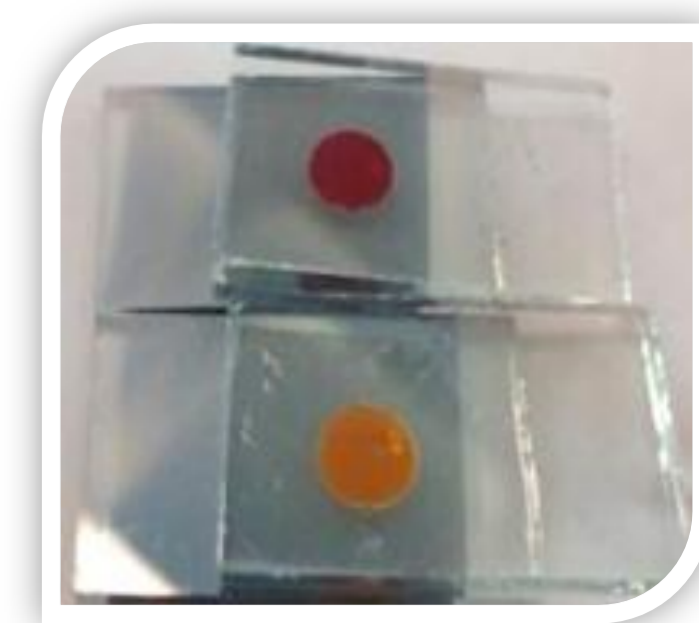


# Dye assessment in nanostructured TiO<sub>2</sub> sensitized films by microprobe techniques



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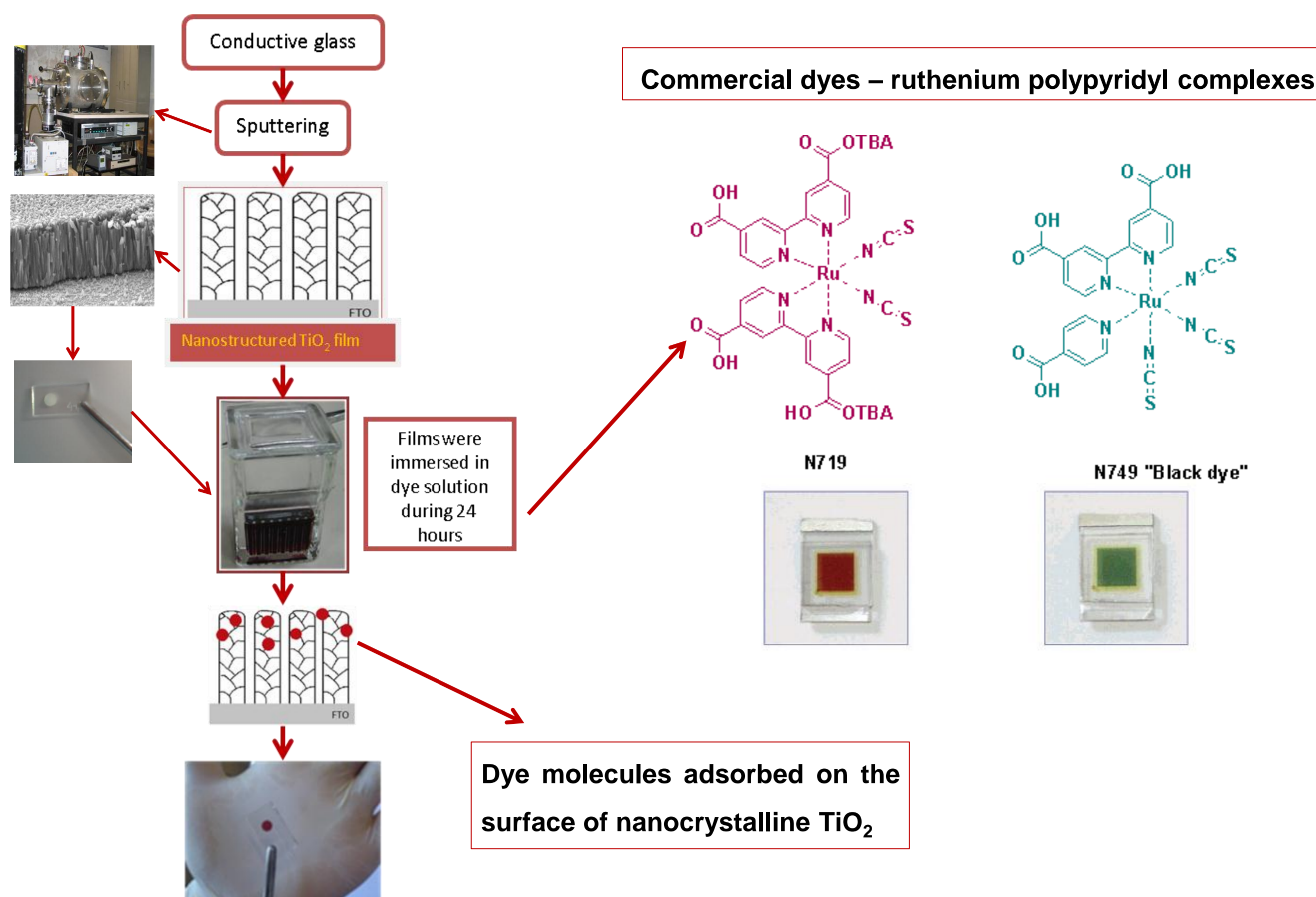


