



# PHOTOVOLTAIC TEXTILES: MYTH OR REALITY?

Barbero N., Barni E., Barolo C., Quagliotto P., Viscardi G.

Università degli Studi di Torino  
NIS Interdepartmental Centre of Excellence  
Dipartimento di Chimica Generale e Chimica Organica  
Corso M. D'Azeglio 48 - 10125 Torino - Italy

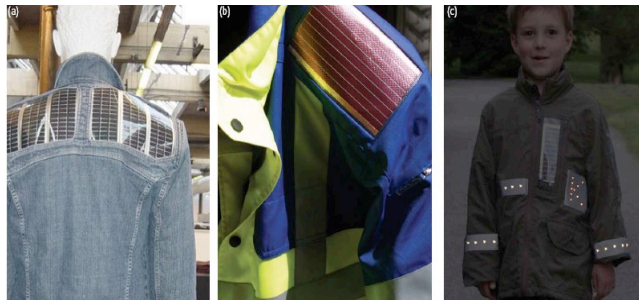
---

22nd IFATCC INTERNATIONAL CONGRESS, Stresa, 5-7 Maggio 2010

# **OUTLINES:**



- What does it mean Photovoltaic Textiles?
- Silicon - based prototypes.
- Wire-shaped Dye Sensitized Solar Cells.
- Wire-shaped All Organic Solar Cells



## ➤ What does it mean Photovoltaic Textiles?

**Photovoltaic Textiles means:**

**fabrics with the capability of generating clean, usable and wearable energy thanks to their sun exposure; this property determines a great added value.**

## ➤ What does it mean Photovoltaic Textiles?

**Photovoltaic Textiles means:**

**fabrics with the capability of generating clean, usable and wearable energy thanks to their sun exposure; this property determines a great added value.**

**Uses: Energy supplier for**

- Mobile phones
- Mp3 players
- Personal digital assistants (PDAs)
- Cameras
- Global positioning systems (GPS)
- notebook





## ➤ Silicon based prototypes.

**Initial approach:  
textiles with integrated rigid Si based photovoltaic cells**



M.B. Schubert et al.



Courtesy of Mustang



**SOLARTEX Project;  
Courtesy of Maier Sports**

M.B. Schubert et al. Materials Today 2006, 9, 42-50

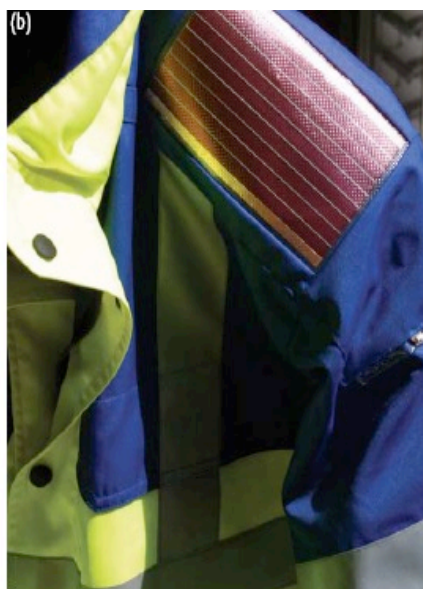
## Photovoltaic Textiles Requirements:

- **easy to use**
- **comfortable and reliable**
- **offer a universal socket for the countless different charging adapters and devices**
- **deliver plenty of energy**
- **affordable price**
- **attractive and integrate well with the particular design of the garments**
- **washable**
- **conformal flexibility**

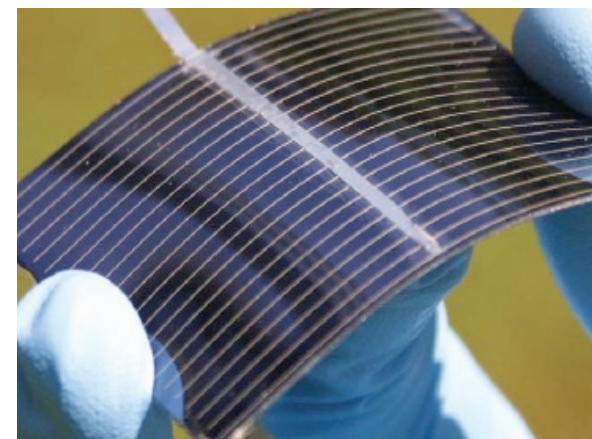
## Photovoltaic Textiles Requirements:

- **easy to use**
- **comfortable and reliable**
- **offer a universal socket for the countless different charging adapters and devices**
- **deliver plenty of energy**
- **affordable price**
- **attractive and integrate well with the particular design of the garments**
- **washable**
- **conformal flexibility**

# Novel approach: textiles with integrated flexible Si-based photovoltaic cells



**Cristalline Si (Shell Solar)**



**SOLARTEX Project**

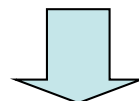
M.B. Schubert et al. Materials Today, 2006, 9, 42-50



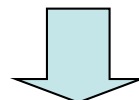
## **Novel approach: textiles with integrated flexible Si-based photovoltaic cells**

### **Limits of Si-based photovoltaics:**

- they bend well but do not crinkle
- strong dependence on the radiation angle, intensity and spectrum of light source
- high cost



