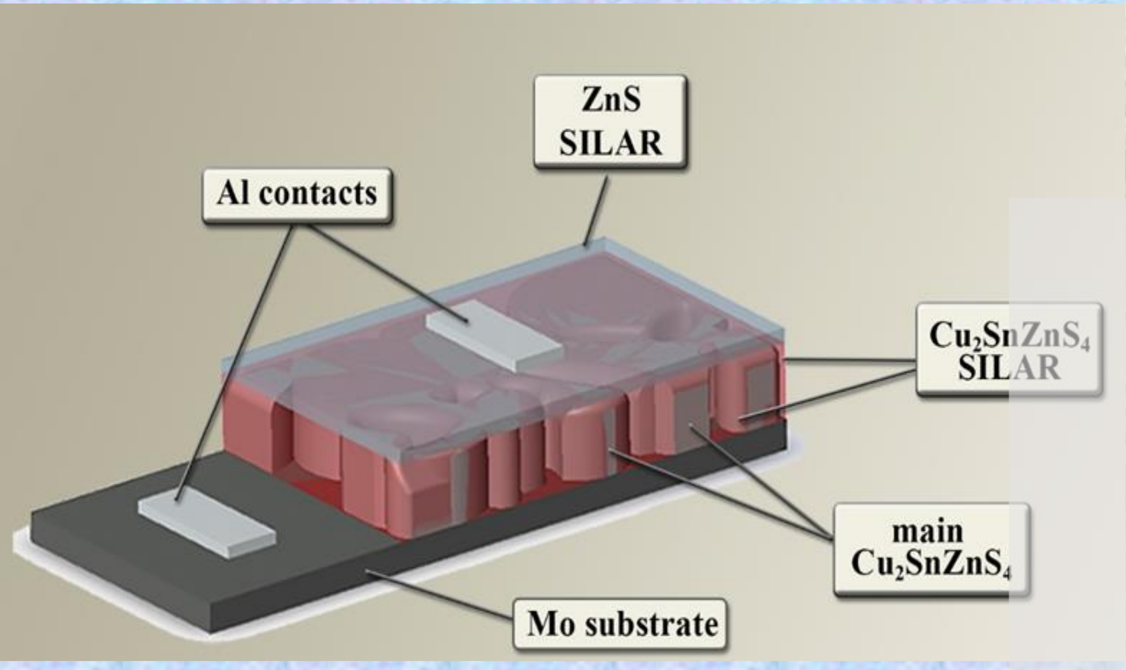


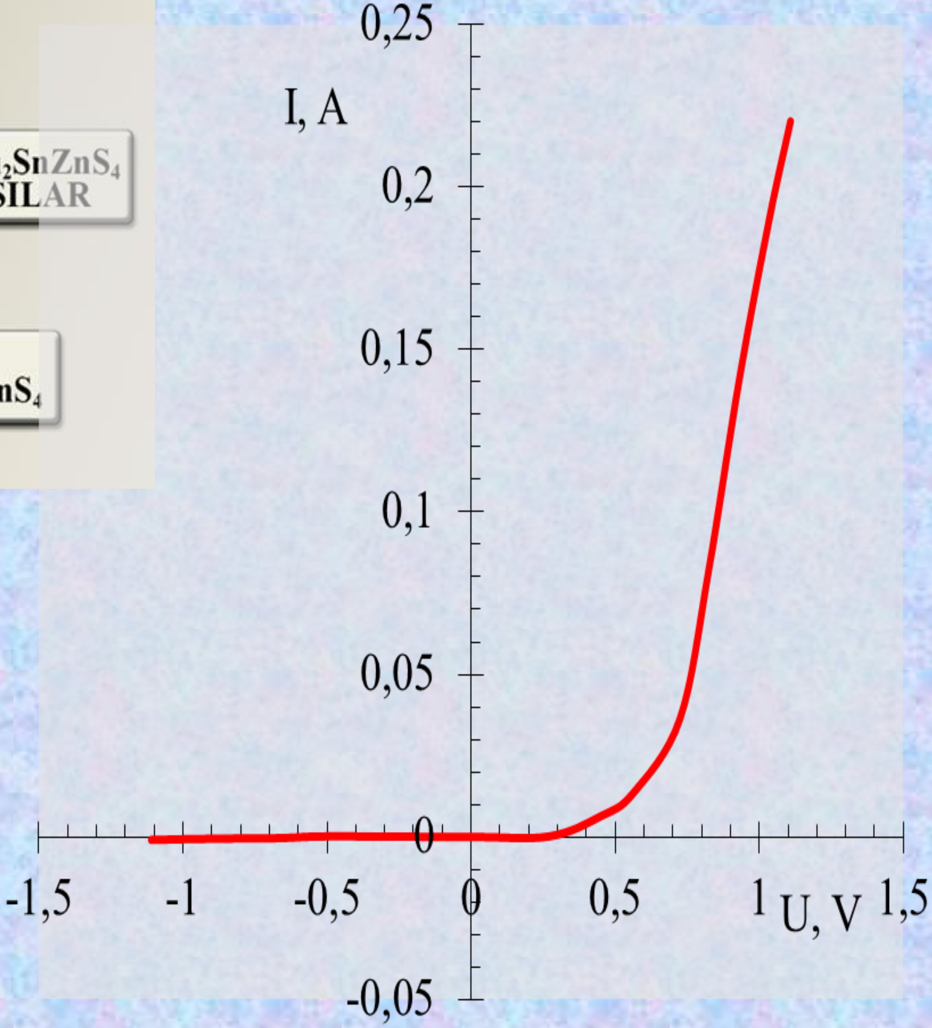




X-ray diffraction patterns of kesterite layers obtained by sulfurization of electrodeposited on Mo substrate Cu/Sn/Zn precursors and their micrographs

KESTERITE/ZINC SULPHIDE HETEROSTRUCTURE





Schematic illustration of thin film composition for Cu2ZnSnS4 solar cell on Mo substrate with Al contacts and its dark I–U characteristic:
Rsh = 2 kOhm, RS = 2 Ohm,
Jo= 0,56 mA/cm2, A = 2, φB = 0,6 eV

EXTREMELY THIN ABSORBER (ETA) SOLAR CELLS

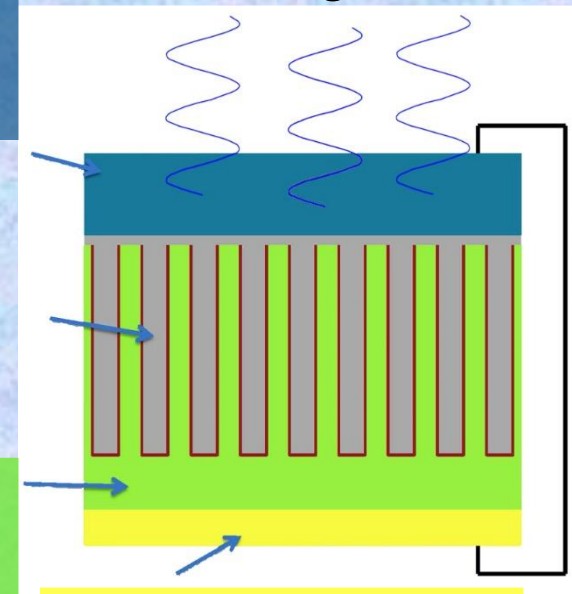
- Electron mobility in ZnO is much greater than in TiO_2
- ZnO is an ***inexpensive and environmental friendly material*** that can be synthesized in high purity and crystallinity ***at low temperature***
- Each nanowire is a single crystal with a wurtzite structure, oriented in the c-axis (002) direction that ***provides a highly efficient direct conduction path for electrons to the electrode (back contact)***

Electrically conducting glass (Fluorine doped tin oxide or FTO)

Zinc oxide nanorods with thin absorber layer (usually, CdTe, $CuInS_2$, a-Si, CdSe, CdS, $Cu(In,Ga)S_2$)

Hole conducting material (CuI, CuSCN, $CuAlO_2$, NiO, or organic polymer, etc.)

