Period 1: Publishable Summary

Summary of project objectives

HIFLEX aims to develop a cost-effective **Highly Flexible Printed ITO-free Organic Photovoltaics (OPV) module technology** that matches the particular requirements of mobile and remote ICT applications, delivering the required efficiency under different light conditions, sufficient lifetime, acceptable cost structure, appropriate power-to-weight ratio and fit-to-purpose mechanical flexibility. The project intends to accelerate the exploitation of this OPV technology for a wide variety of ICT products in the mobile electronics market.

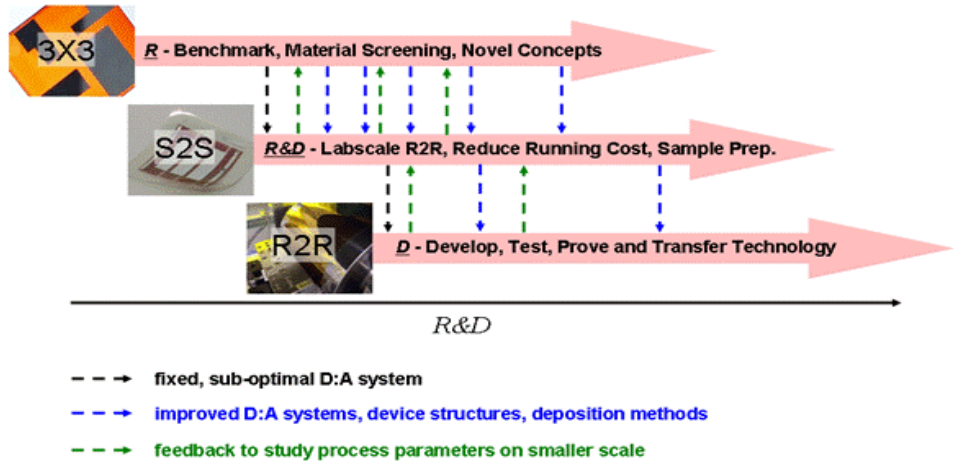
An application-driven research approach will be followed by developing large area, solution processable ITO-free OPV using scalable, reproducible and commercially viable printing and coating techniques enabling the **low-cost** production of **highly flexible** and **lightweight** OPV products. At the same time it guarantees the technological compatibility with other printed electronic ICT components and systems. The high flexibility and low costs will be addressed by the **solar cell module design** we intend to bring into production.

Description of the work performed since the beginning of the project

Approach:
HIFLEX aims to develop materials, device architectures and manufacturing procedures for large scale fabrication of OPV modules with increased power conversion efficiencies and lifetimes that are sufficiently long for the first commercial mobile applications in the low-power market segment (mobile telephones, PDAs, laptop computers).
In order to reach the targets, the the Hiflex consortium had developed an operational approach schematically shown in scheme I.

In the so called **R**esearch line, substrates with sizes up to 3x3cm^2 will be used. These substrates consist of a few single cells with active areas up to 1cm^2 and will be used to screen and optimize new available materials and explore novel ITO free device architectures. The performance of these lab scale devices, based on a particular set of materials and device architecture, will subsequently function as the benchmark for experiments that will be carried out on a Sheet-to-Sheet (S2S) and Roll-to-Roll (R2R) basis.

The final objective is to produce low cost polymer solar cells on a R2R basis. It is important to build up a knowledge base concerning the influence of process conditions on the performance of polymer solar cells. R2R experiments will give results that are most relevant for a final production line; however experiments on R2R scale are typically more laborious, consume significant amounts of materials and are therefore more expensive. To collect the required data, experiments will be performed both on R2R scale (designated as **D**evelopment-line) as well as on sheet-to-sheet (S2S) scale (designated as **R&D** line). The S2S coating technique will be chosen in such a way that the basic physical and chemical processes are similar to those in R2R model. Different module designs and ink formulations will be compared based on a limited set of "fixed" materials combinations which are selected from the research line. It will be important to select the proper substrate and deposition method for experiments on S2S scale in order to be able to translate these results to the deposition method used for R2R production The S2S experiments in the **R&D** line thus form a stepping stone in the process from lab scale devices in the research line towards the production of R2R processed modules in the **D**evelopment line.
The general aim of the experiments in the **D**evelopment line is to develop and prove the technology, and more specifically they will be used to formulate the right research questions for the experiments that will be carried out in the **R**esearch and **R&D** line. This feedback loop is important and essential to accelerate the development of OPV to a fully mature PV technology for the first generation of products in the mobile ICT market.



