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Deposition of FTO thin films on large area glass substrates by conventional and ultrasonic spray pyrolysis method

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Introduction of FTO

- Fluorine doped tin dioxide (FTO) thin films are emerging as the choice of transparent conducting oxide (TCO) material in most opto electronic applications like lasers, electrochromic devices, light emitting diodes, LCDs, heat resisting windows, solar control glasses, thick film gas sensors and solar cell applications.

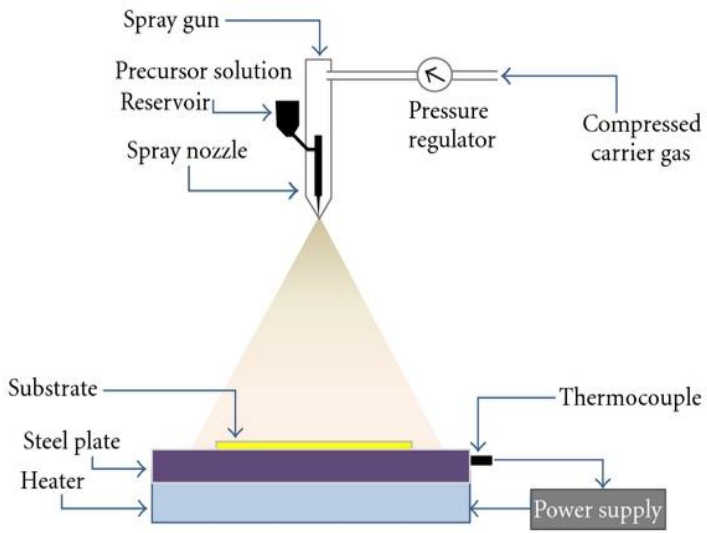
- High electronic conductivity, low cost, chemical and mechanical strength and moderate visible light transmission are the major advantages of FTO thin films compared to In_2O_3, ZnO etc.

- In contrast to indium tin oxide (ITO) which is known to be the highest performance TCO material, FTO can withstand most reactive chemicals and especially high temperatures in which ITO films face degradation and lose most of their performance by means of electrical conductivity.

- FTO is the choice of TCO material for applications requiring high temperature treatments like laminated and tempered glass.

