Perovskites for Photovoltaic Efficient Conversion Technology (PERPHECT)

UNIVERSITY OF ICELAND

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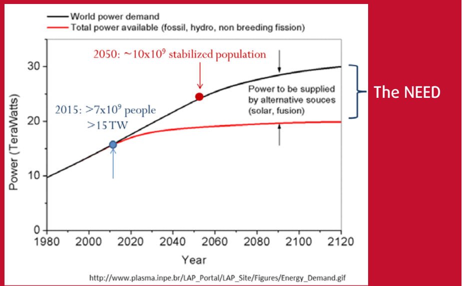
The NEED for research in photovoltaics

Starting with the industrial revolution in the eighteenth century the fossil fuel resources as stored during hundreds of millions of years are being rapidly depleted by excessive exploitation. Today's world population exceeds $7x10^9$ people consuming energy at a total amount of ~ 15 TW/year. The population is estimated to stabilize around 10×10^9 people somewhere beyond 2050 and then the energy demand may significantly exceed the one supplied by conventional sources. This shortfall in energy, which may occur already in a few decades from now, becomes larger after the depletion of fossil fuels, about 100 years in the future. A good solution to this problem is to get advantage of the renewable sources of energy available on Earth.

The most abundant, clean and secure renewable energy is coming from the Sun. However, presently, only a very small part of this energy is harvested and used by mankind. In this respect, one of the major challenge for the research community is to develop reasonable cheap materials, devices and integrated photovoltaic systems efficiently converting the sunlight directly in to electricity. Our research efforts are focusing on a new type of solar cell that has entered recently (in 2013) on the emerging low-cost photovoltaics arena, called Perovskite Solar Cell.

The topic of the PERPHECT research project is to optimize the performances of the perovskite photovoltaic cells by introducing new concepts for the separation of the photo-generated charge carriers, replacing some of the deficient materials with others more affordable and environmental friendly. The following step is to develop low costs fabrication technologies easily adaptable to large scale production.

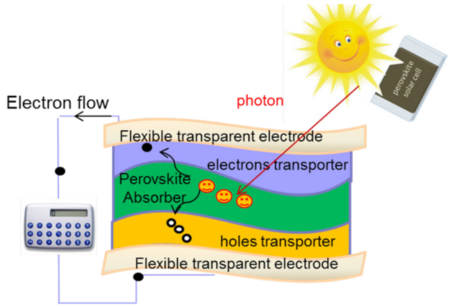
Estimates of the world energy use



Personnel: 39 researchers and technicians, 10 of them PhD students and Postdocs.

PEROVSKITES FOR PHOTOVOLTAIC EFFICIENT CONVERSION TECHNOLOGY (PERPHECT)

The main objective of the project is to develop perovskite-based photovoltaic devices towards "all perovskite" solar cells with power conversion efficiencies (PCE) approaching 20% and fabricated with affordable, environmental friendly materials and technologies (printing like methods). The final goal is to have an efficient, flexible structure with transparent electrodes on both sides, able to collect not only the sun-light but also the light coming from the artificial sources used, especially during the winter, inside office buildings or large malls.



Scientific challenges with relevance for direct practical use to be solved are:

- Replacing the actual transparent conducting electrodes based on ITO or FTO (In, Sn are deficient materials, while F can be potentially harmful for the environment) with metal nanowebs covered with Al doped ZnO.
- Optimizing the interfaces between the halide perovskite light absorber and the electron and hole transporters.
- Enhancing the charge collection by introducing more efficient active layers in intimate contact with the light absorber.

The innovative aspects of the project are:

- Fabrication of solar cells with transparent electrodes on both sides. Deposited on glass windows, these cells will harvest not only the Sun light but also the indoor light which otherwise is wasted.
- Use of printing-type technology for fabricating the test structures at pre-industrial level.

The project includes both basic and applied research. The first two years are dedicated more to basic research in order to understand the physics behind the working principle of the new halide perovskite absorber, as well as in finding ways to optimize the overall efficiency by enhancing the charge collection and minimizing the deleterious effects of series resistance. The third year will be dedicated more to applied research in order to optimize the low cost technology and build up a laboratory demonstrator.

PROJECT RESULTS AFTER THE FIRST 18 MONTHS

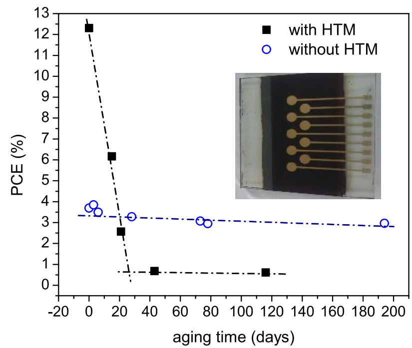
From the beginning of the project (july 2014) efforts were made mainly in basic research aiming to understand the physics behind the working principle of the new perovskite solar cells and to find the ways for optimizing the overall efficiency. Some research time has been dedicated also to applied research in order to optimize the low cost technology and build up a laboratory demonstrator.

Fabrication by cheap chemical methods (spin-coating)

We have used spin-coating technique for the fabrication of the cells, some of the layers depositions being performed in glove-box under controlled atmosphere.

We have explored several technological processes for layers deposition in order to reduce the recombination effects at the interfaces between different layers and to enhance PCE. The maximum PCE we have obtained is 12.5%. Unfortunately, these perovskite solar cells are not stable in time when kept in ambient atmosphere.