**the advent of real products in the market has been hindered and delayed.**

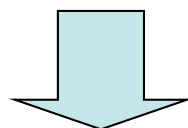


**MITH?**

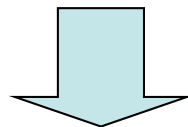
M.B. Schubert et al. Materials Today, 2006, 9, 42-50

## **Photovoltaic Textiles applications for customer:**

- ✓ **sports, leisure, clothing**
- ✓ **home and architecture**
- ✓ **automotive textiles**
- ✓ **solar tents and parasols**



**Deep interest and expectation from customers**

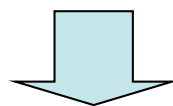


**ADVANCED PHOTOVOLTAIC TECHNOLOGIES  
BASED ON NANOSCIENCE**

## ADVANCED PHOTOVOLTAIC TECHNOLOGIES

- ✓ Dye Sensitized Solar Cells (DSSC)
- ✓ All Organic PhotoVoltaics (OPV)

Low Capital Costs  
High Production Rates  
Integrability  
Trasparency  
Lightness  
Design Opportunities



**MEGAWATTS GENERATION AT UNPRECEDENTED LOW COST  
INTEGRABILITY WITH BUILDING**

# ADVANCED PHOTOVOLTAIC TECHNOLOGIES

- ✓ Dye Sensitized Solar Cells (DSSC)
- ✓ All Organic PhotoVoltaics (OPV)

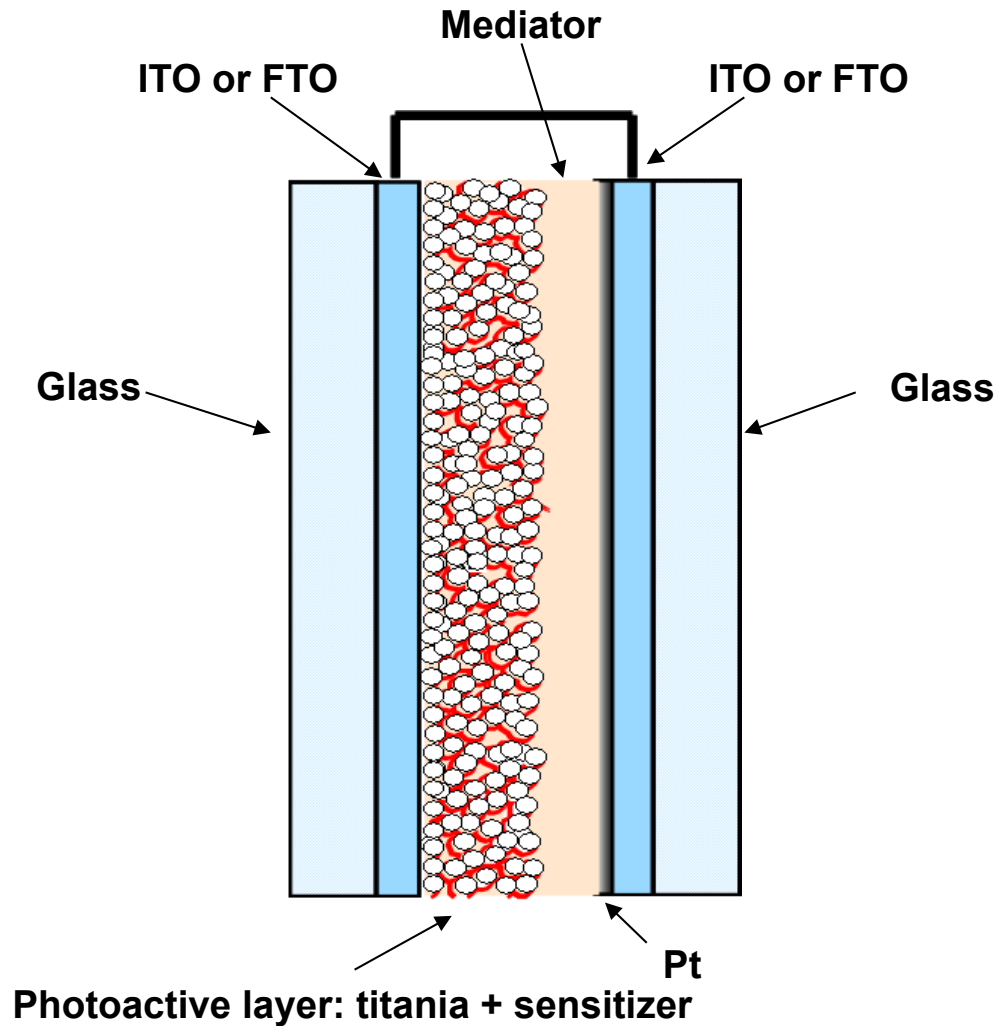
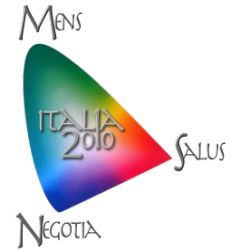