## DSCs

✓ The dye sensitized solar cell (DSC) is the only photovoltaic cell using molecules that generate charge carriers after photo-excitation without the need for excitonic transport



## Sample Preparation



## Analytical Techniques

### SEM / EDS

- PHILIPS XL 30 FEG
- Acceleration voltage 7 - 10 kV
- EDS microanalysis EDAX

### EPMA/WDS / EDS

- JEOL JXA – 8500F
- Acceleration voltage 15 kV
- 5 WD Spectrometers
- EDS Oxford Instruments INCA X-act

### Nuclear Microprobe - RBS set-up

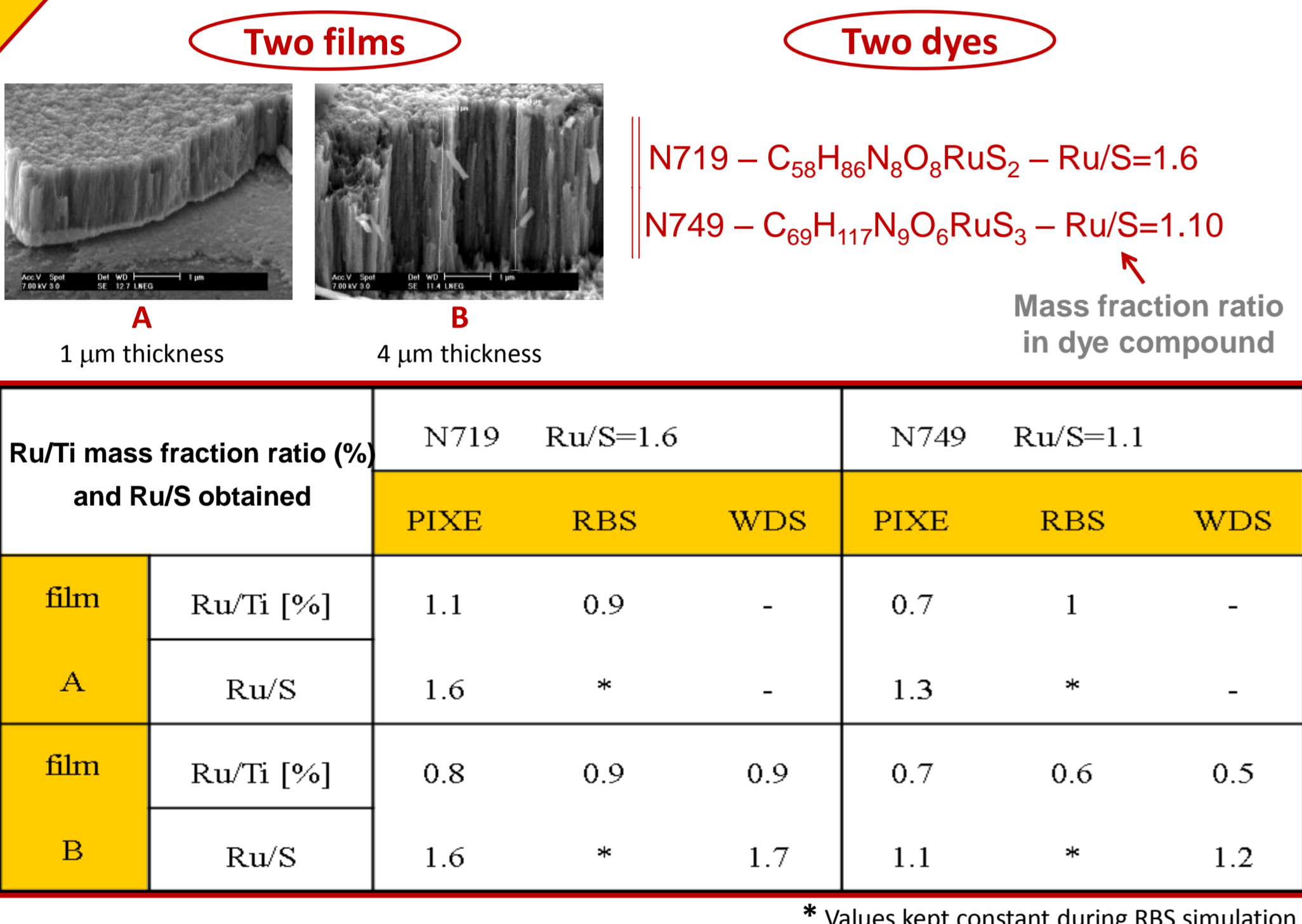
- 1.8 and 2.0 MeV proton or alpha beam
- Resolution ~ 3x3 μm<sup>2</sup>
- PIPS RBS detector
- Si(Li) X-ray detector
- Software: Gupix Win for PIXE and WinDF for RBS spectra