Spray Pyrolysis

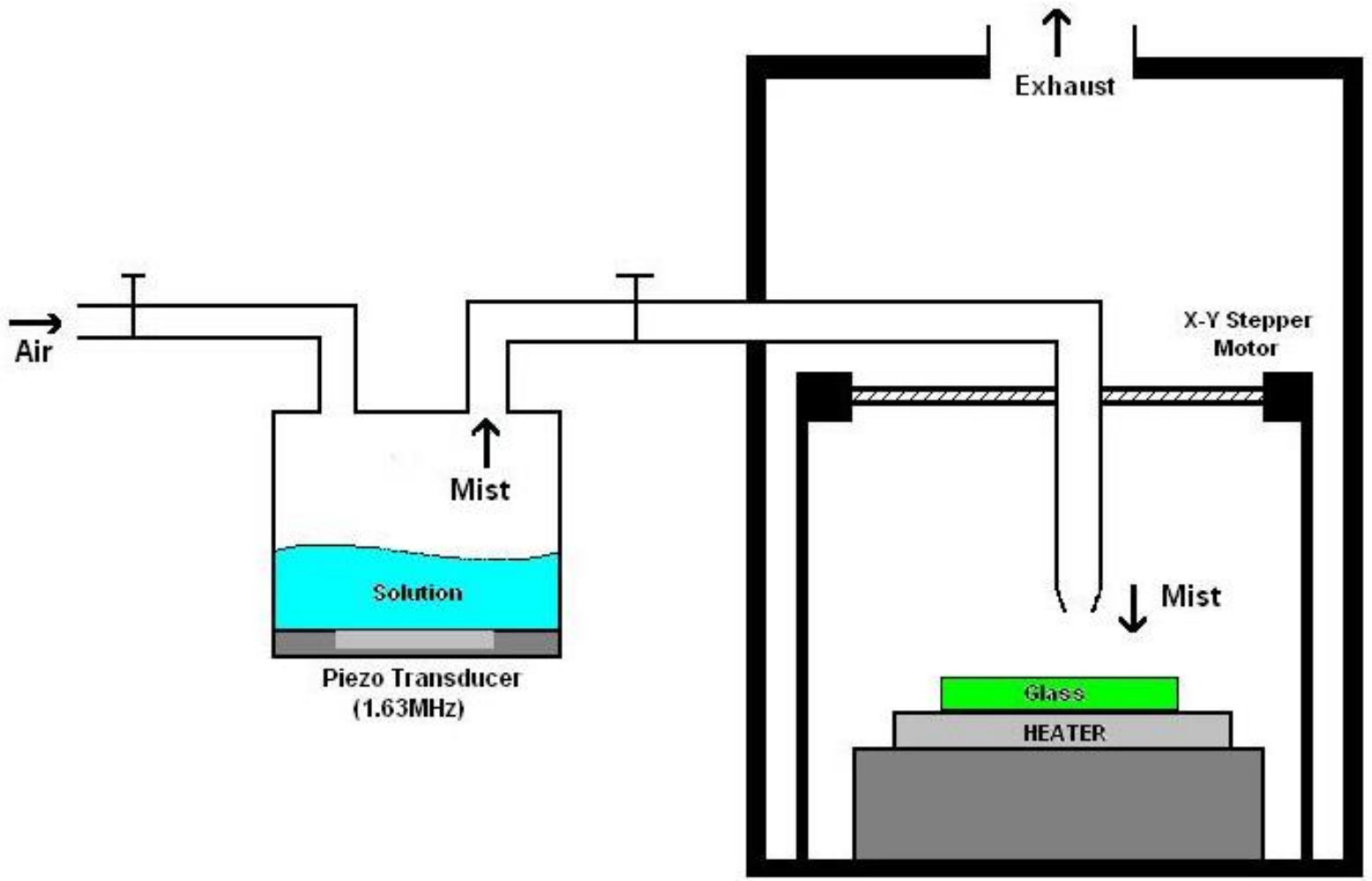
Non-vacuum, athmospheric deposition greatly reduces deposition cost compared to sputtering, CVD etc...



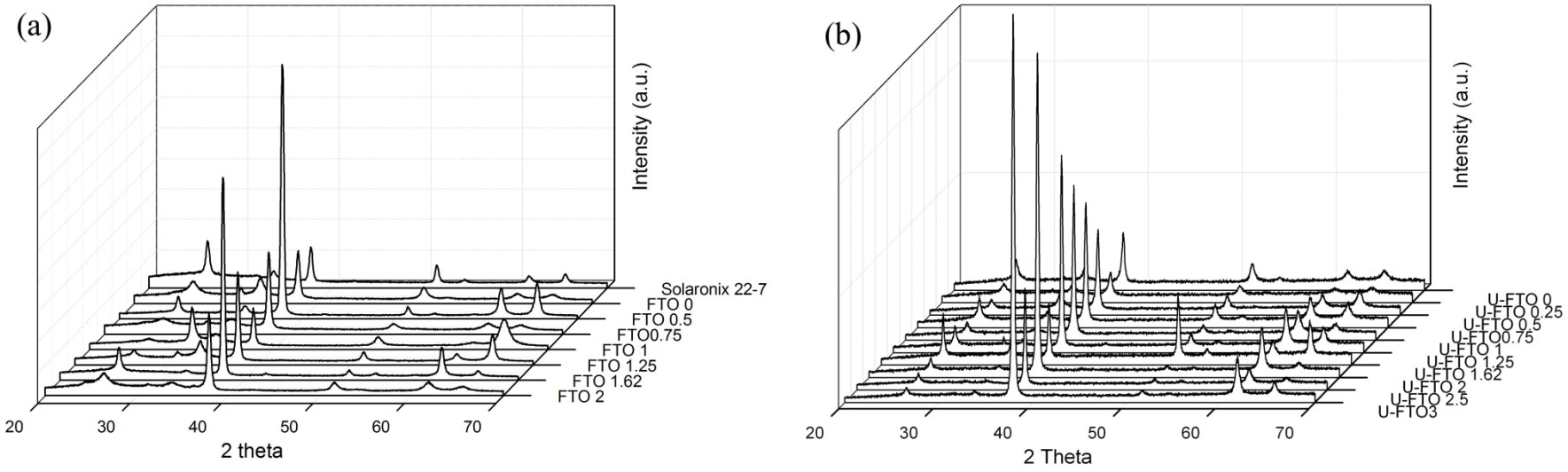
Schematic representation of spray pyrolysis deposition