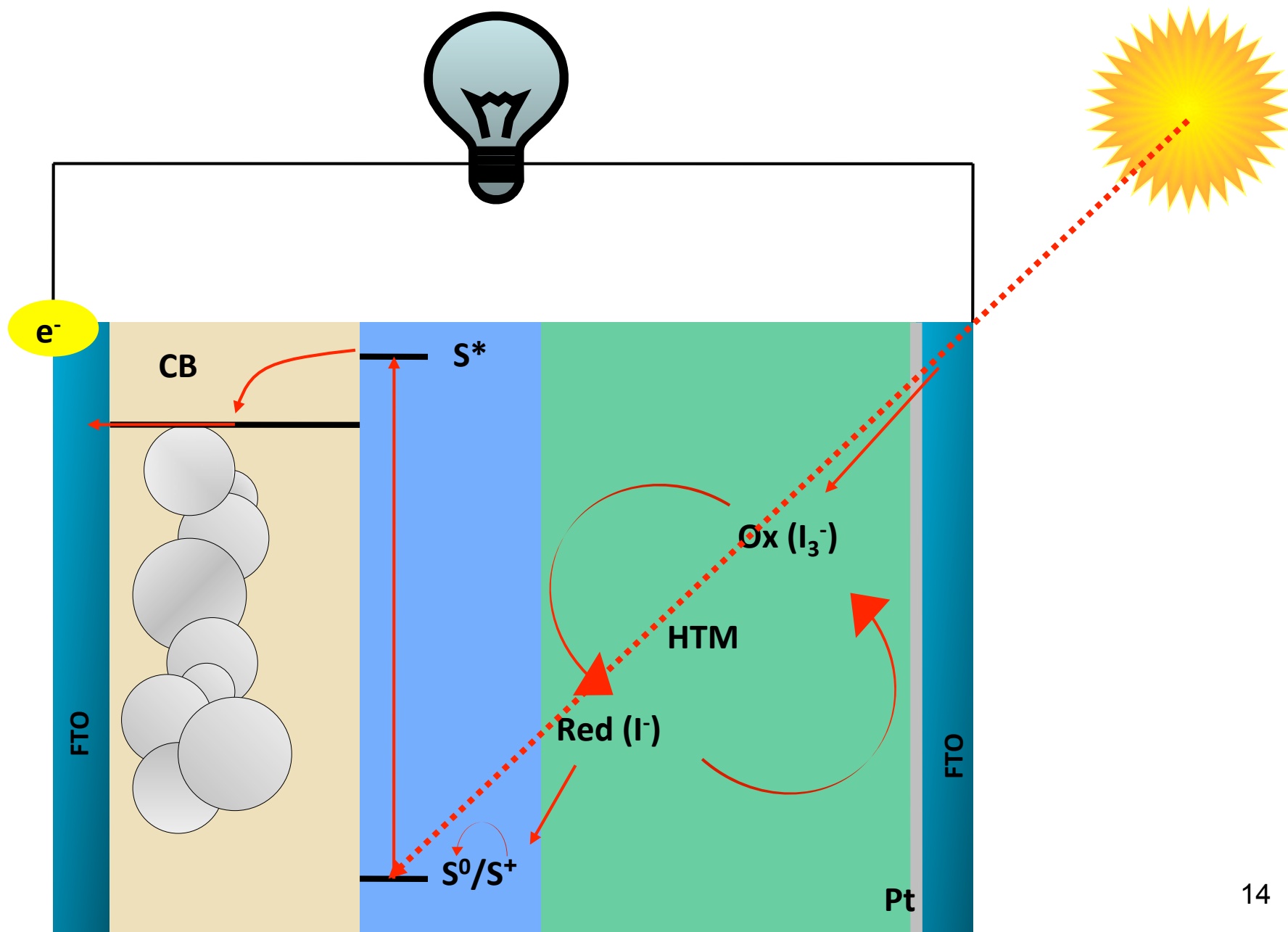
Grätzel M. et al., *Nature*, 1991, 353, 737-740



# ADVANCED PHOTOVOLTAIC TECHNOLOGIES

- ✓ **D**ye **S**ensitized **S**olar **C**ells (DSSC)
- ✓ All Organic PhotoVoltaics (OPV)





## ADVANCED PHOTOVOLTAIC TECHNOLOGIES

- ✓ **Dye Sensitized Solar Cells (DSSC)**
- ✓ All Organic PhotoVoltaics (OPV)

**Cell efficiency depends from:**

- **Photons collection of sensitizer**
- **Surface area of semiconductor nanoparticle film**
- **Electrons transport in semiconductor**
- **Effectiveness of charges collection and transport by the electrodes**

## ADVANCED PHOTOVOLTAIC TECHNOLOGIES

- ✓ **Dye Sensitized Solar Cells (DSSC)**
- ✓ All Organic PhotoVoltaics (OPV)