## Motivation

- ✓ Dye adsorption on the TiO<sub>2</sub> is considered one key step of DSCs manufacturing
- ✓ Effective loading of the dye in the TiO<sub>2</sub> electrode is important for controlling and optimizing solar cell parameters ( $J_{SC}$ ,  $V_{OC}$ , ...)
- ✓ Few methods known and used today for quantitative evaluation of the total dye adsorbed in the film, but without taking into account the dye distribution profile
- ✓ Microprobe techniques can be powerful tools to evaluate the dye distribution and dye depth profile in sensitized films

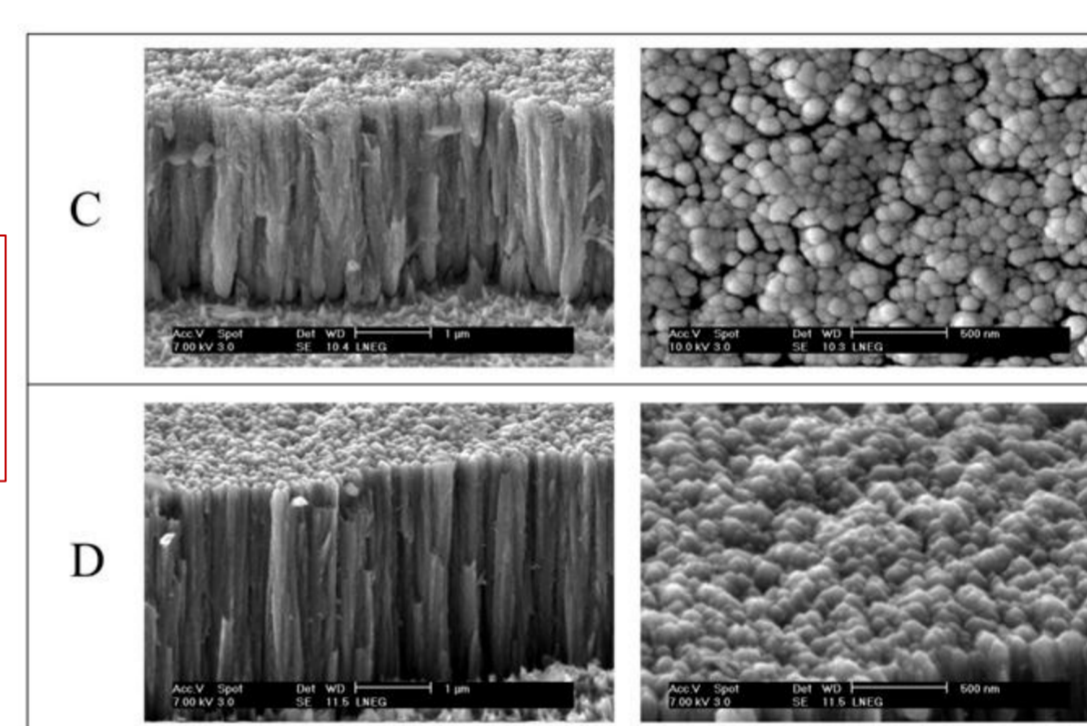
## RESULTS AND DISCUSSION

## Dye load assessment

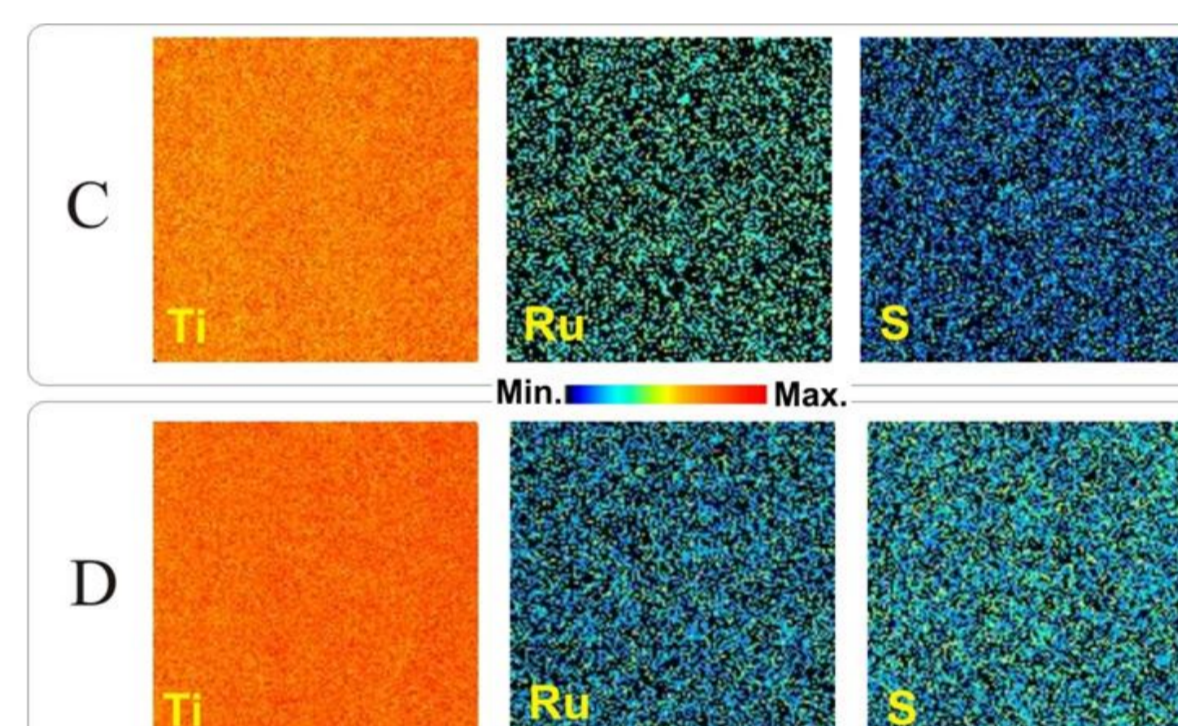


## Dye distribution

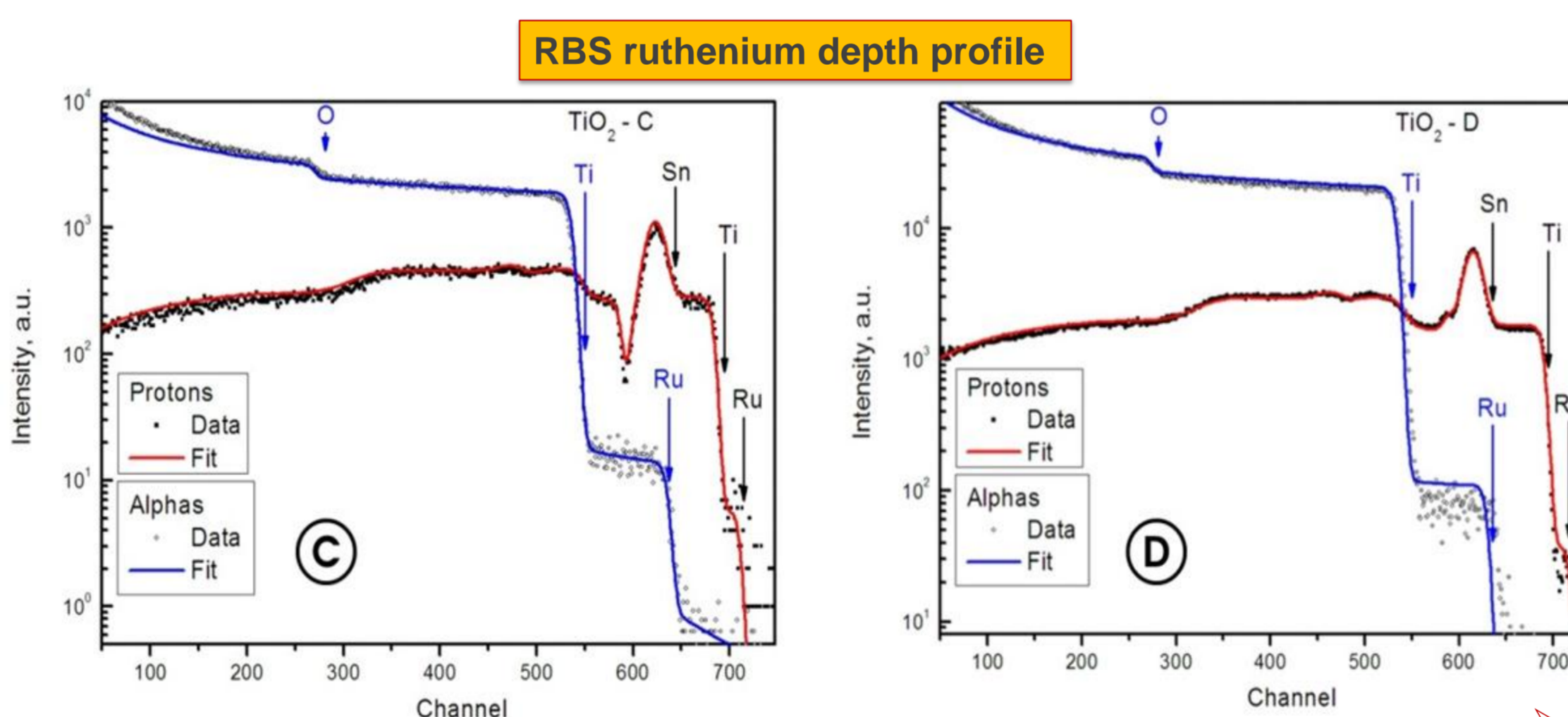
- C and D TiO<sub>2</sub> films (4 μm thickness)
- different sputtering deposition conditions
- sensitized with N719



✓ homogeneous surface distribution of the dye Ru and S



