



# **DRY HYDROGEN PRODUCTION IN A CRITICAL RAW MATERIAL-FREE TANDEM PHOTOOXIDATION-REDUCTION CELL**

**S. TROCINO**

**C. Lo VECCHIO, O. BARBERA, G. GIACOPPO, S. CAMPAGNA ZIGNANI,  
A. CARBONE, A. SACCÀ, V. BAGLIO, A. S. ARICÒ**

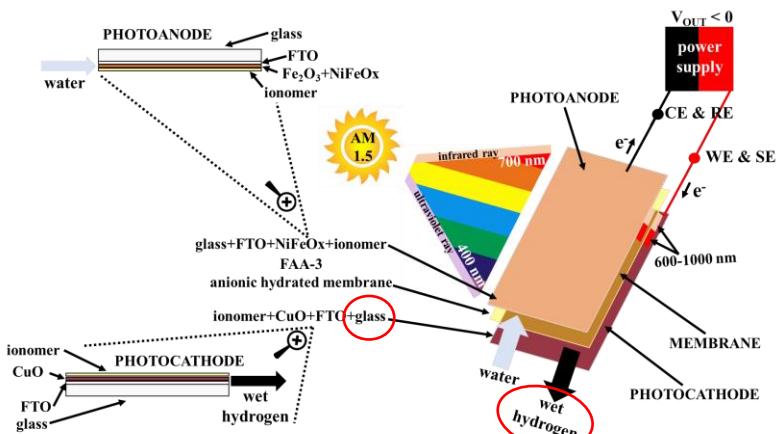
**CNR-ITAE, Via Salita S. Lucia sopra Contesse, 5 – 98126 Messina Italy**

**Alternative hydrogen supply  
17.12.2021 – 10:00 am**

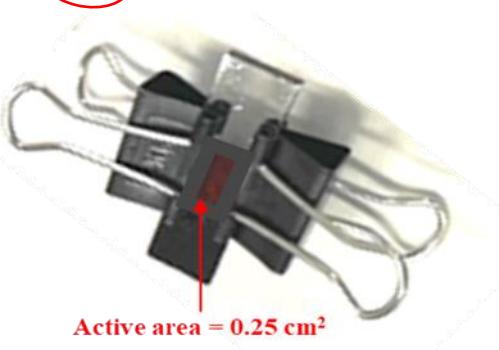


# PHOTOELECTROCHEMICAL TANDEM CELL

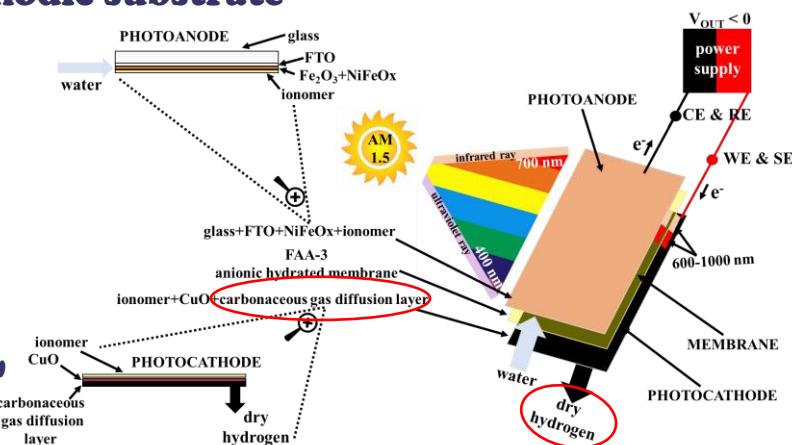
## Wet hydrogen production



**PICTURE OF DEVICE UNDER TEST**

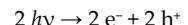


## Dry hydrogen production

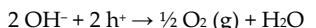


## PHOTOCONVERSION REACTIONS

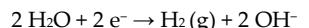
Photogeneration:



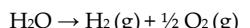
Anode—oxygen evolution reaction:



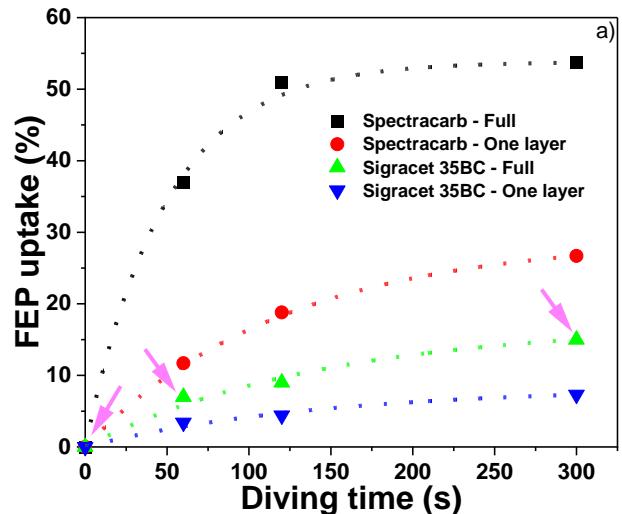
Cathode—hydrogen evolution reaction:



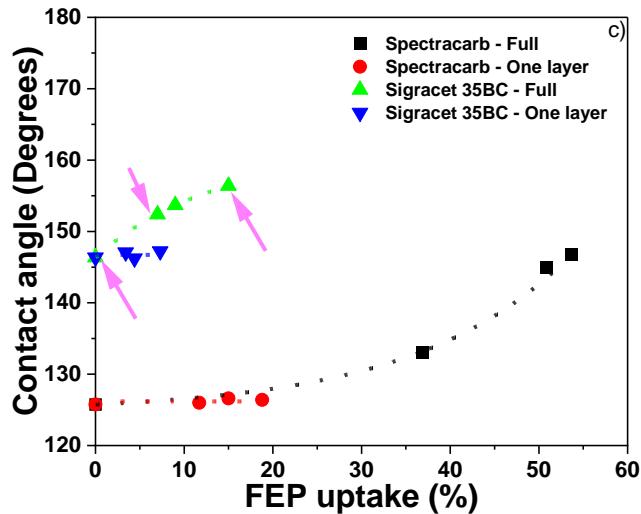
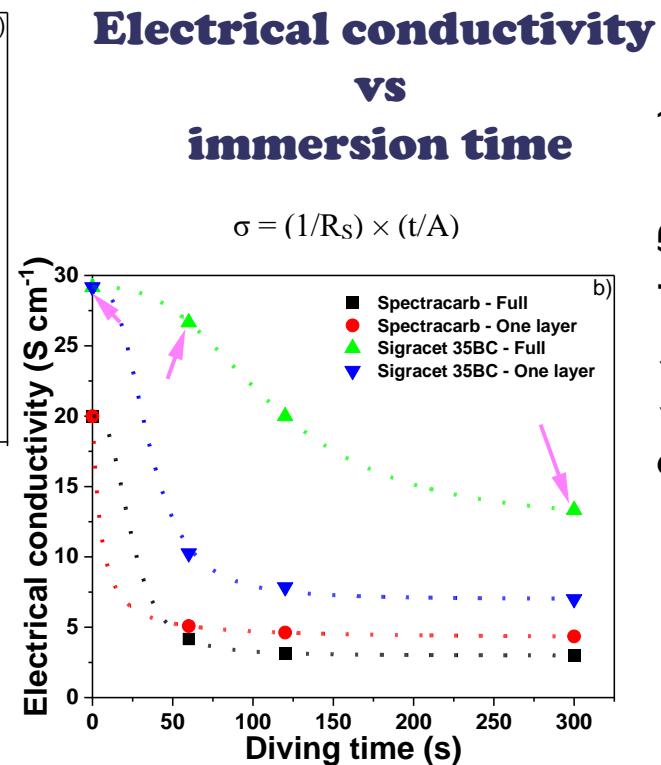
PEC—overall water splitting:



## UNDER DIFFERENT HYDROPHOBISATION CONDITIONS



**FEP uptake**  
vs  
**immersion**  
**time**



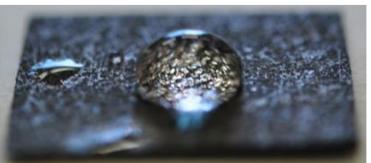
OCA-25 model of the  
DataPhysics Instruments GmbH

**Contact angle top layer**  
vs **immersion time**

# PICTURES OF WATER DROP ON THE BACKING SUBSTRATES

**Spectracarb**  
**after 0 s**

a)

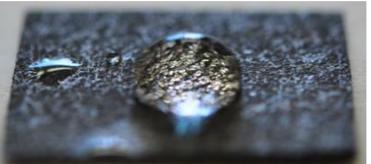


b)



**Spectracarb**  
**after 1800 s**

c)

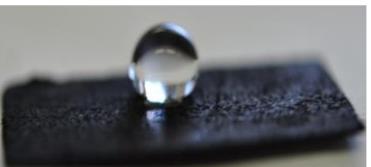


d)

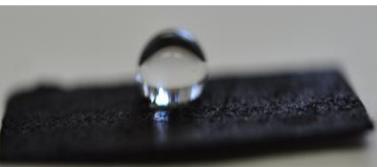


**Sigracet 35BC**  
**+ FEP 7%**  
**after 0 s**

e)



f)