**Cell efficiency depends from:**

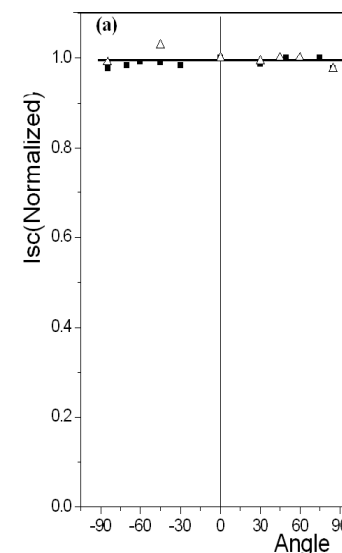
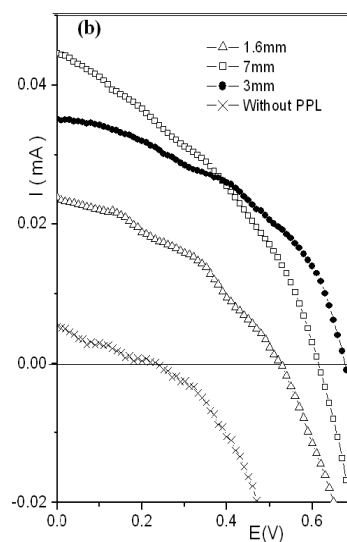
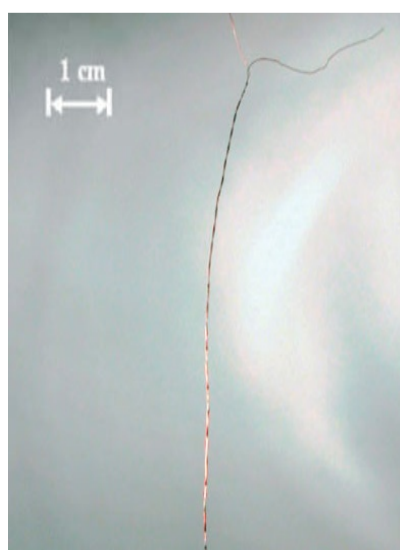
- Photons collection of sensitizer
- Surface area of semiconductor nanoparticle film
- Electrons transport in semiconductor
- **Effectiveness of charges collection and transport by the electrodes**



# ADVANCED PHOTOVOLTAIC TECHNOLOGIES

## ✓ Dye Sensitized Solar Cells (DSSC)

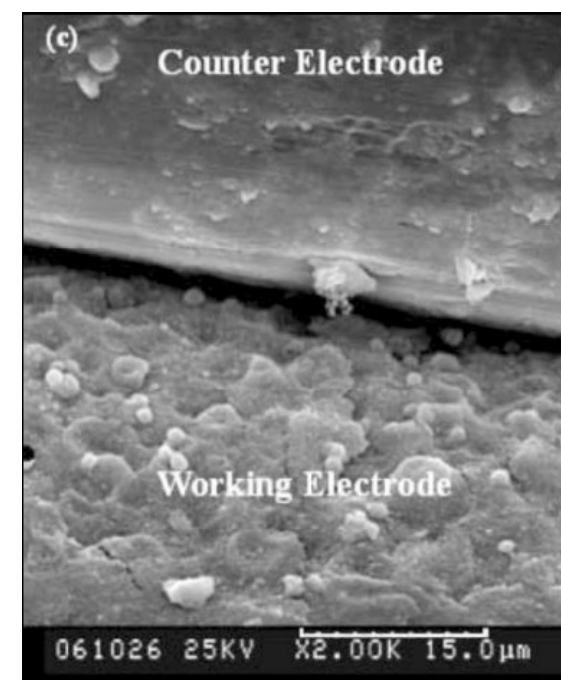
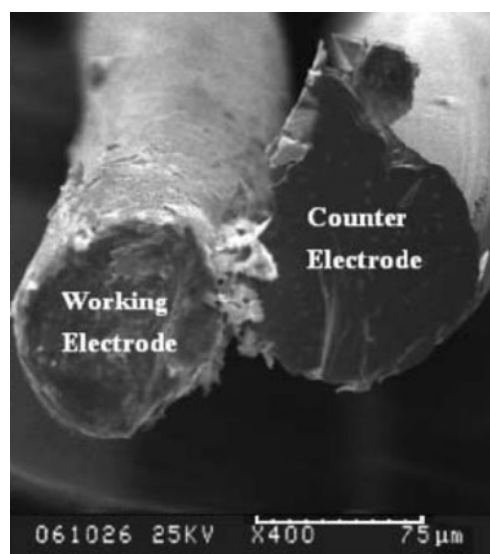
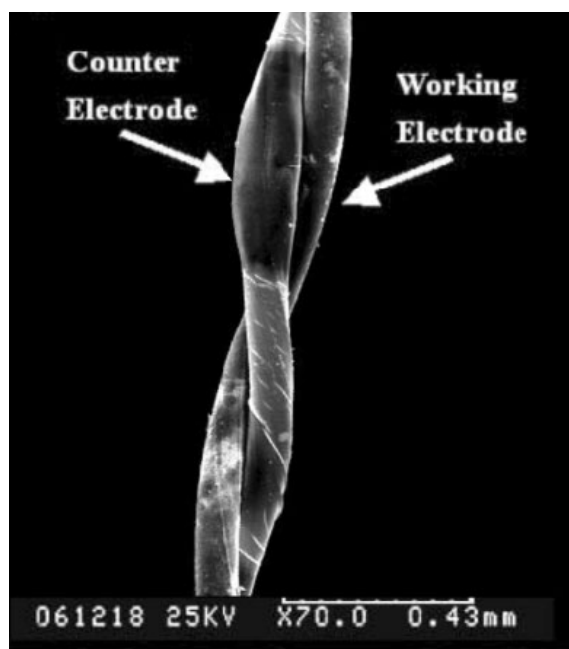
- ✓ All organic photovoltaics (OPV)



Zou D. et al. *Adv. Mater.* **2008**, 20, 592; *Appl. Phys. Lett.*, **2008**, 92, 113510

# ADVANCED PHOTOVOLTAIC TECHNOLOGIES

## ✓ Dye Sensitized Solar Cells (DSSC)

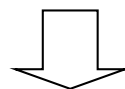


## ADVANCED PHOTOVOLTAIC TECHNOLOGIES

### ✓ Dye Sensitized Solar Cells (DSSC)

#### Problems of wire - type DSSC:

- Cracking of sintered titania layer if the wire bends around a small radius or it is elongated in excess of 1%.