Spray deposition system equipped in our laboratory

Ultrasonic Spray Pyrolysis (USP)



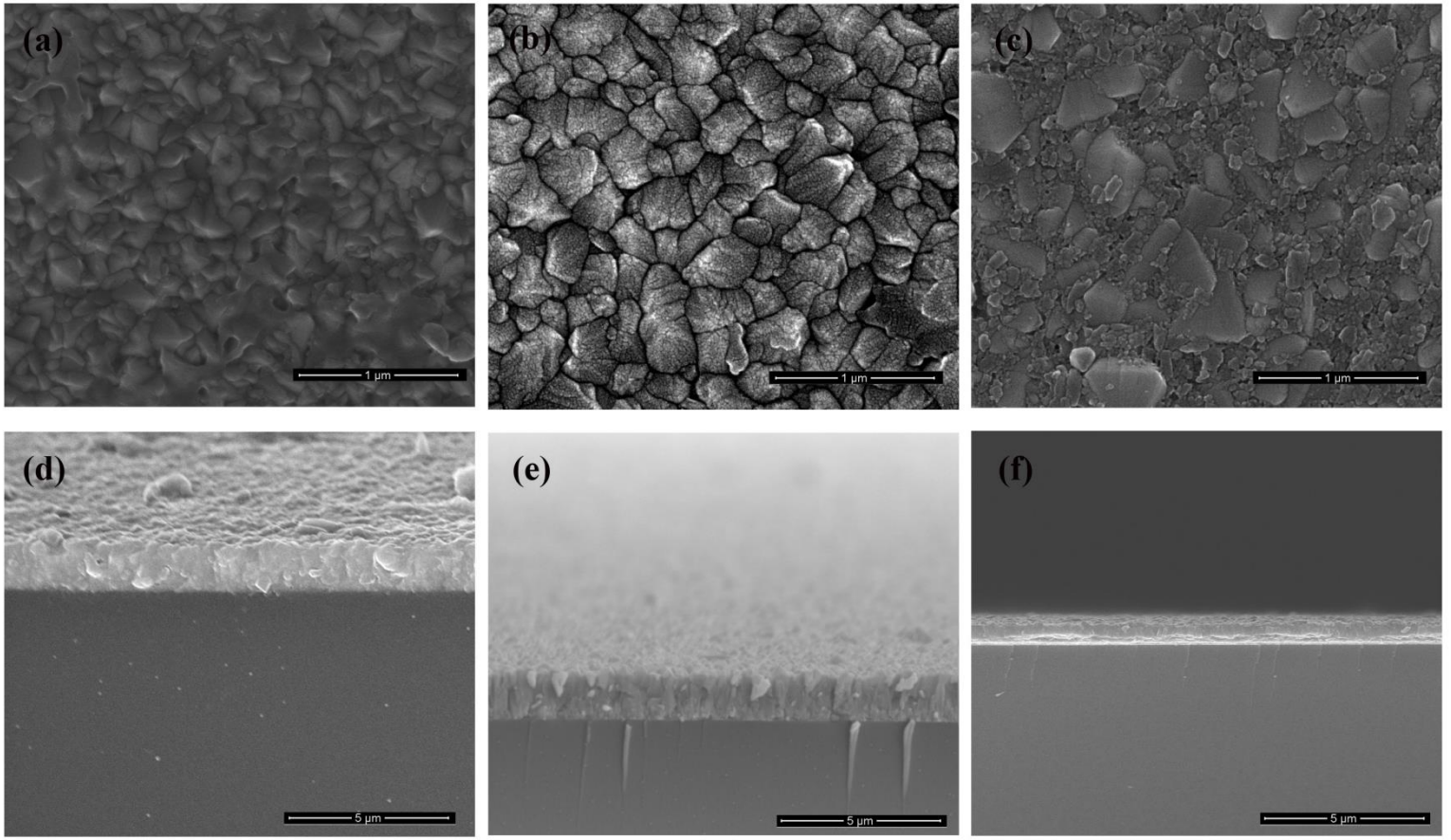
XRD Analysis of the FTO Coatings



XRD spectra of FTO films with different F/Sn ratios in the precursor solution for a) conventional spraying, b) ultrasonic spray deposition.

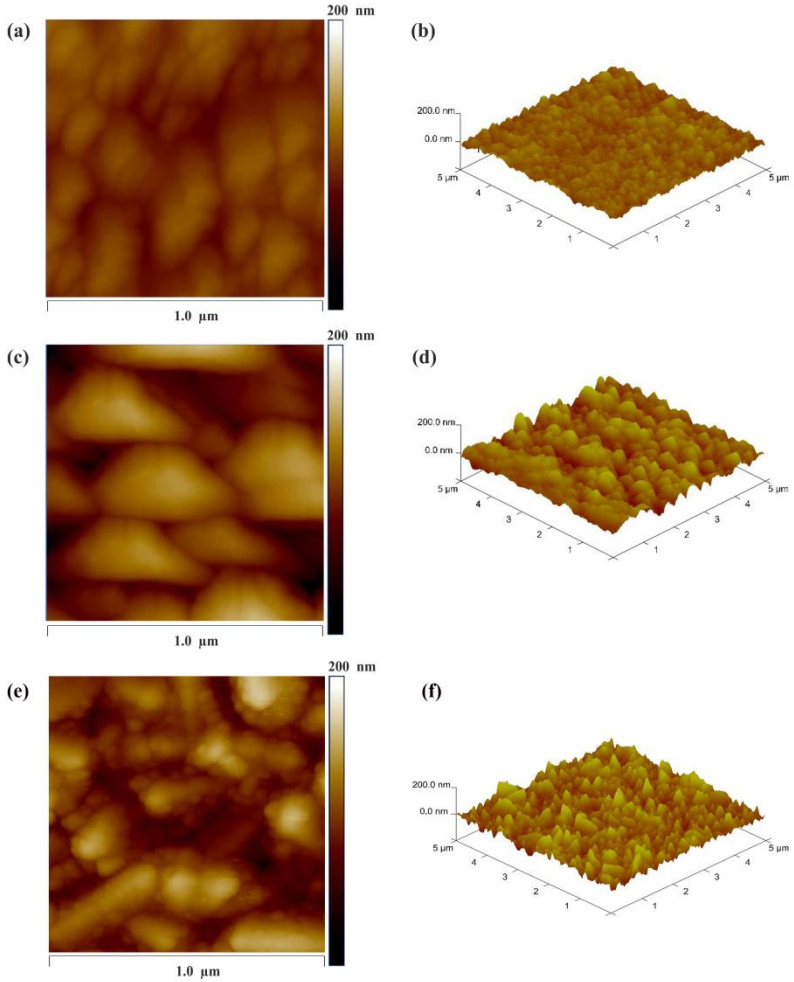
K. C. Icli, B. C. Kocaoglu, M. Ozenbas, "Comparative study on deposition of fluorine-doped tin dioxide thin films by conventional and ultrasonic spray pyrolysis methods for dye-sensitized solar modules," Journal of Photonics for Energy 8(1), 015501 (2018)

Morphology of FTO Coatings



SEM images of a) surface of conventional spray deposited, b) surface of ultrasonic spray deposited, c) commercial substrate, d) cross section of conventional spray deposited, e) cross section of ultrasonic spray deposited and f) commercial FTO thin films.