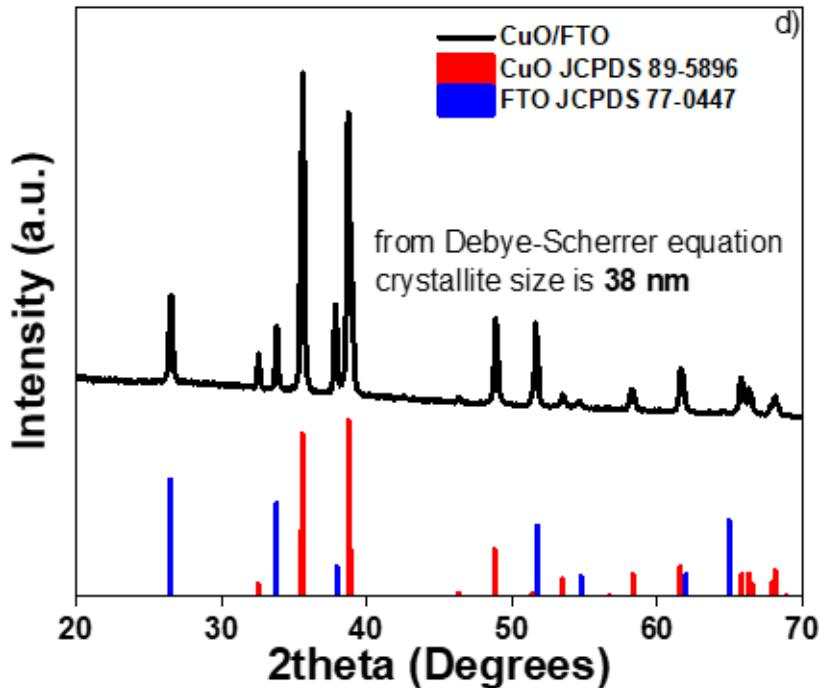


**Sigracet 35BC**  
**after 0 s**

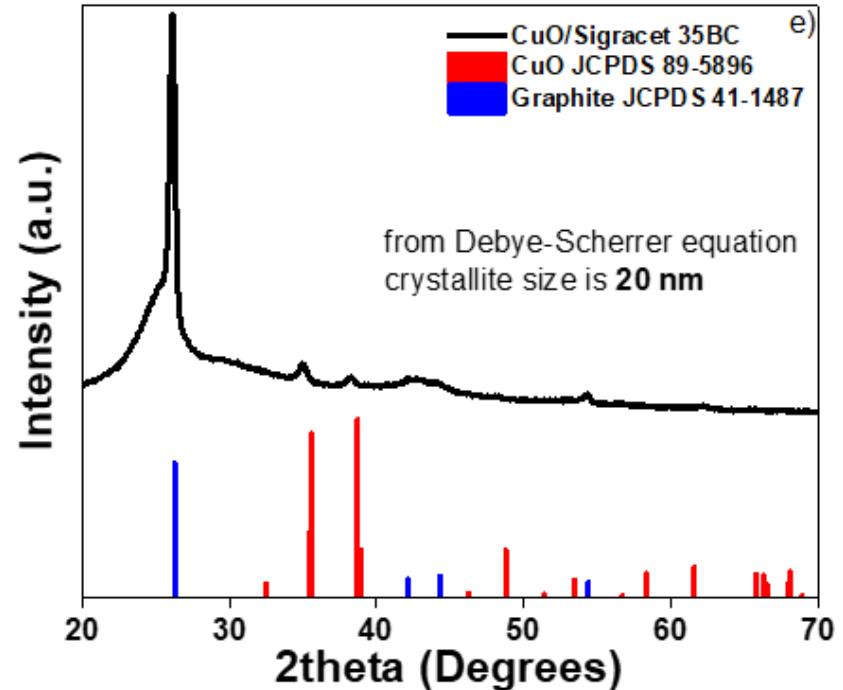
**Sigracet 35BC**  
**after 1800 s**

**Sigracet 35BC**  
**+ FEP 7%**  
**after 1800 s**

# XRD ANALYSIS