Light



Metal back electrode

- The choice of the absorber is guided by their ability to absorb visible light (1.1 < Eg < 1.8 eV) and transfer electrons to large bandgap semiconductors
- Candidate materials to be used as transparent hole conductors can be inorganic semiconductor

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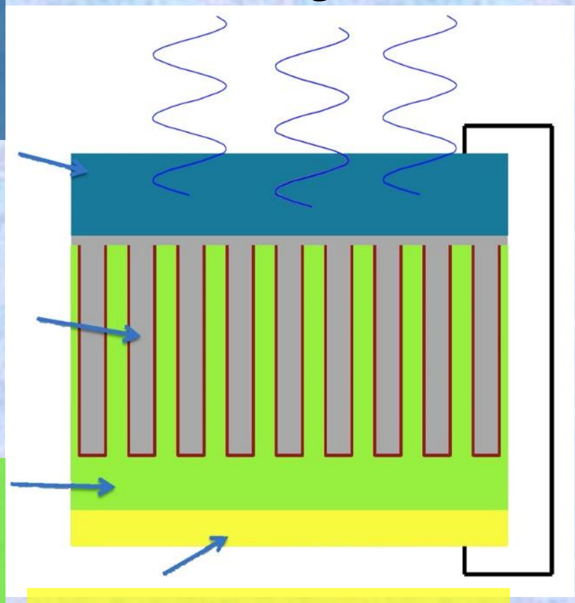

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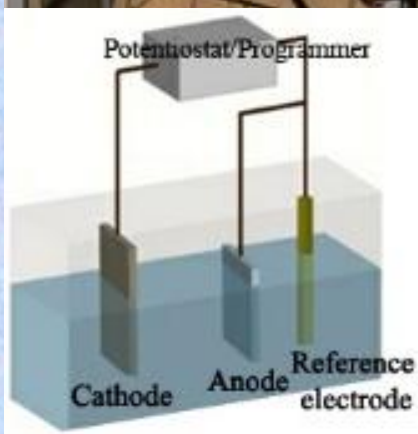
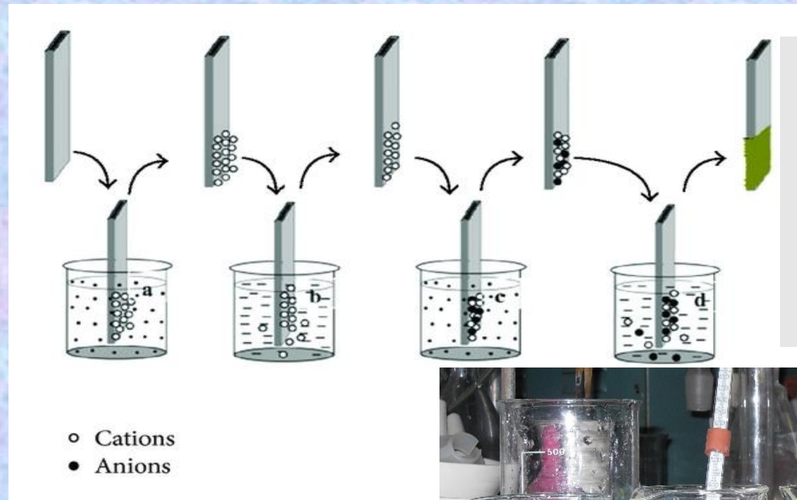
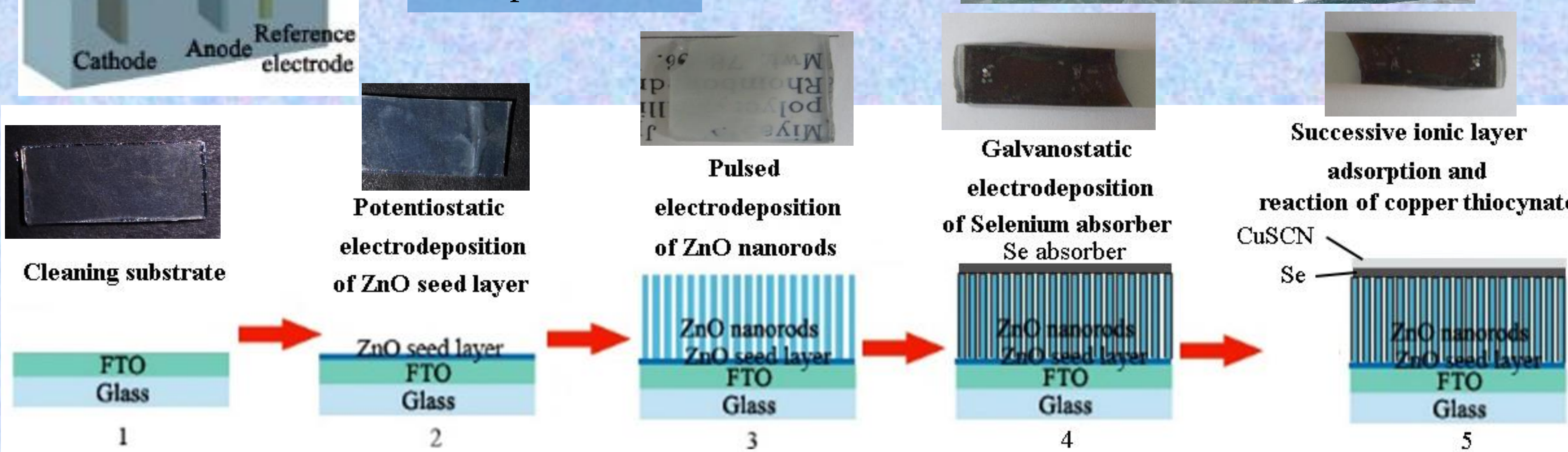
ETA SOLAR CELL PREPARATION STAGES



