

Electronic Supplementary Data

Dielectric core-shells with enhanced scattering efficiency as back-reflectors in dye sensitized solar cells

Nahid Ghazyani¹, Mohammad Hossain Majles Ara¹, Fariba Tajabadi^{*3}, Ali Dabirian^{*2}, Raheleh Mohammadpour³, and Nima Taghavinia^{*2,3}

¹ Physics Department, Kharazmi University, Tehran 15614, Iran

² Physics Department, Sharif University of Technology, Tehran 14588, Iran

³ Institute for Nanoscience and Nanotechnology, Sharif University of Technology, Tehran 14588, Iran

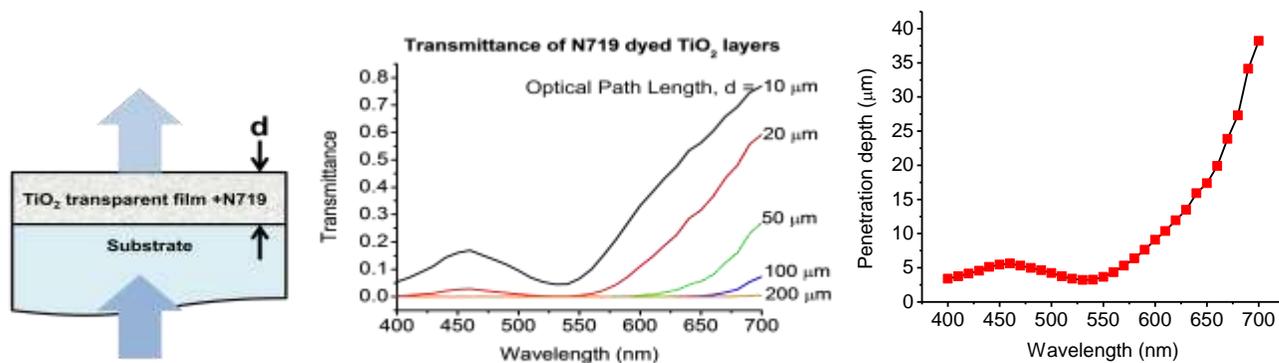


Figure S1. The transmittance behavior of light from a transparent film of dye sensitized TiO₂. In the left graph, the transmittance for the films with different thickness are presented. The calculations are based on the extinction coefficient of N719 dye with a film roughness factor of 1000. One notes that to completely absorb the red-NIR light, a thickness of about 100 μm is required. The left graph is the estimated light penetration depth for the films at different wavelengths. At 700 nm the penetration depth is about 38 μm.

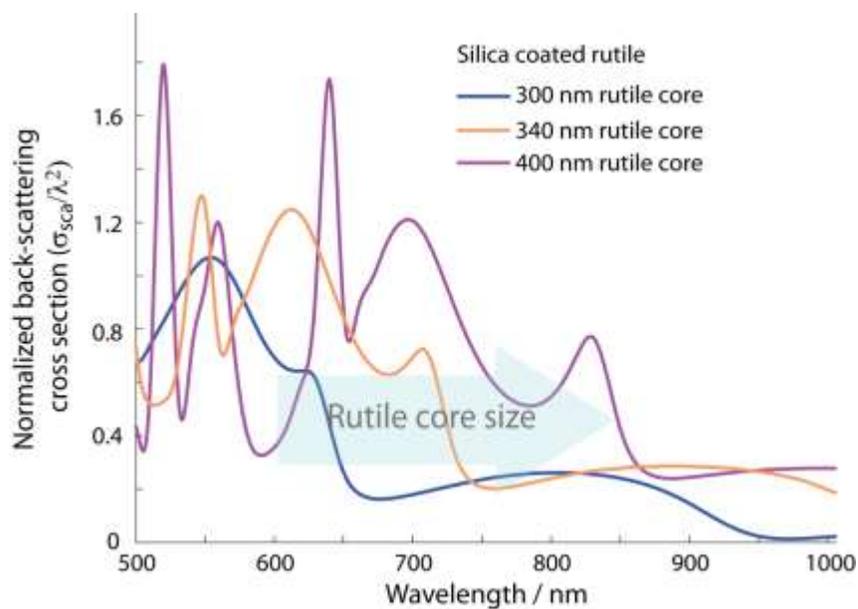


Figure S2. Influence of rutile core size. Back-scattering cross section normalized to the square of wavelength calculated for 300 nm, 400 nm, and 500 nm rutile nanoparticles with 50 nm silica coating. The broad peak gradually red shift and becomes broader as the rutile particle size becomes larger.