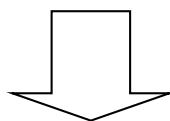
optimal compromise among oxide thickness  
photon collection efficiency  
flexibility and integrity of oxidic layer

# ADVANCED PHOTOVOLTAIC TECHNOLOGIES

## ✓ Dye Sensitized Solar Cells (DSSC)

### Problems of wire - type DSSC:

- liquid electrolyte is sensitive to water entry
- liquid electrolyte can leak from the cell through the thin cladding



**development of solid electrolytes**

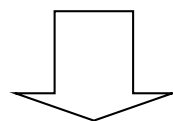


## ADVANCED PHOTOVOLTAIC TECHNOLOGIES

### ✓ Dye Sensitized Solar Cells (DSSC)

#### Problems of wire - type DSSC:

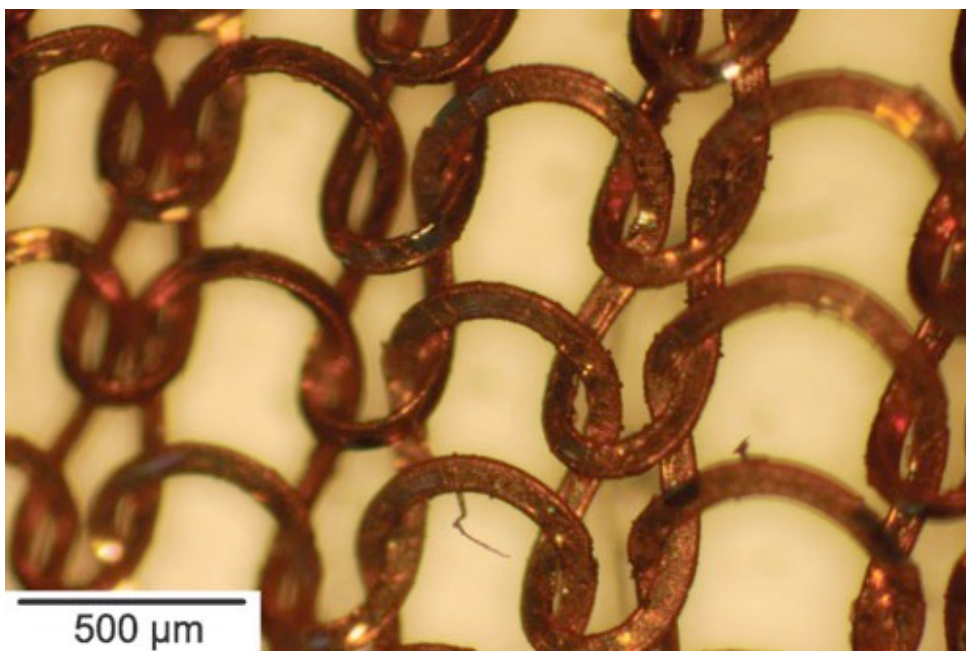
- an optically transparent counterelectrode with high conductive properties able to carry current over long distances does not exist



**a second wire must be used as the counterelectrode**

# ADVANCED PHOTOVOLTAIC TECHNOLOGIES

✓ Dye Sensitized Solar Cells (DSSC)

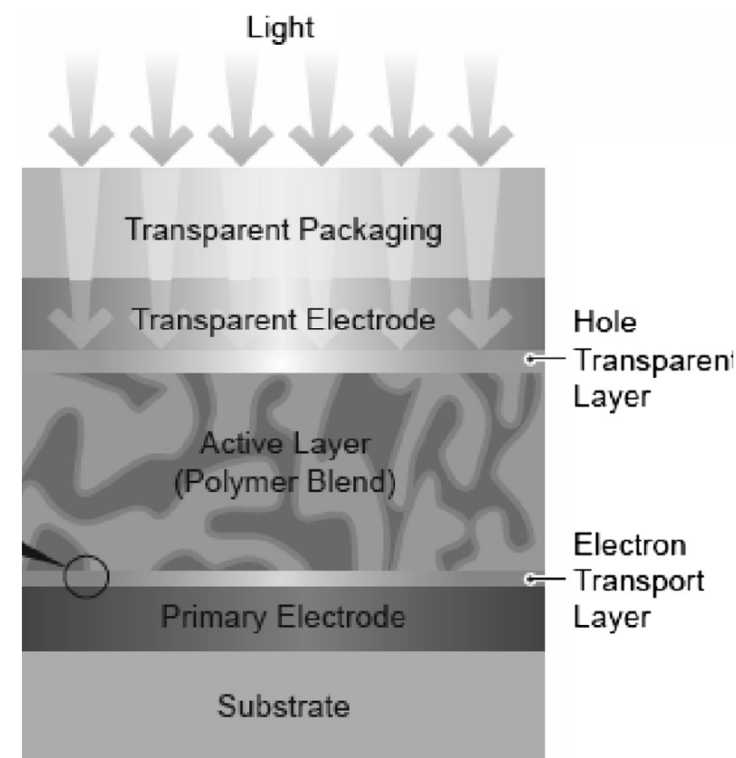


Current Intensity: 1,3 mA/cm<sup>2</sup>

Y. Zimmermann et al. Phys. Chem. Chem. Phys., **2008**, 10, 1844–1847

# ADVANCED PHOTOVOLTAIC TECHNOLOGIES

- ✓ Dye Sensitized Solar Cells (DSSC)
- ✓ All Organic PhotoVoltaics (OPV)