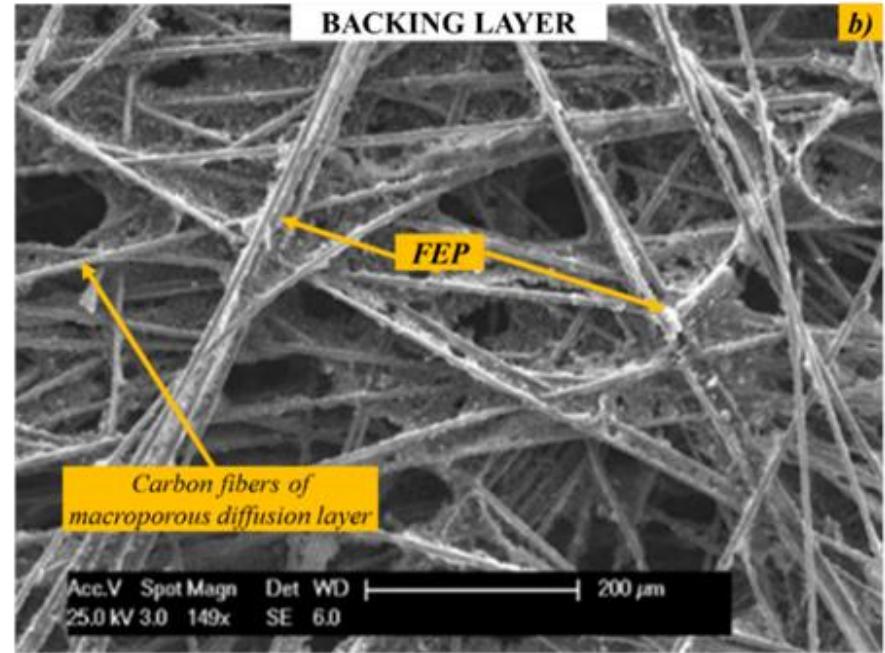
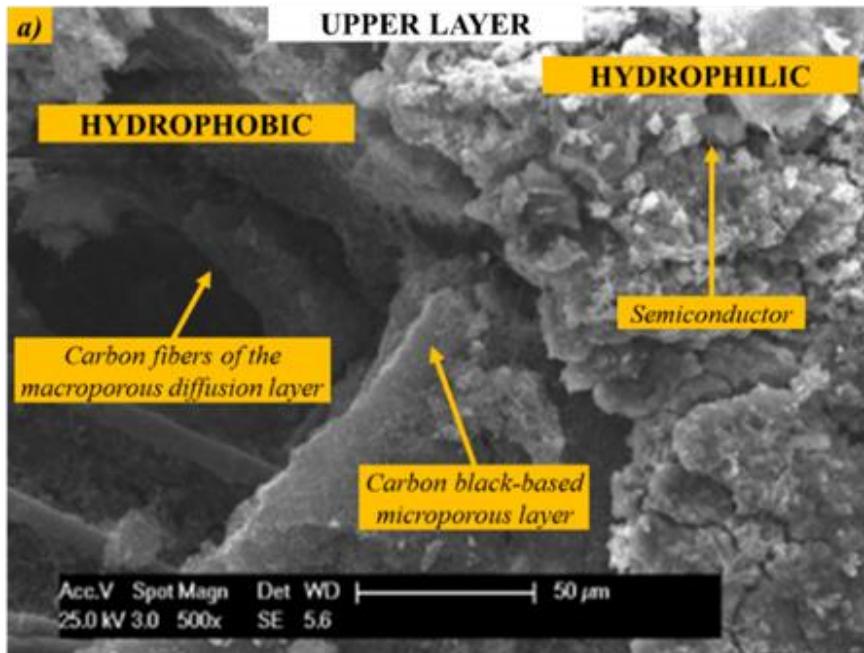


**FTO backing layer**



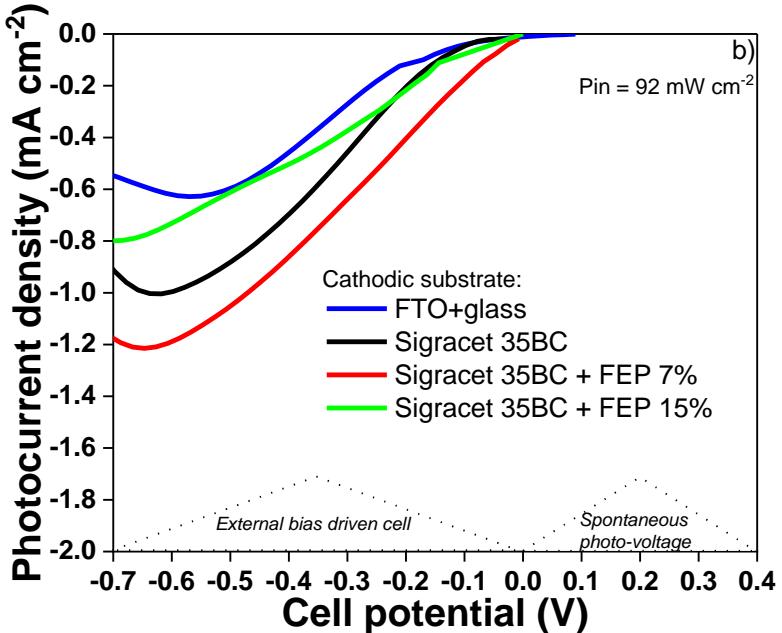
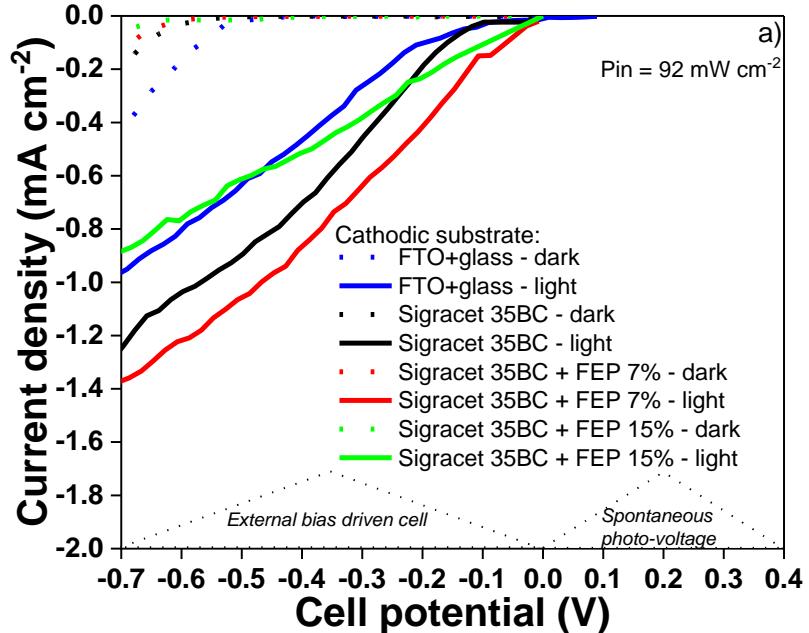
**Sigracet 35BC backing layer**