Our studies revealed that the observed degradation is associated with the used hole transporter material (HTM) namely, spiro-OMeTAD. Studies for the encapsulation of the cells as well as for finding the proper HTM

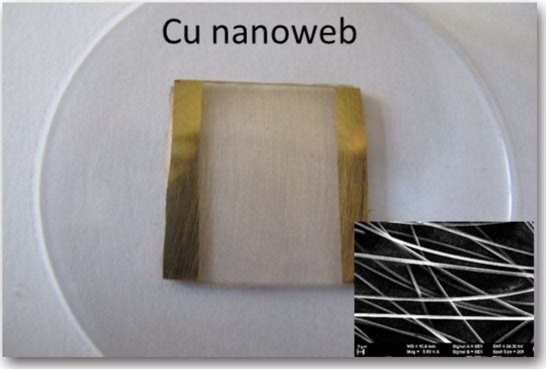


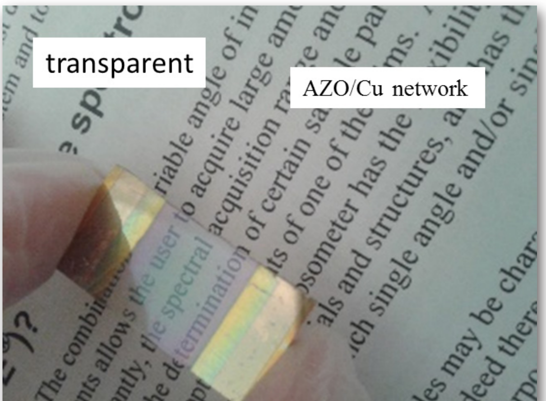
have just begun.

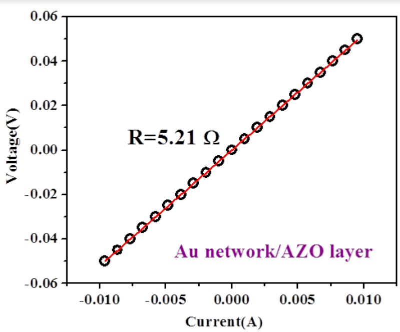
Flexible electrodes

One important issue to be solved during the project is to find a replacement for the actual rigid transparent conducting electrodes based on ITO or FTO /glass.

Our idea is to fabricate metal (Cu, Ag or Au) nanowebs and cover them with a transparent conductive oxide as is AZO. The metallic nanowebs are obtained by electrospinning, a facile process for aligning nanofibers in regular arrays. A thin AZO layer filling the holes of net is then deposited over the metallic nanowebs. This procedure results in a transparent and conductive electrode. Therefore, AZO material on metallic nanowebs is a promising solution for developing cheap and flexible solar cells.







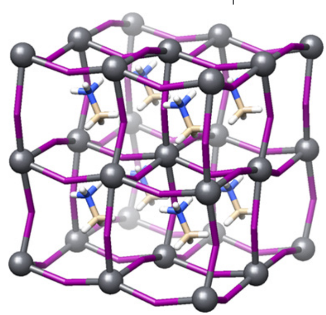
Theoretical Calculations

The simulations are based on an ab-initio atomistic approach, where each atom is described with quantum mechanics and density functional methods. The role of such simulations is to calculate the band structure of the solar cell device, the material parameters, the electric polarization, and other important features.

Based on such studies one can anticipate whether a new compound included in the device, with the role of electron transporter, can increase the photoconversion efficiency.

For example, it has been calculated that in the $CH_3NH_3PbI_3$ halide perovskite cell (depicted in the figure bellow) the CH_3NH_3 molecules (represented in blue-yellow) have electric dipole moments and perform fast rotations within the cell.

The individual dipoles tend to be correlated resulting in a net polarization of the cell. We thereby qualitatively describe the modus operandi of formation of microscopic ferroelectric domains in the perovskite.



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Project ID: 8 SEE

Project Program: EEA-JRP-RO-NO-2013-1

Funded by: Ministry of National Education-Research Department

Donator States: Norway, Iceland, Liechtenstein

Duration: July, 2014 - April, 2017

Budget/grant/own contribution:

€ 1,297,000 / € 1,102,450/ € 296,099

Coordinator: National Institute of Materials Physics (Romania)

Partners:

- University of Oslo (Norway)
- University of Iceland (Iceland)
- Reykiavik University (Iceland)
- Bucharest University (Romania)
- Optoelectronica 2001 S.A. (Romania)

Through the EEA Grants and Norway Grants, Iceland, Liechtenstein and Norway contribute to reducing social and economic disparities and to strengthening bilateral relations with the beneficiary countries in Europe. The three countries cooperate closely with the EU through the Agreement on the European Economic Area (EEA).

For the period 2009-14, the EEA Grants and Norway Grants amount to €1.79 billion. Norway contributes around 97% of the total funding. Grants are available for NGOs, research and academic institutions, and the public and private sectors in the 12 newest EU member states, Greece, Portugal and Spain. There is broad cooperation with donor state entities, and activities may be implemented until 2016.

Key areas of support are environmental protection and climate change, research and scholarships, civil society, health and children, gender equality, justice and cultural heritage.

http://www.infim.ro/projects/perovskites-photovoltaic-efficient-conversion-technology-o

www.eeagrants.org