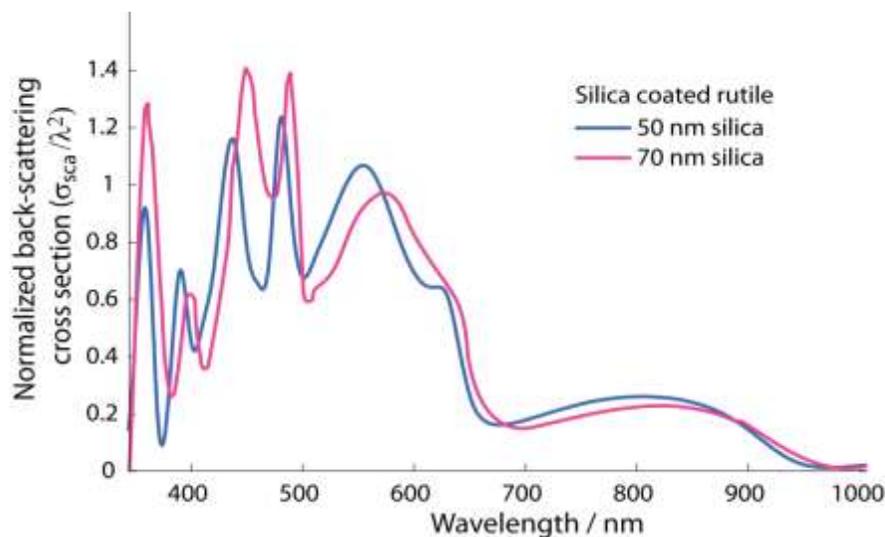


Figure S3. Influence of the silica shell thickness. Back-scattering cross section normalized to the square of wavelength calculated for 300 nm rutile nanoparticles with 50 nm and 70 nm silica coating in air.

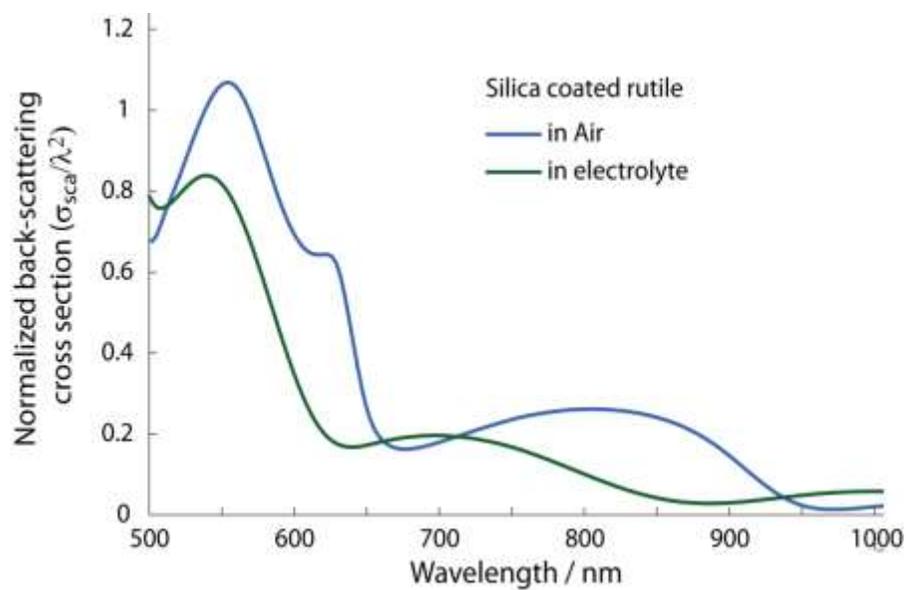


Figure S4. Influence of the surrounding refractive index. Back-scattering cross section normalized to the square of wavelength calculated for 300 nm rutile nanoparticles with 50 nm silica coating in air and in electrolyte ($n=1.4$).

Fabrication Process of DSCs

The FTO (fluorine doped tin oxide) substrates were pre-treated in a 40 mM TiCl_4 solution at 70 °C for 30 min. The transparent TiO_2 paste (Sharif Solar) was then deposited by screen-printing method. After heating the mesoporous film at 120 °C for 5 min, the back-reflector paste was deposited on top of it for 1 (1L) or 2 (2L) times. The TiO_2 electrodes were gradually heated under an air flow at 325 °C for 5 min, 375 °C for 5 min, 450 °C for 15 min, and finally at 500 °C for 30 min. The deposited films used as working electrode were $5 \times 5 \text{ mm}^2$ in size. The thickness of the transparent mesoporous film was 6 μm . The electrodes were then again TiCl_4 treated similarly, and annealed at 500 °C for 30 min. Then, they were sensitized in C101 dye solution (0.3 mM) containing 10 % DMSO in acetonitrile and tert-butyl alcohol (volume ratio: 1:1) at 4 °C overnight.

FTO substrates coated by one drop of 5 mM H_2PtCl_6 ethanolic solution and heated at 450°C for 15 min were used as the counter electrode. Dye-adsorbed TiO_2 electrodes and the Pt counter electrodes were assembled into a sealed sandwich-type cell by heating at 110 °C using a hot-melt film (Surlyn) as the spacer between electrodes. A drop of the electrolyte solution was placed on the hole in the counter electrode and was driven into the cell via vacuum backfilling. Finally, the hole was sealed using additional Surlyn and a cover glass. The electrolyte solution contains 1.0 M 3-dimethylimidazolium iodide, 0.03 M I_2 , 0.05 M lithium iodide, 0.1 M guanidinium thiocyanate and 0.5 M tert-butylpyridine in acetonitrile and valeronitrile solvent mixture (85 : 15, v/v).