# SEM ANALYSIS



**CuO semiconductor on a Sigracet 35BC  
gas diffusion layer containing 7% FEP**

# ELECTROCHEMICAL CHARACTERIZATION

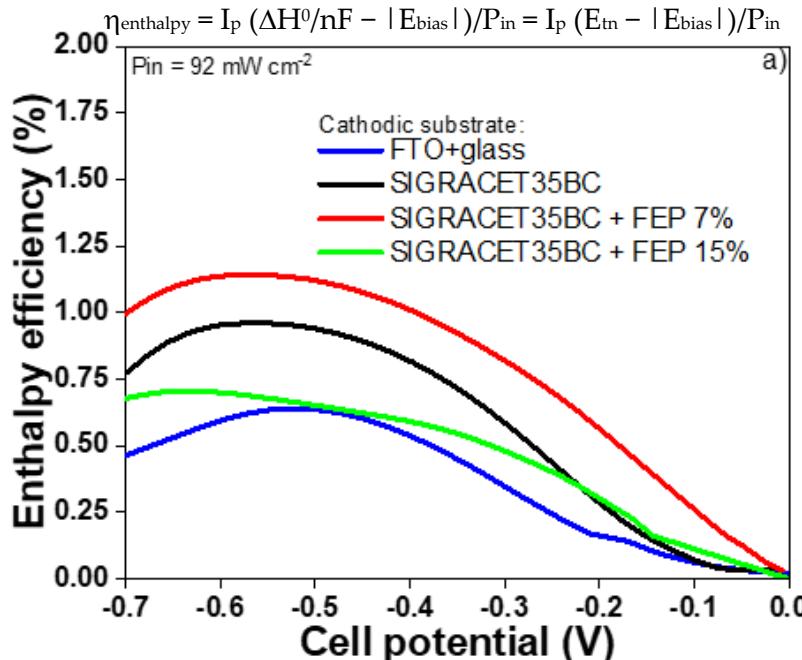


**Polarisation curves of the PEC cell**

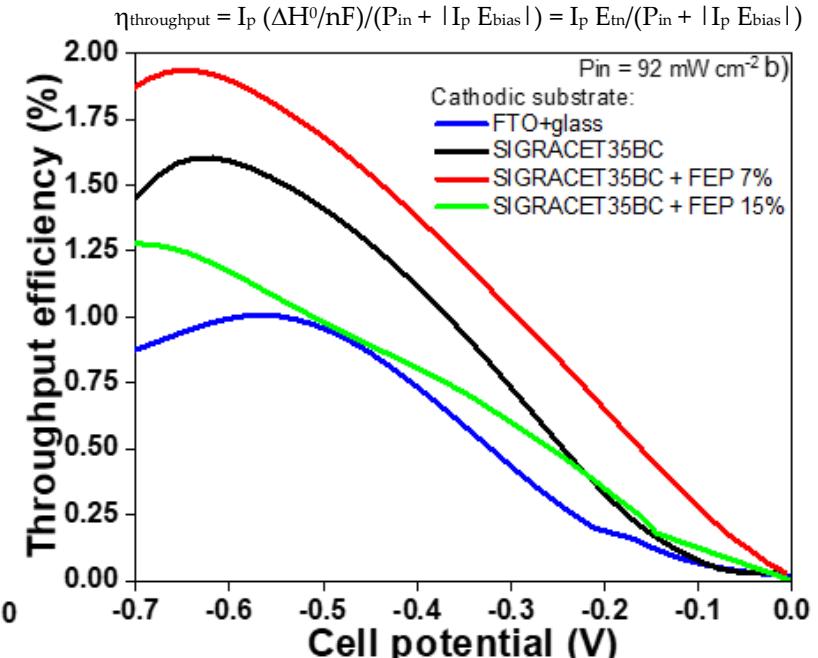
(glass + FTO +  $\text{Fe}_2\text{O}_3$  + NiFeOX + ionomer/FAA-3/ionomer + CuO + cathodic substrate) for various cathodic substrates

# EFFICIENCY

Enthalpy efficiency:

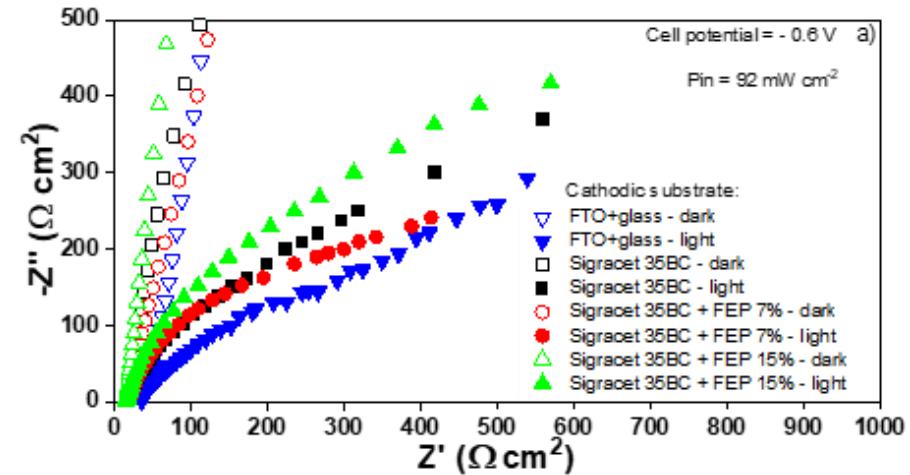


Throughput efficiency:



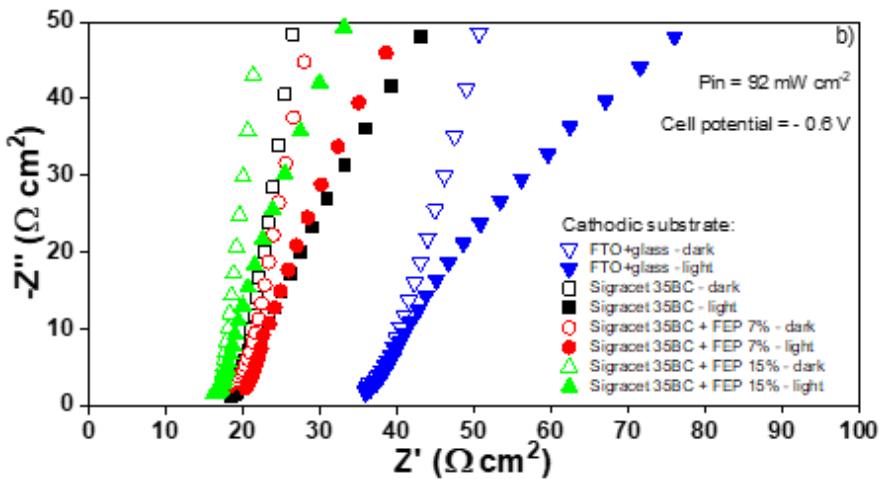
**PEC enthalpy efficiency and throughput efficiency as a function of cell potential for various photocathode substrates**

# ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY

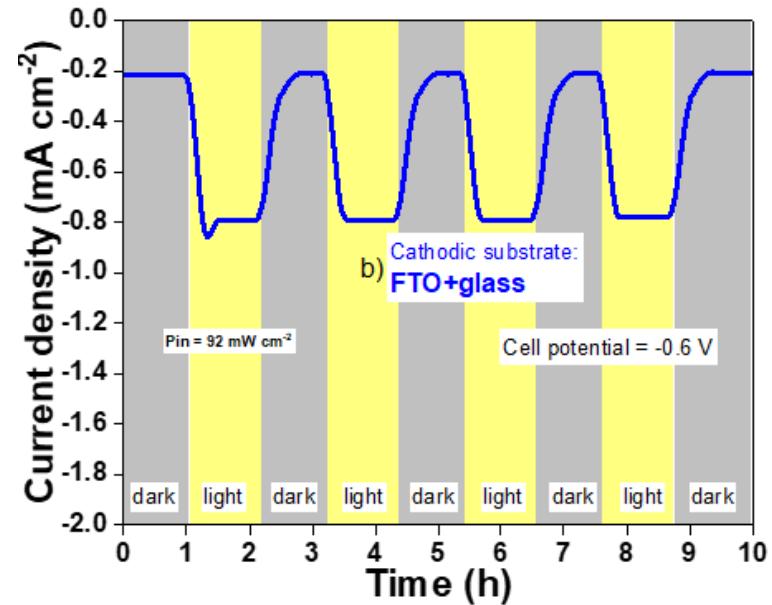
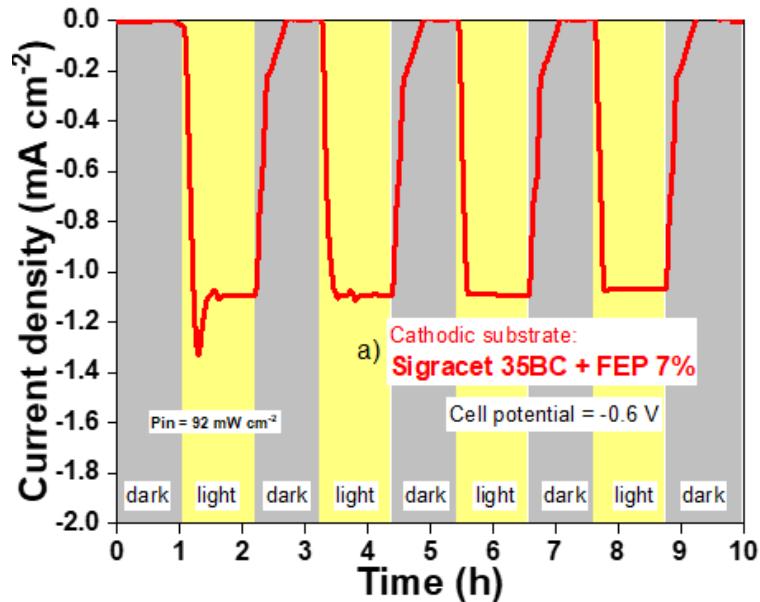