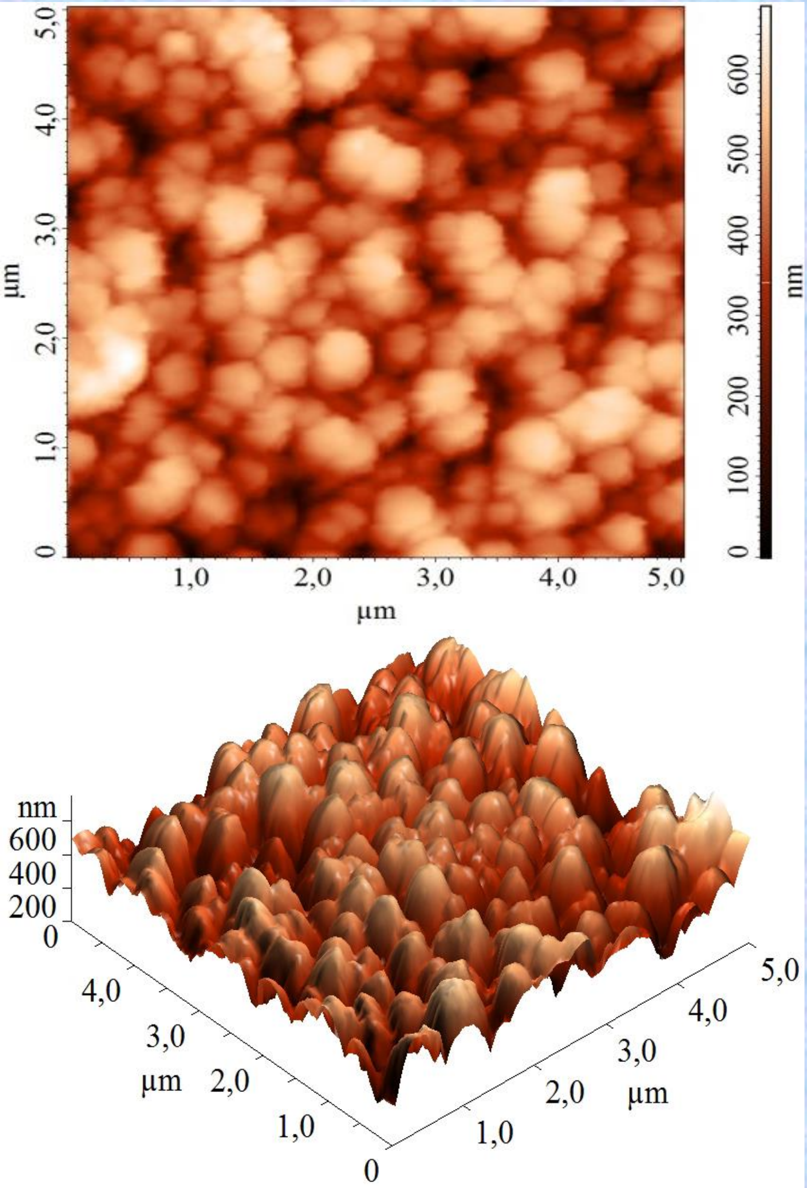
Setup for electrochemical deposition



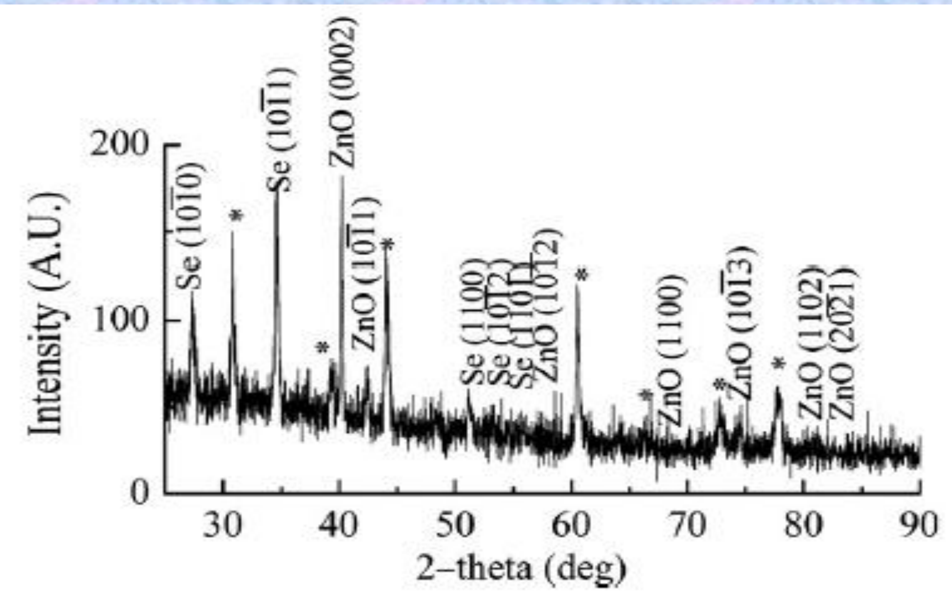
Schematic view of successive ionic layer adsorption and reaction approach