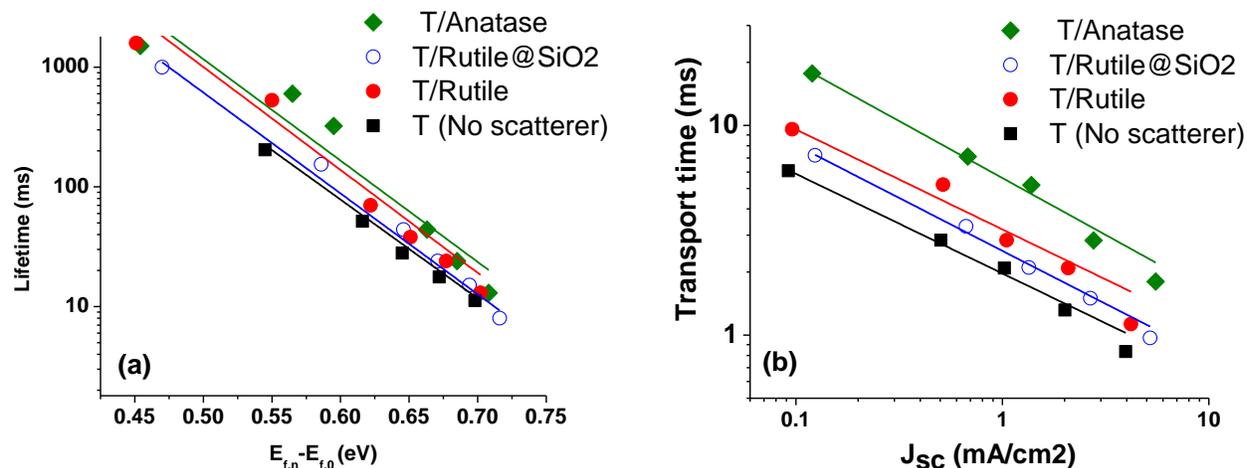


Figure S5 The measured electron lifetime and electron transport time for the cells incorporating different back-reflector films. The measurements were carried out using IMVS and IMPS methods (Ivium Compactstate). It is observed that the electron lifetime of the cells is almost the same for the cells. The electron transport times for the sample "T" (no scatterer) is shorter, due to being excited only from the FTO side, that is, the photoelectrons are generated near the FTO electrode. For the cells utilizing back-reflectors the transport time is slightly longer. For the commercial anatase back-reflector the transport time is longest. This can be due to the dual role of the anatase reflector film which also acts as the light absorber.

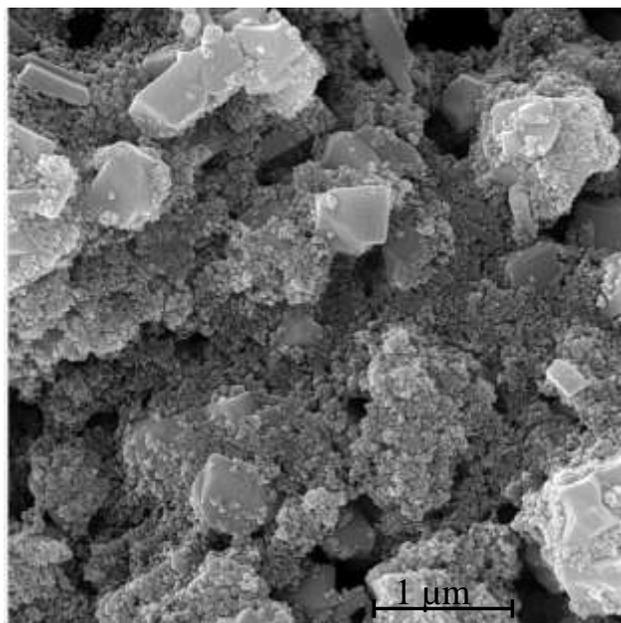


Figure S6. SEM image of screen printed layer of JGC particles. The very small particles in the images are 20 nm TiO₂ particles used as the binder. The image shows a large distribution of particle size between 100- 550 nm for JGC particles.

Table S1. The number of dye adsorbed on the 3 back-reflector films of commercial anatase, rutile and rutile@SiO₂. The thickness of the films were 8 μm, 6 μm and 6 μm, respectively. The values are measured by dye desorption using aqueous solution of 0.1 M NaOH and measurement of absorptivity of the dye in the solution.

	Number of dye molecule(#/cm ²)*10 ¹⁵	Roughness factor	Roughness factor/μm
Anatase	11.16	167	20.9
Rutile	4.64	69.6	11.6
Rutile@SiO₂	4.53	68.0	11.3