The work that has been performed since the beginning of this project in the **R**esearch , **R and D** and **D**evelopment line can be summarized as follows:

- Design, fabrication and first performance evaluation of ITO benchmark and ITO-free device structures (WP 1)
- Development of fabrication technologies for optimal S2S and R2R processing of OPV (post patterning by laser structuring, via hole drilling of Wrap through devices) (WP2)
- Electrical modeling to design optimal cell and module structures for ITO-free device concepts (WP2) and experimental validation (WP1,3)

- First evaluation of large Area characterization methods (optical inspection, LBIC) for process control (WP2,4)
- Development of low resistance ITO-free substrates composed of current collecting printed grids and highly conductive PEDOTs (WP3) as input for device fabrication (WP1,2)
- R2R production of ITO-based and ITO-free module structures (WP4)
- Inventory of public available LCA's for OPV and definition of workplan to conduct in depth LC and cost assessment (WP5)
- Dissemination activities (WP6)

Description of main results so far

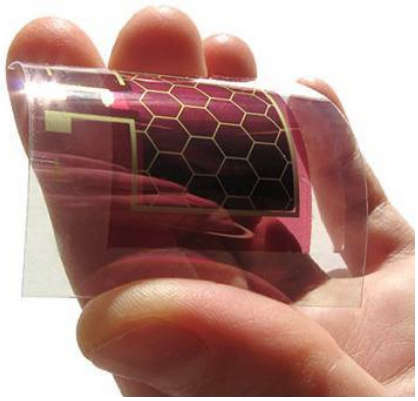
- A novel ITO-free polymer solar cell structure is manufactured in which all layers, including electrodes, are solution processed. This new roll-to-roll compatible device yields an efficiency of 2.5 % (active area <1 cm^2) compared to 3 % for an ITO reference device
- Theoretical calculations were performed to calculate optimal designs for composite anodes and wrap through devices. The calculations show that the freedom of design for ITO free modules is much larger than for ITO based systems in terms of efficiency potential for large area modules
- Evaluation of LBIC and optical inspection systems reveal large potential for detection of spatial inhomogeneities and defects in organic layers produced by S2S and R2R processing
- Flexible ITO-free solar cells were encapsulated with Holst Centre's barrier technology developed for flexible OLEDs and lifetime testing was performed during 1000h @ 45°C and 1 sun. The limited efficiency loss (less than 10%) was comparable to the hermetic sealed OPV cells made on glass and sealed with a glued metal lid.
- Large-area modules with PET/ITO/ZnO/P3HT: PCBM/PEDOT: PSS/Ag (ITO-based) were successfully produced in a full R2R process. Modules with area as high as 360cm^2 gave a maximum efficiency of 1.69%.
- Large area ITO-free modules were produced under two concepts;1) striped module that comprised of 16-serially interconnected cells 2) large Area monolithic single cells. For monolithic cells, four different designs of the silver-electrode pattern--honey comb, grid, comb, large honey comb--were studied. A maximum of 0.5% efficiency on a total area of 235cm^2 was achieved on the striped module while the best monolithic device gave a maximum performance of 0.36% with a 'grid' patterned silver electrode.
- Production of first draft of LCA report establishing a strong base position to enable the development of a comprehensive and timely OPV study.
- Dissemination activities: A number of events were attended and scientific publications produced (>5) in the first period, while strong networks with industry and scientific community have been established.

Expected final results and potential impact and use

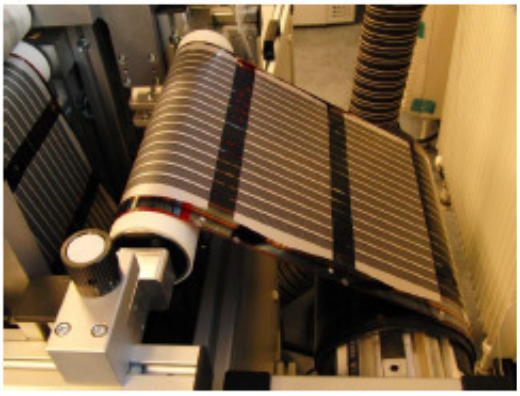
We anticipate that this project will result in the demonstration of a new scalable, low cost, solution processable photovoltaic technology. It will therefore form the basis of a potentially substantial business opportunity aiming at developing a new solar cell product with cost and payback characteristics which are more advantageous than existing technologies. This will benefit the entire European community in creating economically accessible PV technology and significant industrial activity by demonstrating viable production procedures for OPV.

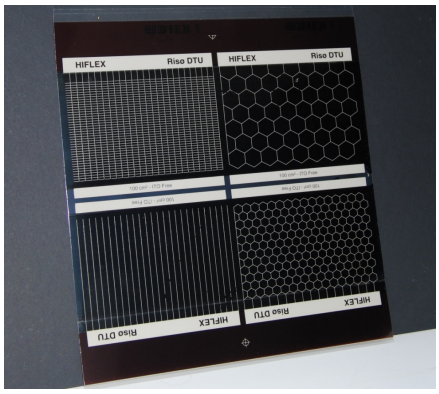
Project website information

http://www.hiflexopv.eu



A flexible ITO-free OPV device with a composite anode based on a Ag grid and highly conductive PEDOT:PSS





Silver screen printing for the serially connected devices (left) and An image of the monolithic cells prepared using four different silver grid patterns