CRYSTALLINE STRUCTURE

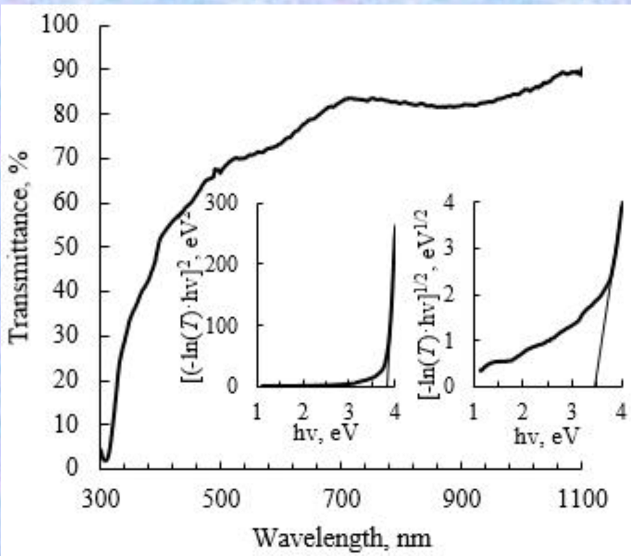


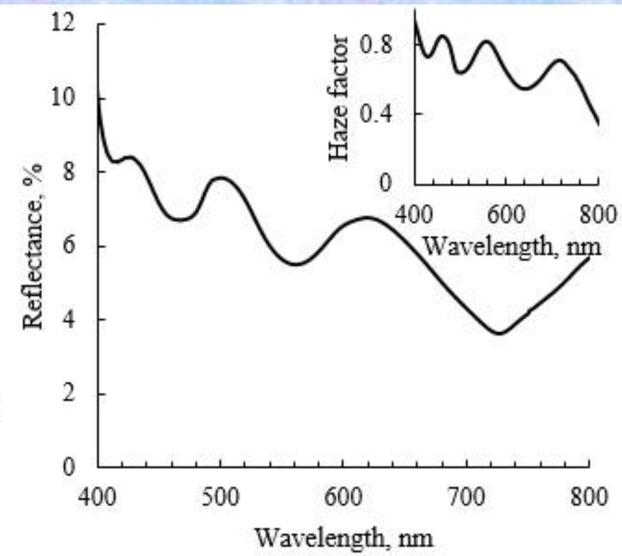
Atomic force microscopy images of pulsed electrodeposited zinc oxide nanorods



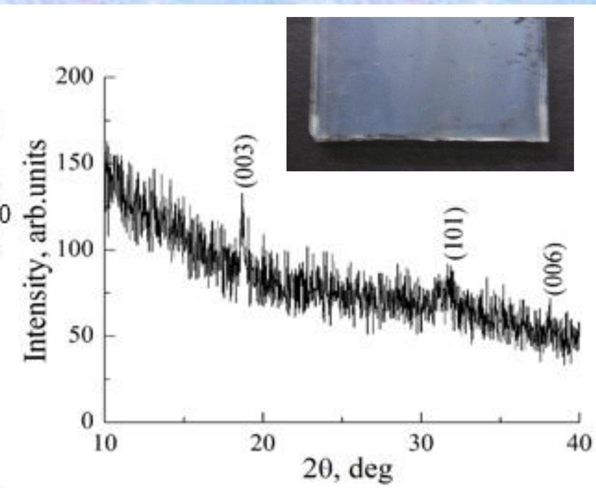
X-Ray diffraction pattern of ZnO nanorods covered by Se absorber

OPTICAL AND PHYSICAL PROPERTIES



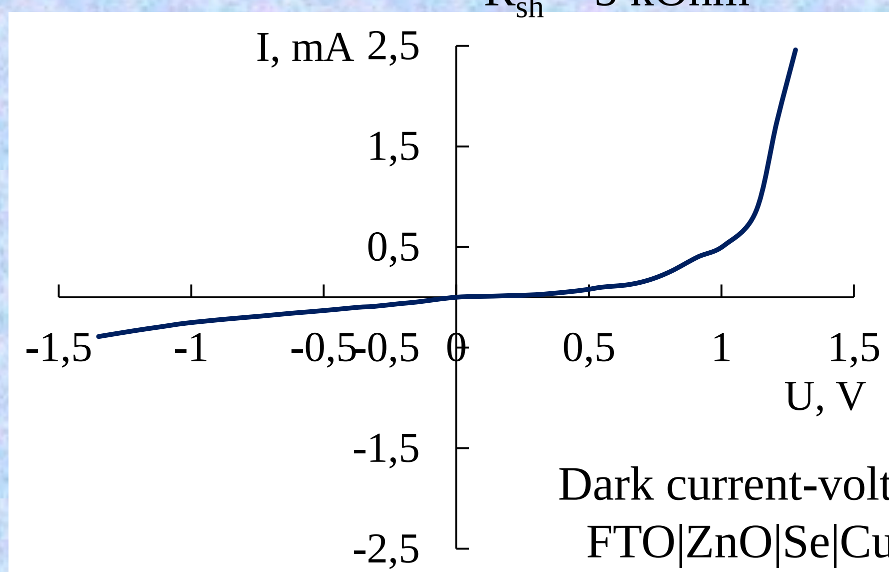


Transmittance and reflectance spectra of CuSCN on glass



X-Ray diffraction pattern of CuSCN on glass (as hole conducting material)

R_{sh} ~ 5 kOhm



Dark current-voltage characteristics of FTO|ZnO|Se|CuSCN|FTO structure

Automated complex certification solar cells based on LED simulator with improved spectral characteristics and functionalities