Morphology of FTO Coatings

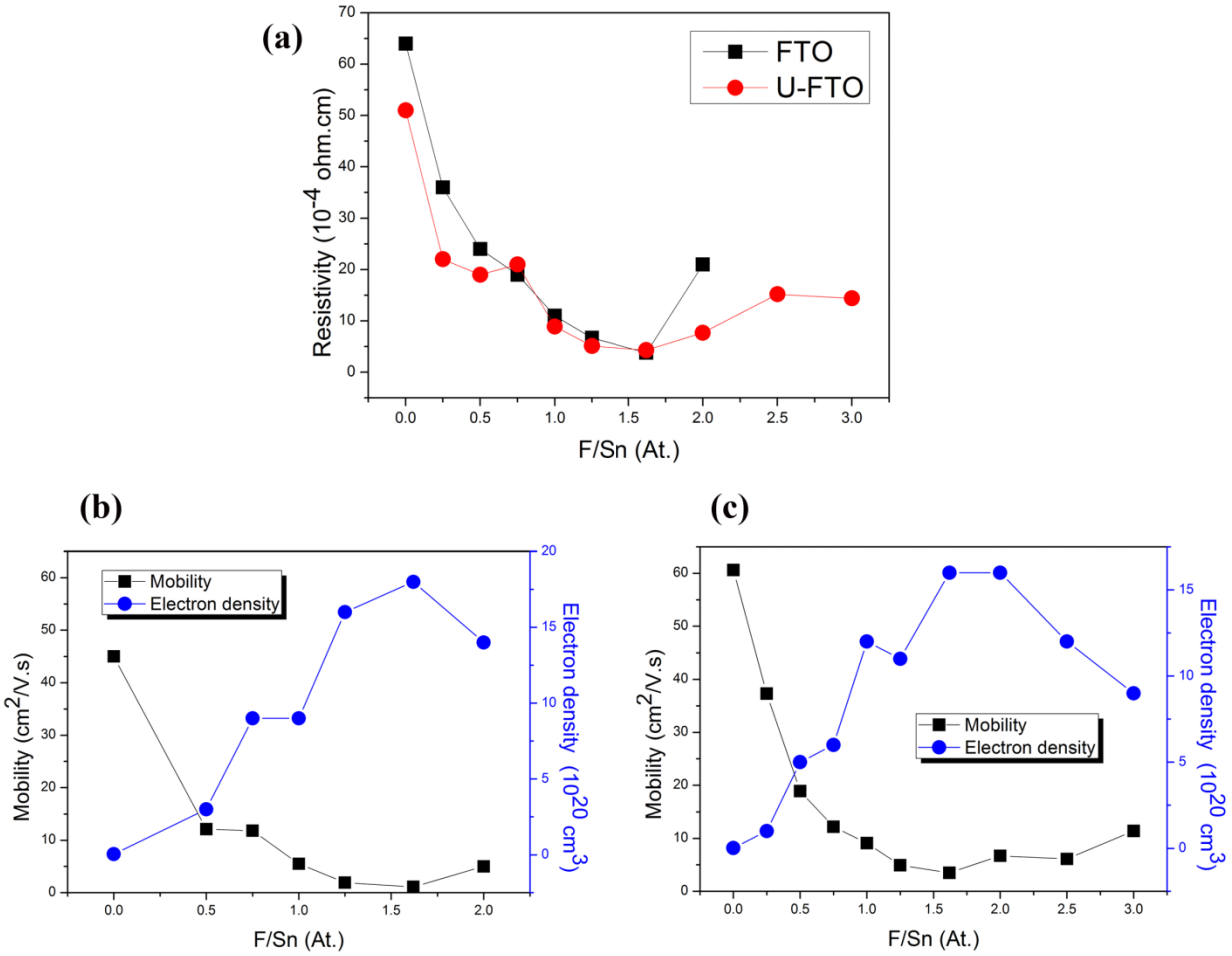


AFM images of conventional spray deposited **(a,b)**, ultrasonic spray deposited **(c,d)** and commercial **(e,f)** FTO thin films