PIXE 2D X-ray maps for Ti, Ru and S recorded with an H<sup>+</sup> beam on the films surface (530 x 530 μm<sup>2</sup> scan)



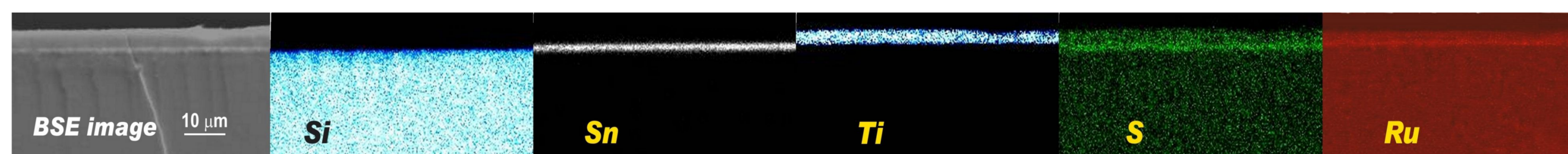
RBS spectra and best fits (when two sample layers are considered), obtained with 2 MeV alpha particle beam and 1.8 MeV proton beam for C and D films

### RBS quantitative results

Ru/Ti [%]	Film C	Film D
Top layer	1.1%	1.1%
Bottom layer	1.3%	1.6%

- bottom layer (close to the FTO) has higher dye load
- Ru/Ti difference between top and bottom layers: 18% in film C and 45% in film D