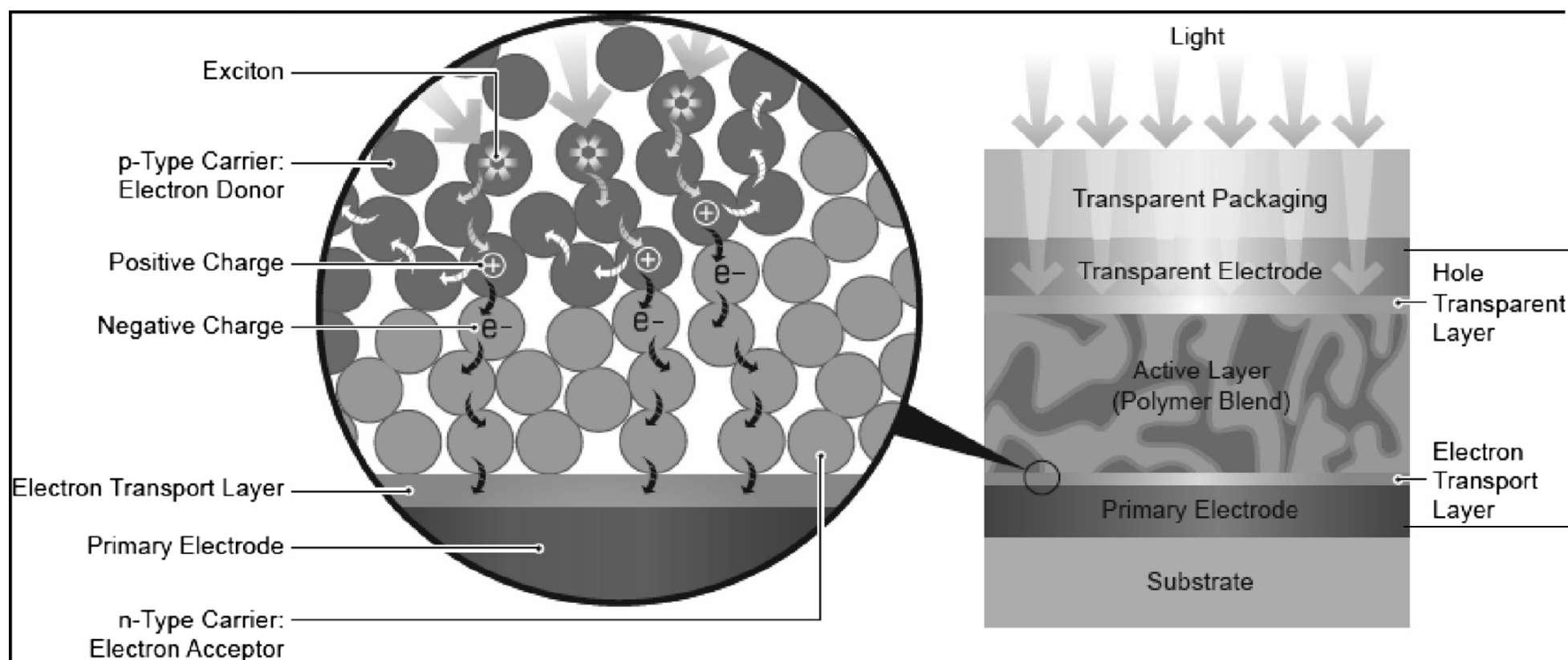


Sariciftci N.S. et al. *Science*, 1992, 258, 1474-1476

R. A. Gaudiana et al. *J. Macromol. Science, A: Pure and Applied Chem.* 2009, 46, 1238–1246

# ADVANCED PHOTOVOLTAIC TECHNOLOGIES

- ✓ Dye Sensitized Solar Cells (DSSC)
- ✓ All Organic PhotoVoltaics (OPV)



Sariciftci N.S. et al. *Science*, 1992, 258, 1474-1476

R. A. Gaudiana et al. *J. Macromol. Science, A: Pure and Applied Chem.* 2009, 46, 1238-1246

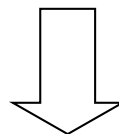


## ADVANCED PHOTOVOLTAIC TECHNOLOGIES

- ✓ Dye Sensitized Solar Cells (DSSC)
- ✓ All Organic PhotoVoltaics (OPV)

Problems of wire - type OPV :

- the thinness of the photoactive coatings can lead to shunting between the electrodes