Sample	Glass	FTO 1.62	U-FTO 1.62	Commercial
Surface roughness (nm)	0.74	26	34	31

Surface roughness values of FTO thin films

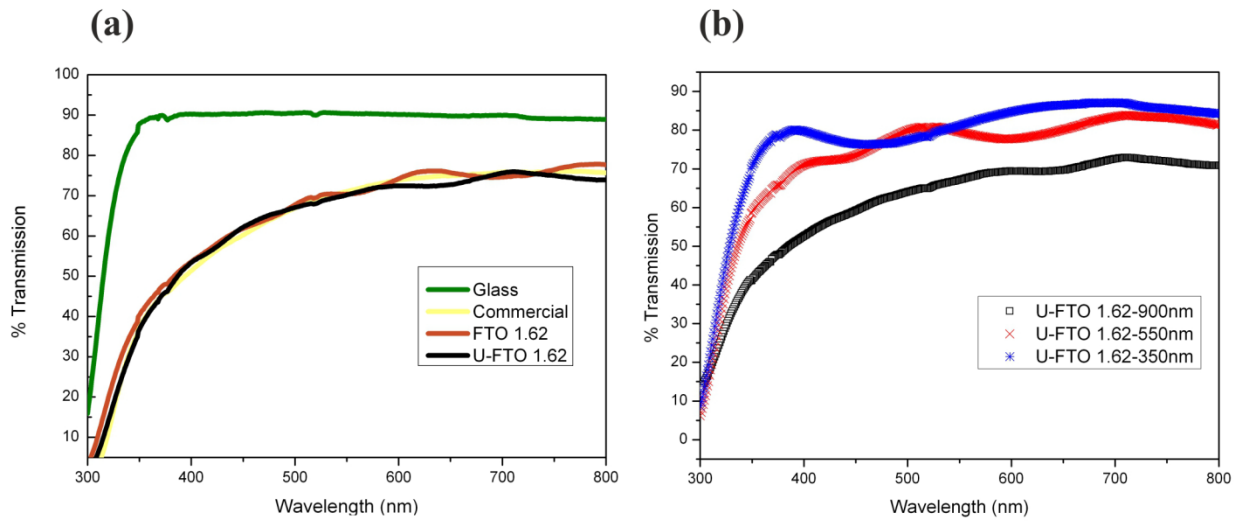
Electrical Properties of FTO Coatings



a) Dependence of resistivity of FTO thin films on F/Sn ratio in the starting solution; variation of mobility and electron density of the FTO films produced by **b)** conventional spraying and **c)** ultrasonic method.

Optical Properties of FTO Coatings

Sample	*Growth rate (nm/min.)*	*Mobility ($cm^2/V\,s$)*	*Electron concentration ($n \times 10^{20}\ cm^3$)*	*Resistivity ($\rho \times 10^{-4}$ ohm.cm)*	*Sheet resistance (ohm/sq)*
FTO 1.62	19.0	1.1	18	3.8	6.6
U-FTO 1.62	24.6	3.5	16	4.3	5.8
Commercial	-	1.7	17	5.6	7.3



UV-Vis transmission spectrum of best performance samples and commercial film and thickness dependent transmission spectrum of USP deposited films