**EIS of the PEC cell for various photocathode substrates under illumination with an applied cell bias of -0.6 V**

**Magnification of the spectra at high frequencies**

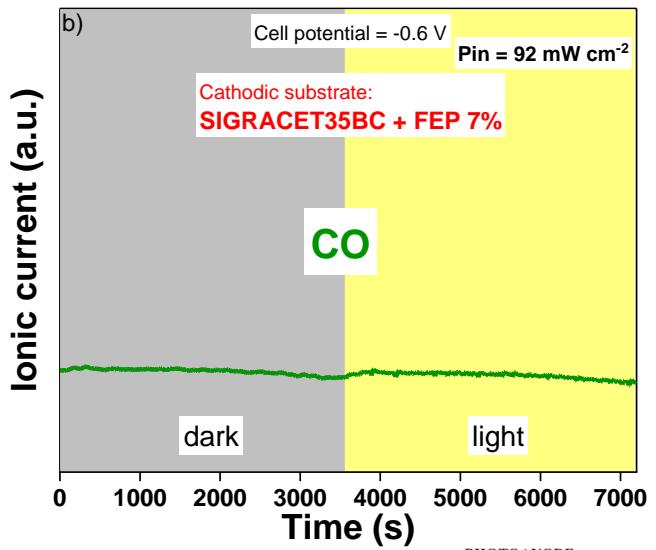
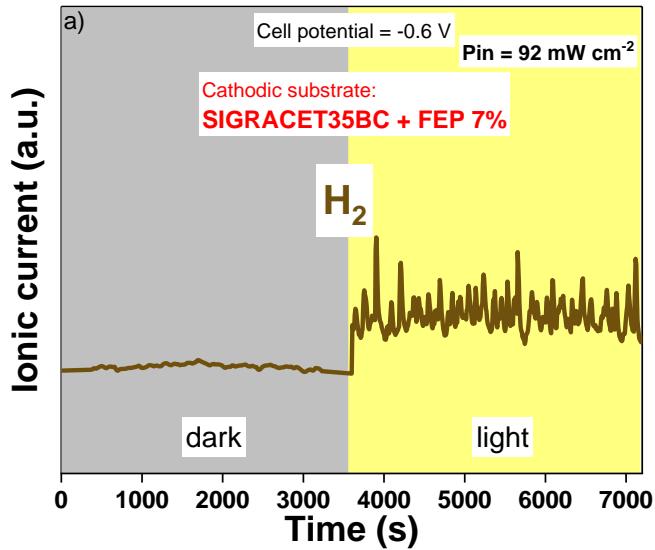


# DURABILITY TEST



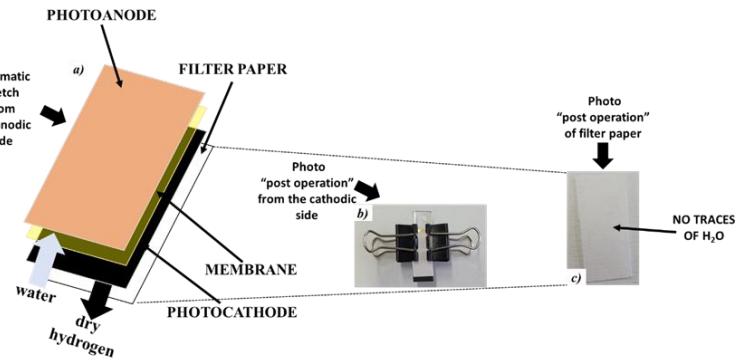
**Potentiostatic durability test (applied cell bias of  $-0.6 \text{ V}$ ) of the PEC cells based on the hydrophobic backing layer (left) and FTO (right) cathode substrates**