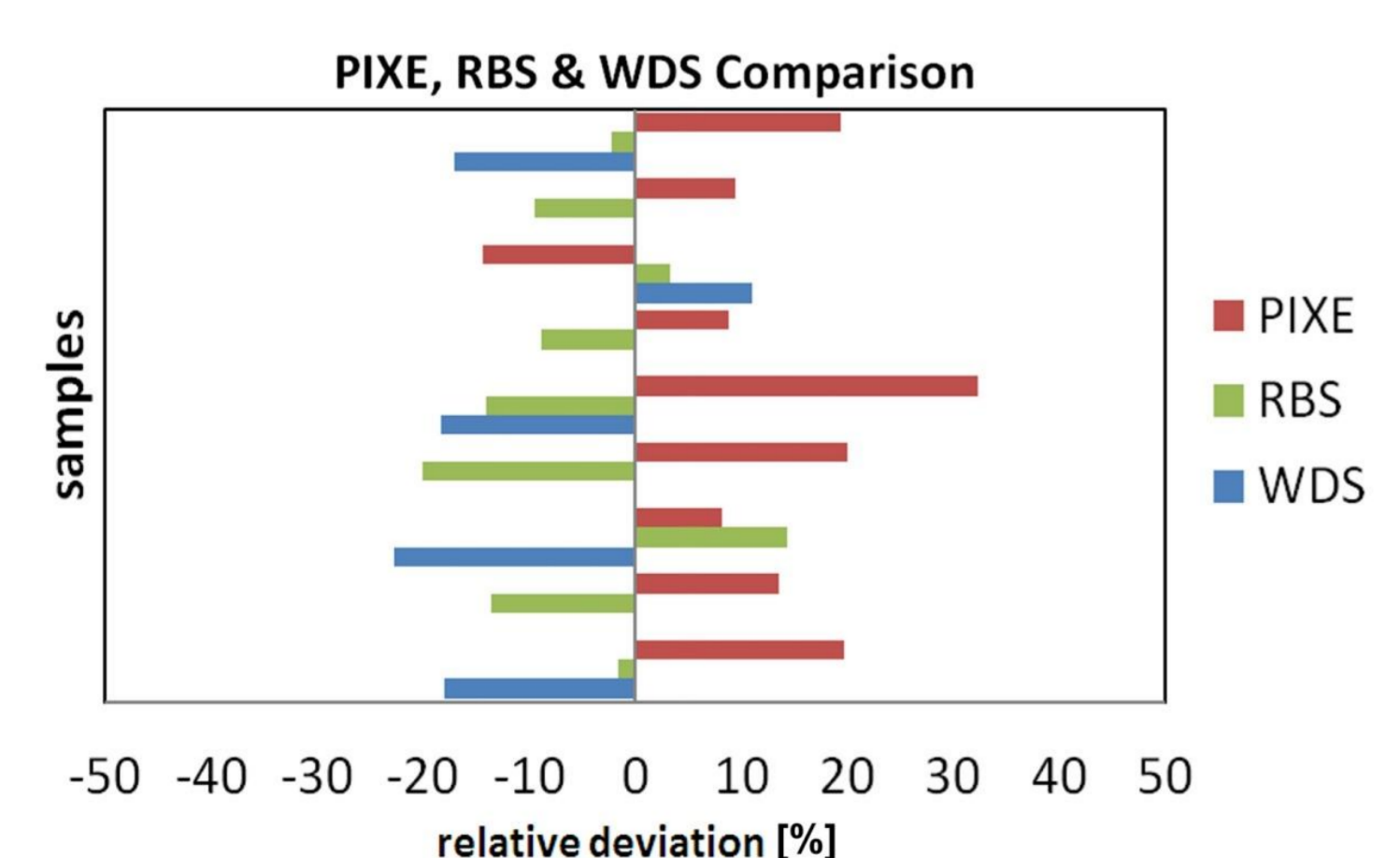
### The same observed in the X-ray maps in cross sectional analysis by EPMA/EDS of film C



Backscattered electrons image and Si, Sn, Ti, S and Ru X-ray maps of film C (cross section) obtained by EPMA/EDS