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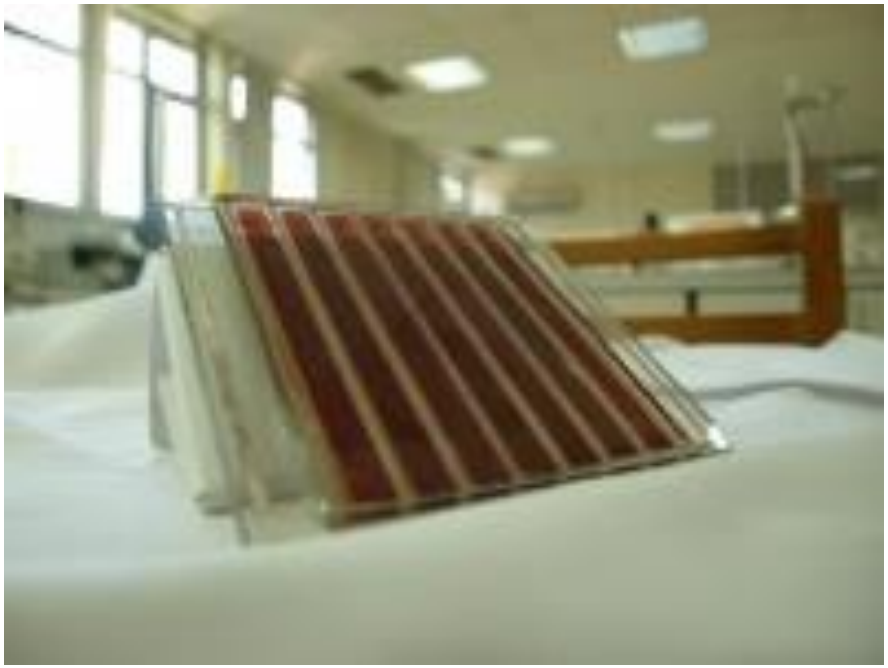
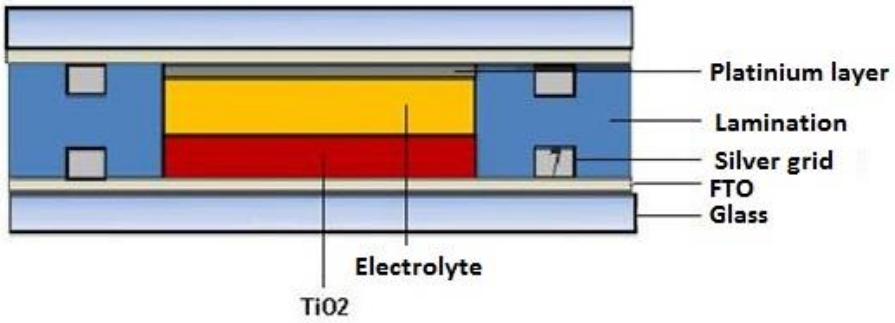
Dye Sensitized Solar Cells

- Low cost abundant materials
- Easy and inexpensive manufacturing
- Applicable on flexible substrates
- Excellent low light intensity performance
- Less dependency on incoming light angle
- No dependency on working temperature