# MASS SPECTROMETRY ANALYSIS

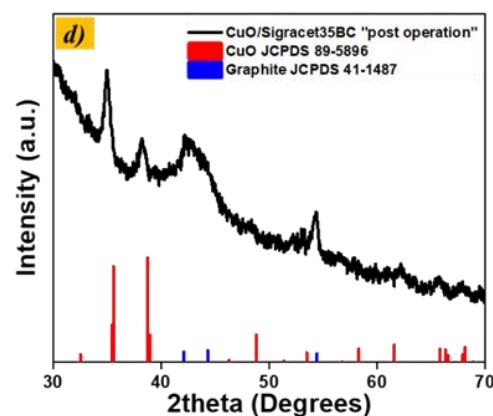
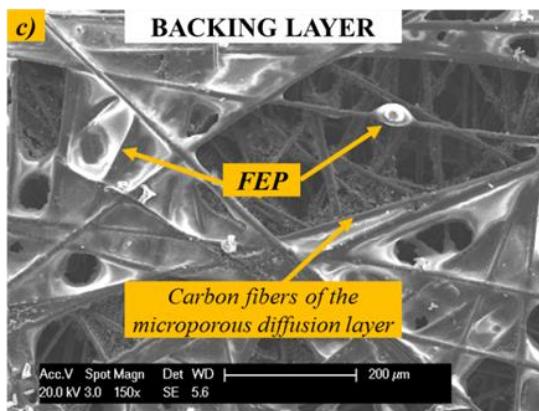
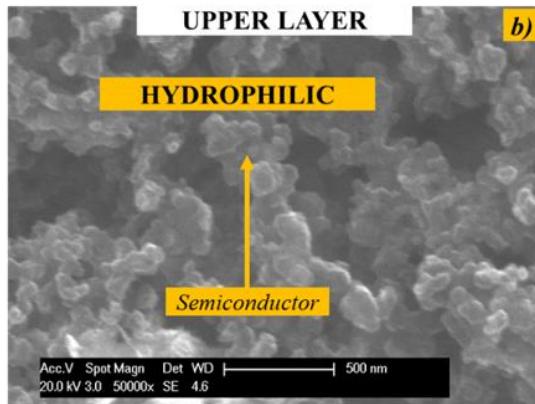
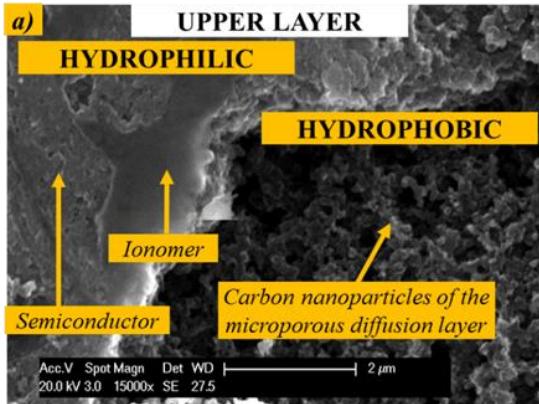


**During potentiostatic test (applied cell bias of -0.6 V) of the PEC cell (glass+FTO+ $\text{Fe}_2\text{O}_3$ +NiFeOX+ionomer/FAA-3/ionomer+CuO+ Sigracet 35BC+FEP7%**

**No traces of humidity below the hydrophobic layer during a durability test**



# POST-OPERATION ANALYSIS



**SEM images of the CuO semiconductor deposited on a Sigracet 35BC gas diffusion layer containing 7 wt%**

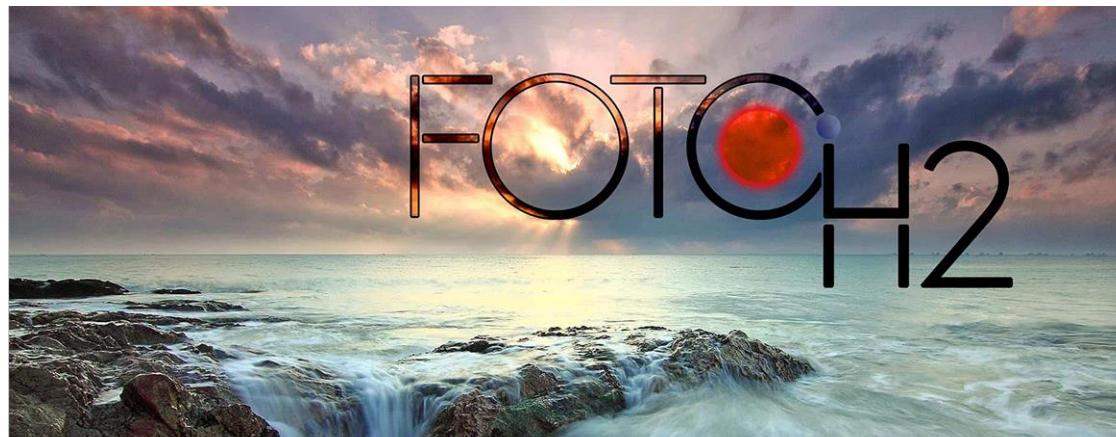
**X-ray diffraction analysis of the photocathode**

# CONCLUSIONS

- **The concept of a porous hydrophobic carbonaceous backing layer as a photocathode substrate in a photoelectrolysis cell to get dry hydrogen is here demonstrated for the first time.**
- **The utilisation of carbonaceous gas diffusion layers provides several advantages.**
- **The use of a gas diffusion layer, based on Sigracet 35BC with the addition of 7 wt% of FEP, doubling the performance of the conventional FTO photocathode substrate-based cell.**
- **A short-term durability test indicated a good stability of the cell as long as a good hydration of the membrane is assured.**
- **These results appear very promising and indicate a possible extension of the gas diffusion layer approach to other types of photoelectrochemical cells.**

# ACKNOWLEDGMENTS

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**Thanks for your kind attention**  
stay tuned to [www.fotoh2.eu](http://www.fotoh2.eu)