УКРАЇНА UKRAINE

ПАТЕНТ

НА КОРИСНУ МОДЕЛЬ

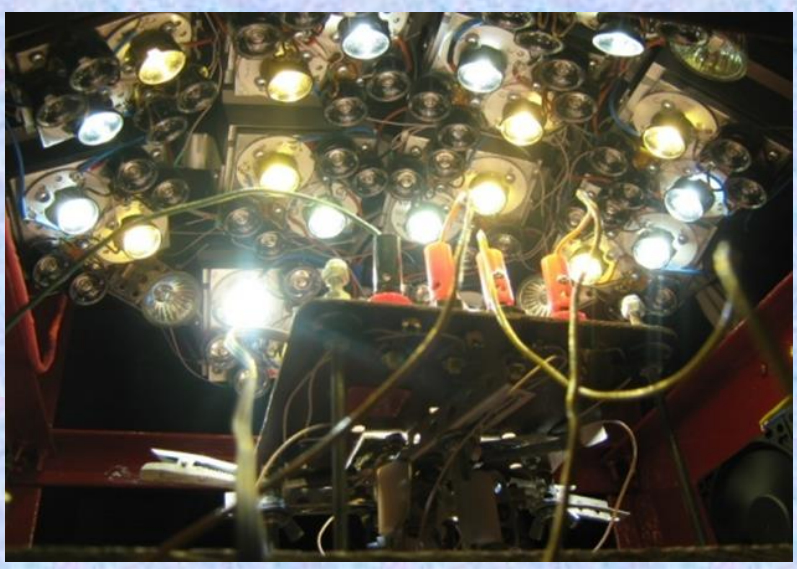
№ 33676

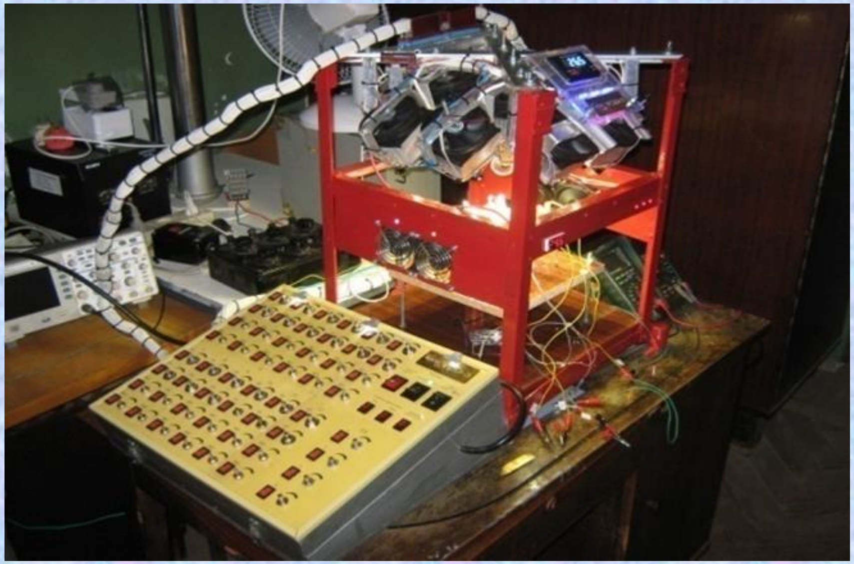
СВІТЛОДІОДНИЙ ОСВІТЛЮВАЧ

Видано відповідно до Закону України "Про охорону прав на винаходи і корисні моделі".

Зареєстровано в Державному реєстрі патентів України на винаходи 10.07.2008.