10x10 cm DSSC module produced at METU

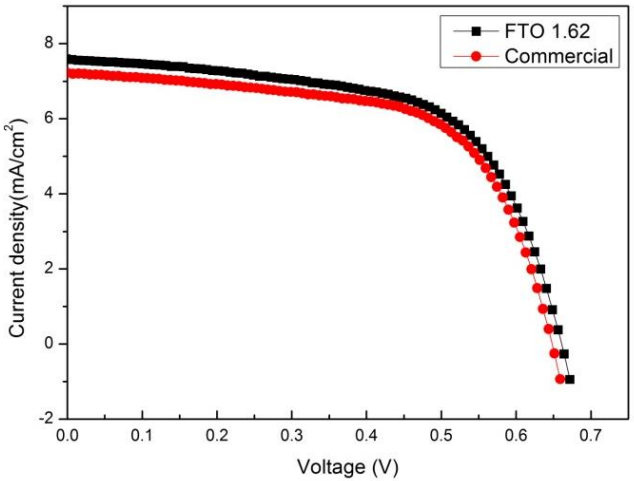
Parallel Connected Modules



10x10 cm sized FTO substrate

7x92 mm sized
paralel connected 8 cells

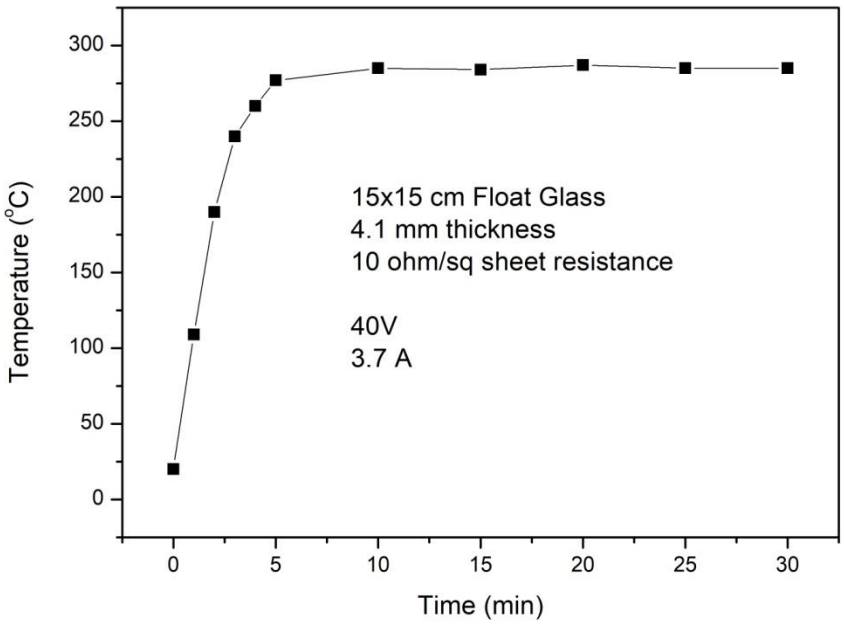
51.5 cm² active area

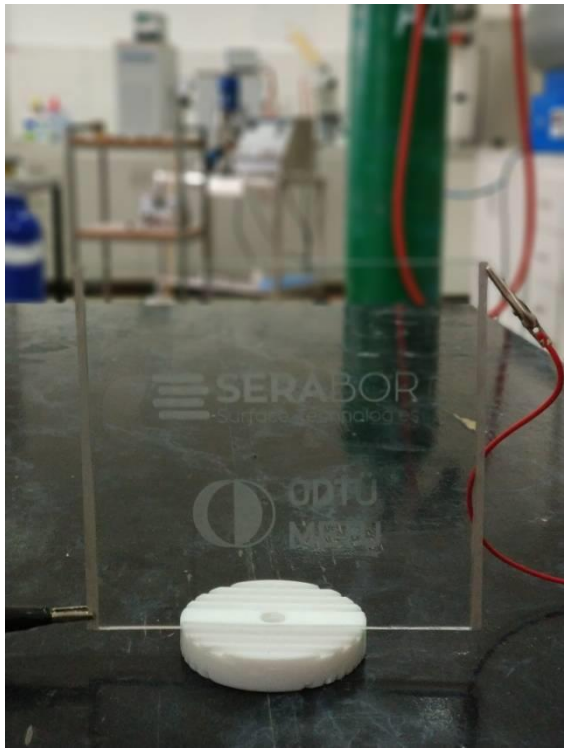


J-V curve of parallel modules using commercial and produced FTO films

Sample	V_{oc} (V)	J_{sc} (mA/cm²)	FF	% Eff	Power (Wp) (mW)
FTO 1.62	0.66	7.57	0.61	3.04	156.5
Commercial	0.64	7.2	0.62	2.85	146.7

Heated Glass Applications in SERABOR





- ✓*Consumer products*
- ✓*Indoor applications (heated windows)*
- ✓*Automobile windshields*

Future of Sprayed FTO Coatings on Glass

- Building Integrated Photovoltaics

- Low-E Heat Control Glasses

- Electrochromic Windows

- Smart Windows

THANK YOU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