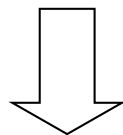
**a very smooth wire core**

## ADVANCED PHOTOVOLTAIC TECHNOLOGIES

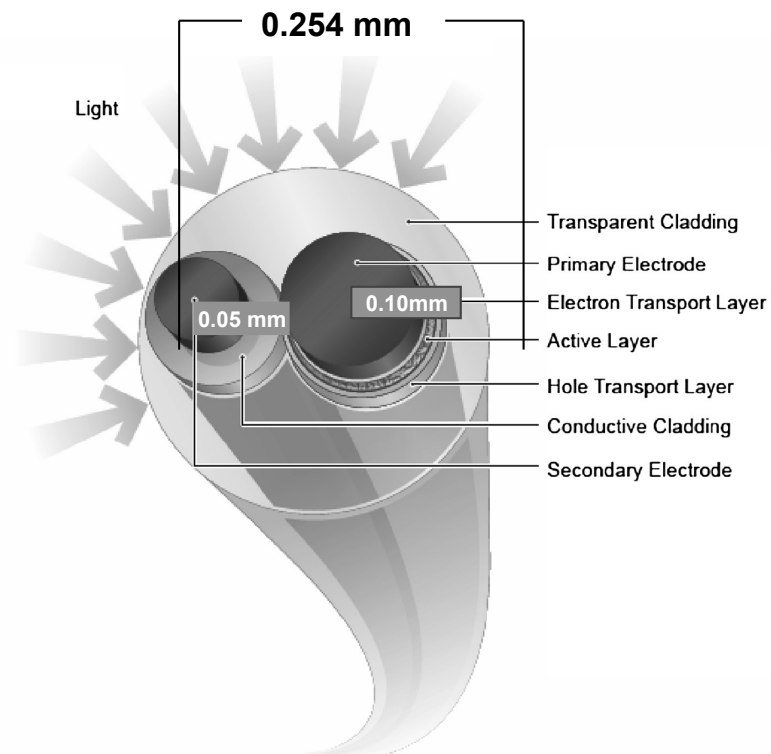
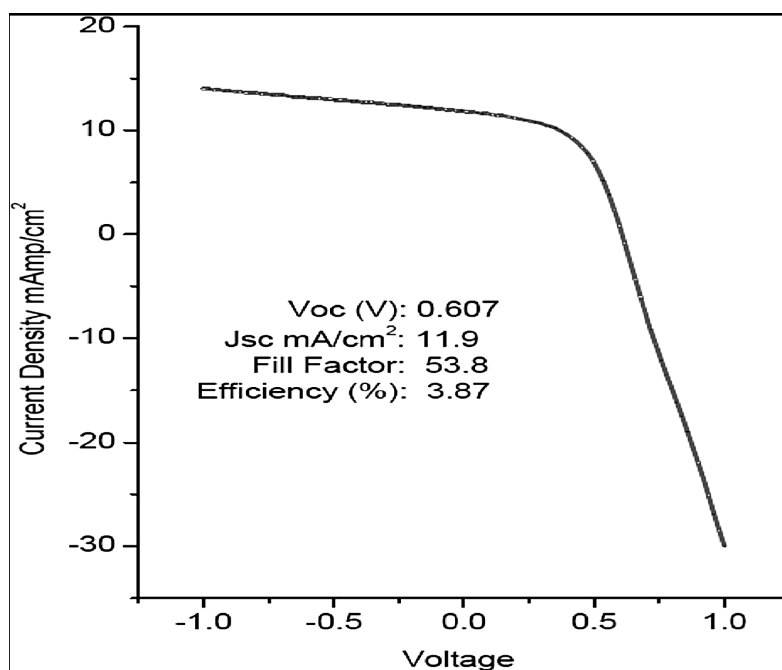
- ✓ Dye sensitized solar cells (DSSC)
- ✓ All Organic PhotoVoltaics (OPV)

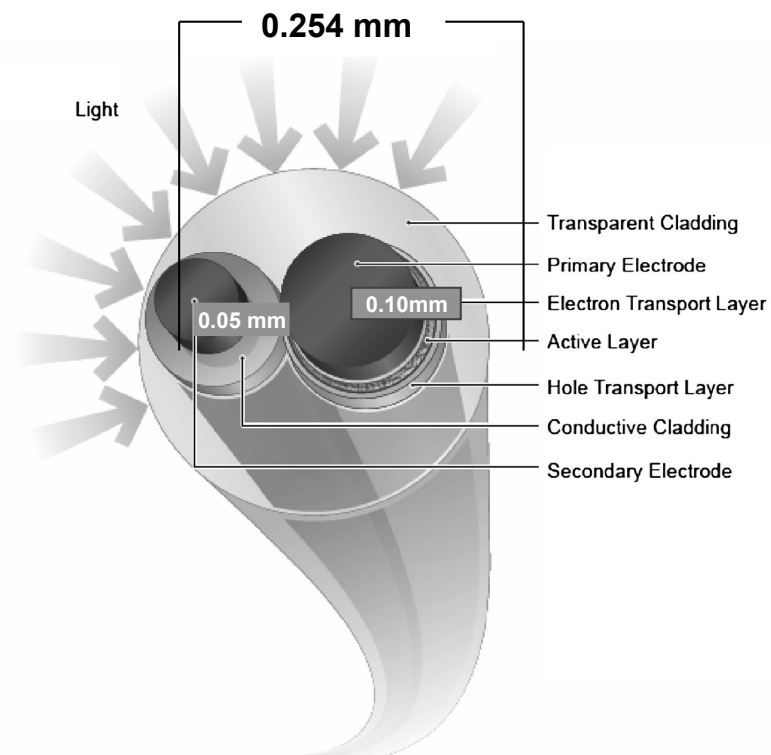
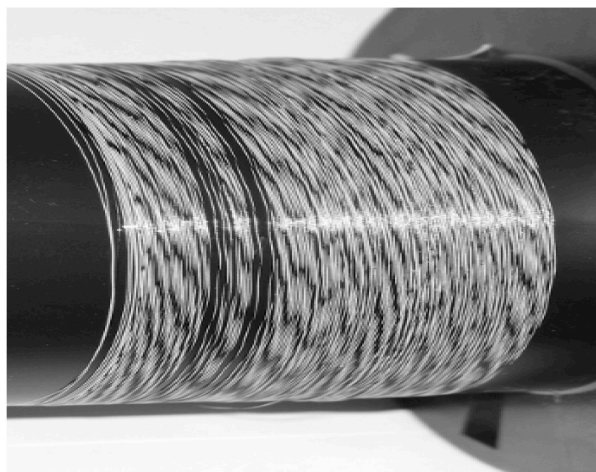
**Problems of wire - type OPV :**