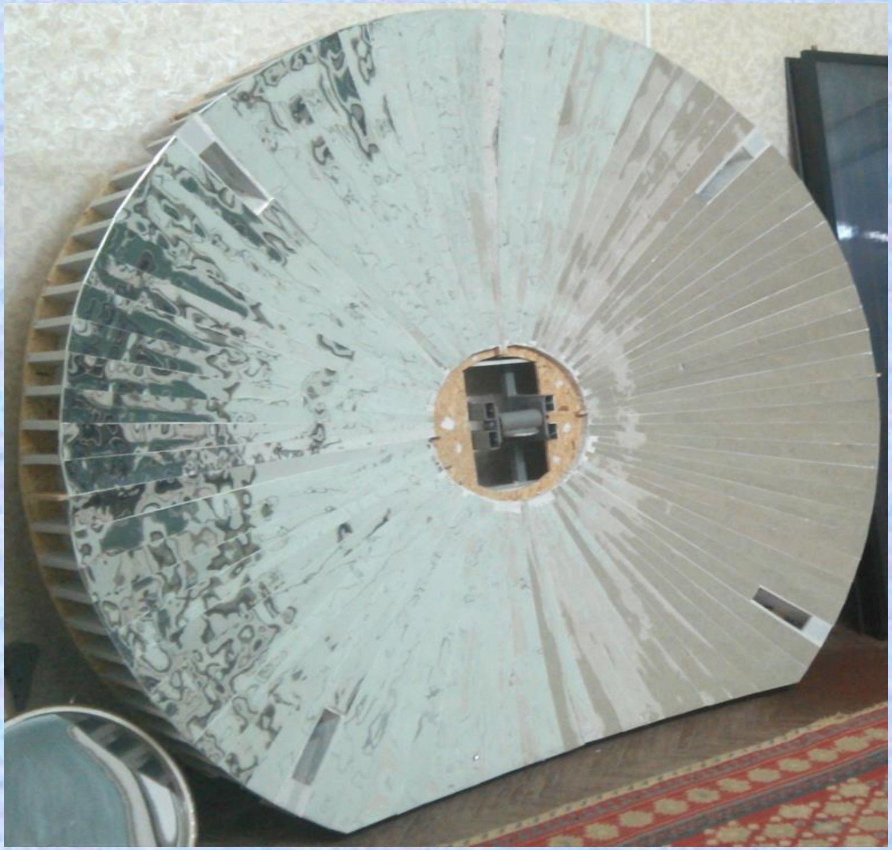
Голова Державного департаменту інтелектуальної власності — М.В. Паладій

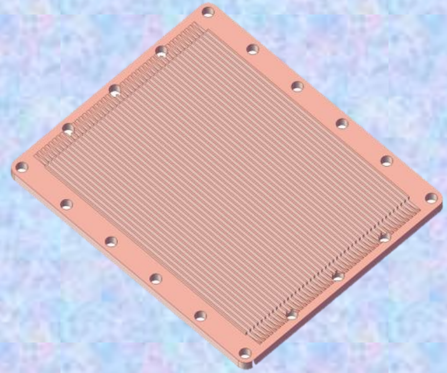


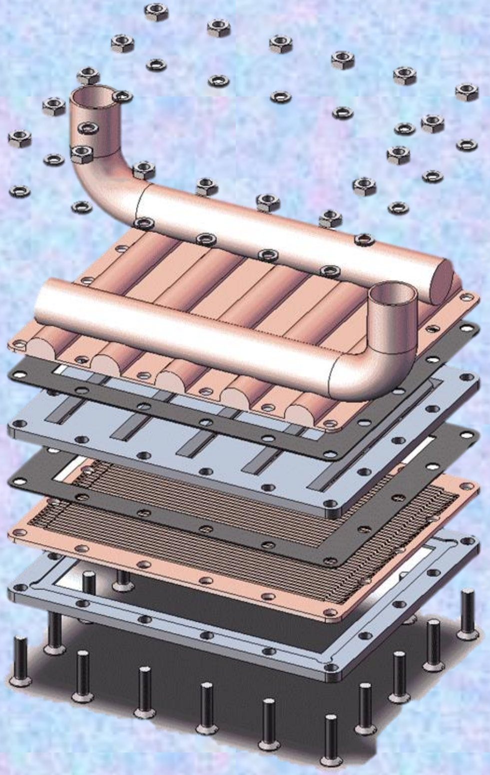


COST-EFFECTIVE SOLAR POWER PLANT

It was creation cost-effective solar power plant for producing electricity and heat energy with total efficiency up to 85%. For photoelectrical conversion solar energy was using industrial low-cost high-efficiency multijunction photovoltaic cells based on the structure of InGaP/InGaAs/Ge. The construction of creation heat exchanger allows to use turbulent flow of the coolant. Therefore heat transfer coefficient was increase up to 20,000. Further development, licensing, and technology transfer is sought.







Thank You