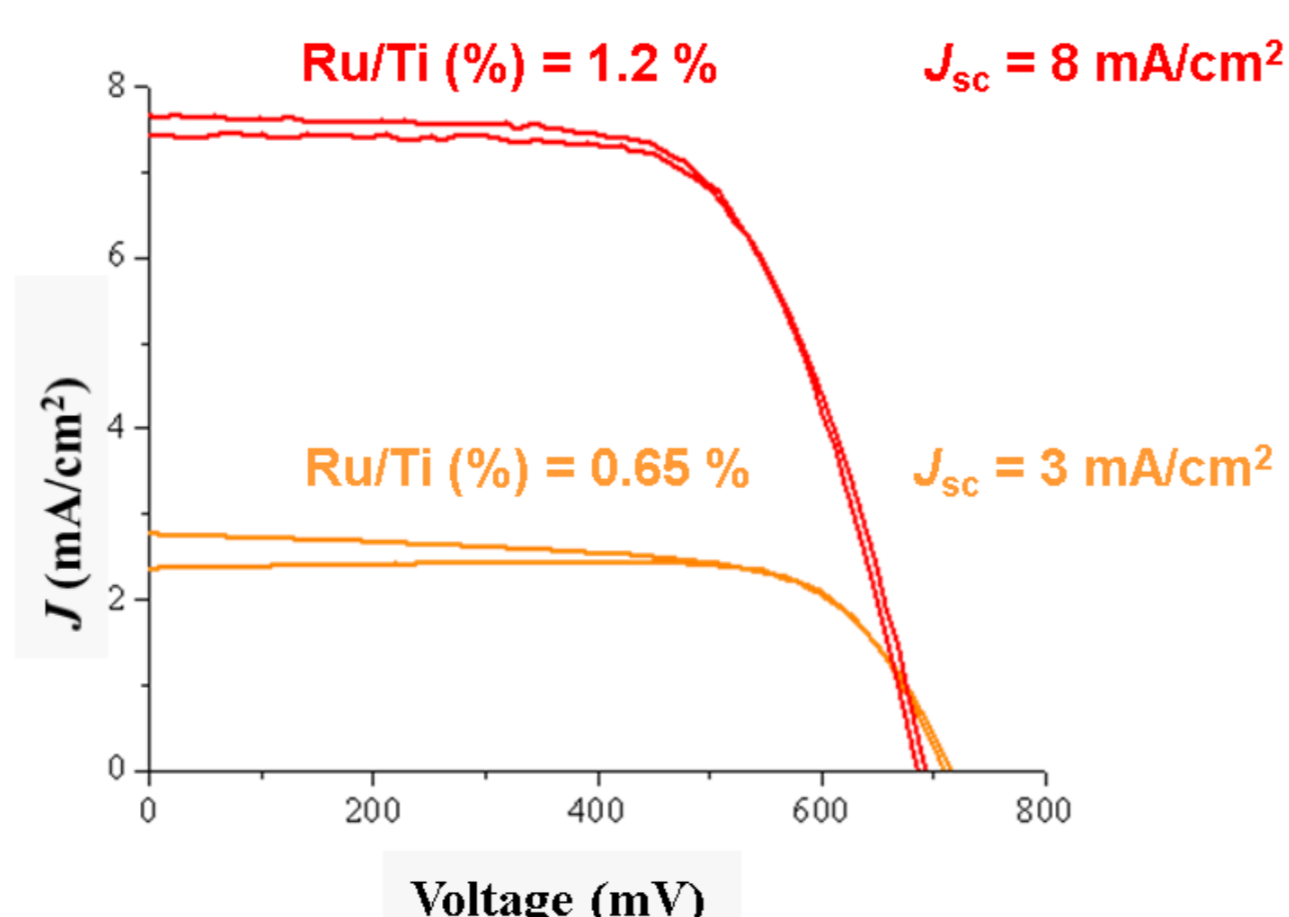
➢ S and Ru maps exhibit increased signal in the lower part of the TiO<sub>2</sub> film

Consensus value for the Ru/Ti mass fraction ratio determined average of all the results ( $\sigma < 20\%$ )



- Relative deviations (from consensus value) < 20% except for one sample by PIXE (30%) and another by WDS (23%)

DSCs based on two sensitized films with Ru/Ti (%) values of 1.2% and 0.65% prepared and characterised under standard conditions



- confirming the importance of the dye load evaluation

## Concluding remarks

- ✓ IBA techniques together with EPMA (WDS and EDS) proved to positively contribute for dye sensitized TiO<sub>2</sub> films characterisation
- ✓ One of the IBA most important features is its versatility and the complementary information obtained when combining data from different techniques such as RBS and PIXE
- ✓ The sensitivity of the techniques used allowed to evaluate Ru/Ti mass fraction ratio with similar results, in different TiO<sub>2</sub> films
- ✓ It was possible to assess dye surface distribution and depth profile and to visualise the dye distribution in sample cross-section
- ✓ Dye assessment by microprobe techniques may contribute to study the photoanode preparation of the DSCs photovoltaic devices