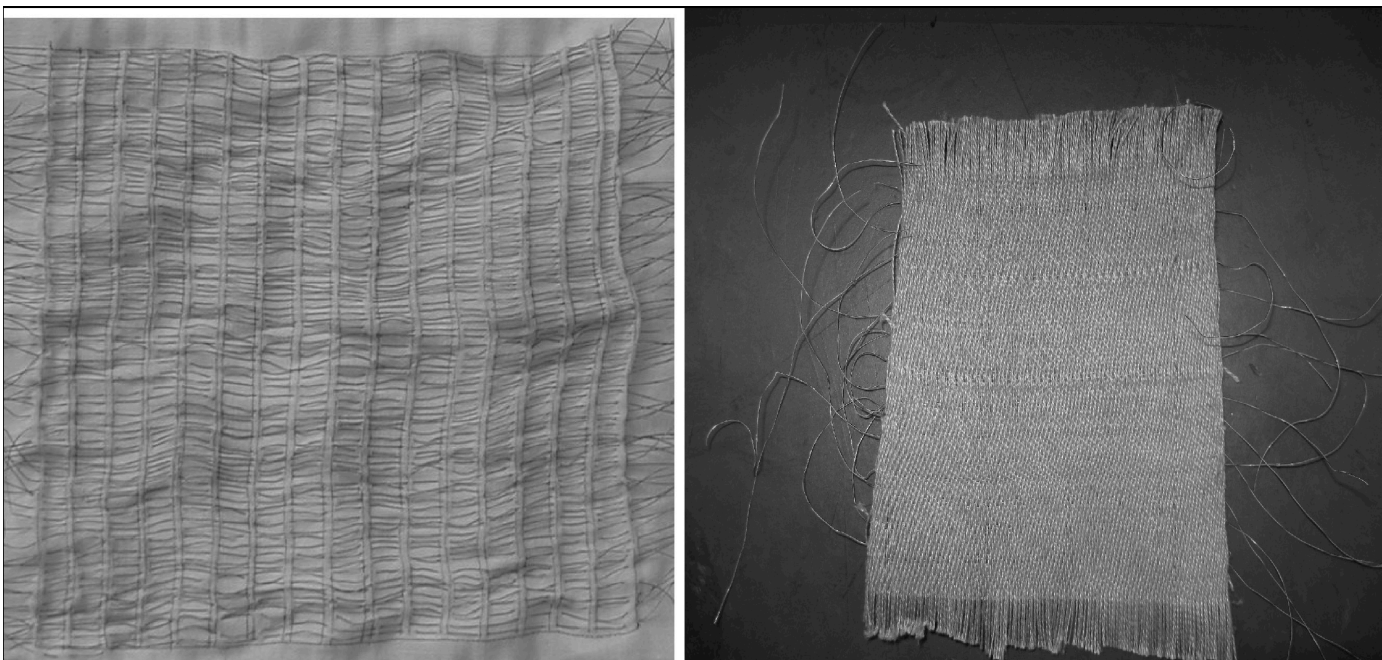
**-an optically transparent counterelectrode with high conductive properties able to carry current over long distances does not exist**



**a second wire must be used as the counterelectrode in analogy to shaped-wire DSSC.**

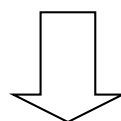






# CONCLUSIONS

- ✓ The photovoltaic textiles can be a re-newable energy source for the portable electronic devices and as active architectural component.
- ✓ Flexible Si-based prototypes are at this moment the reality but their real launching is frozen
- ✓ Nanosciences could unfreeze actual stand by:
  - Dye Sensitized Solar Cells (DSSC)
  - All Organic PhotoVoltaics (OPV)



**PHOTOVOLTAIC TEXTILES IS A REAL RESEARCH TOPIC**





**Prof. Ermanno Barni**  
**Prof. Michael Grätzel**  
**Prof. Niyazi Serdar Sarifcifci**

Dr. Pierluigi Quagliotto  
Dr. Claudia Barolo  
Dr. Roberto Buscaino  
Dr. Nadia Barbero  
Dr. Emma Artuso  
Dr. Luca Bonandini



FINANCIAL SUPPORT  
Innovasol Project (EU)  
Cost D35 (Eu)  
Consortium Dyepower  
Universita' di Torino

**MANY THANKS FOR YOUR KIND ATTENTION**

