Waveguide Enhanced Solar Cells

Shlomit Greenwald, Sven Rühle, Arie Zaban

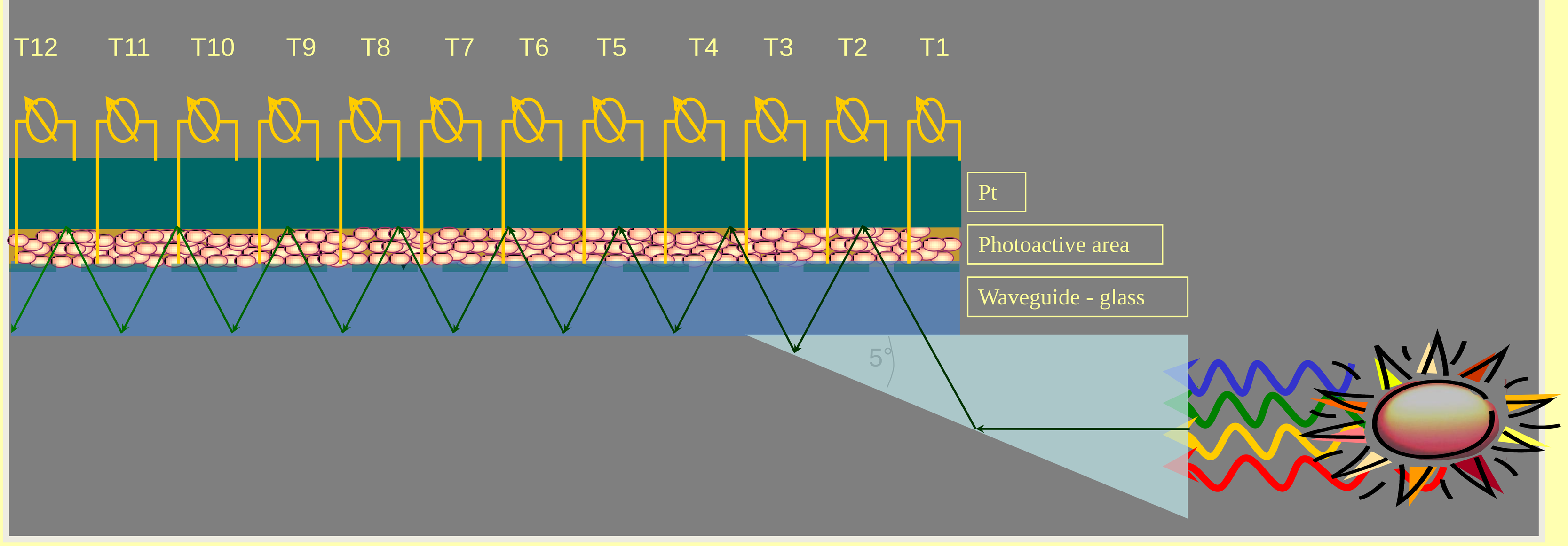
Department of Chemistry, Bar Ilan Institute of Nanotechnology & Advanced Materials

We show here enhanced photovoltaic conversion efficiency of a thin Dye Sensitized Solar Cell (DSSC) mounted onto a waveguide slab compared to illumination at normal incidence. Sunlight propagates along the waveguide due to total internal reflection at the waveguide-air interface and reflection at the Pt counter electrode. The thin photoactive layer guaranties charge generation close to the current collector (TCO electrode) and enables improved conversion of incident photons. The waveguide concept can improve the conversion efficiency of all PV systems with a short charge carrier diffusion length in conjunction with a low absorption coefficient.

Background

Waveguide Coupled Solar Cells

- Total internal reflection at the glass-air (bottom) interface and reflection at the Pt counter electrode (top) lead to waveguiding
- Decoupling of the light path from the charge path:
  - Long optical path preserves effective high optical density
  - Work within thin layers reduces the distance that the separated charges need to travel to the current collectors, thus decreases their recombination



Dye Sensitized Solar Cells (DSSC)

- Photoactive dye layer:

photon absorption excite Ruthenium-based dye molecules (“N3”)

- Charge separation:

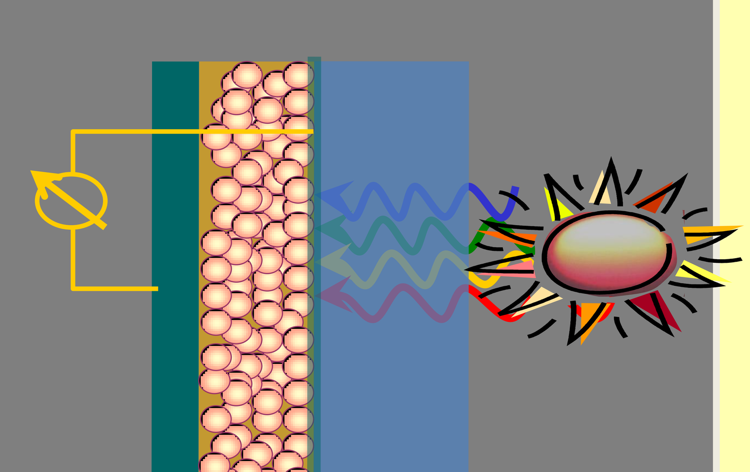
Electron injection from the excited dye to the TiO_2 semi-conductor film

- Hole collection:

regeneration of the dye by the electrolyte solution

- Electron collection:

electrons travel through the TiO_2 to the conductive coated glass

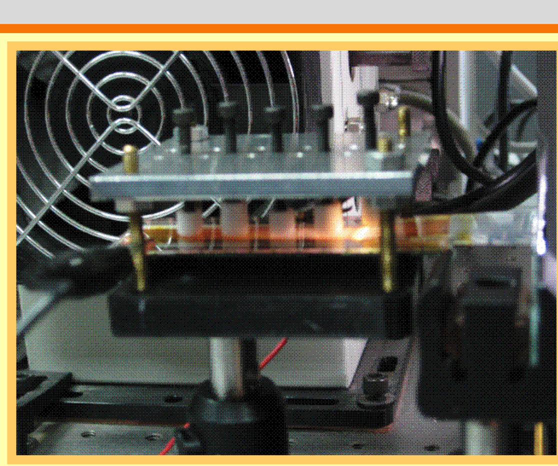


Optical waveguide enhanced photovoltaics

Sven Rühle, Shlomit Greenwald, Elad Koren, and Arie Zaban

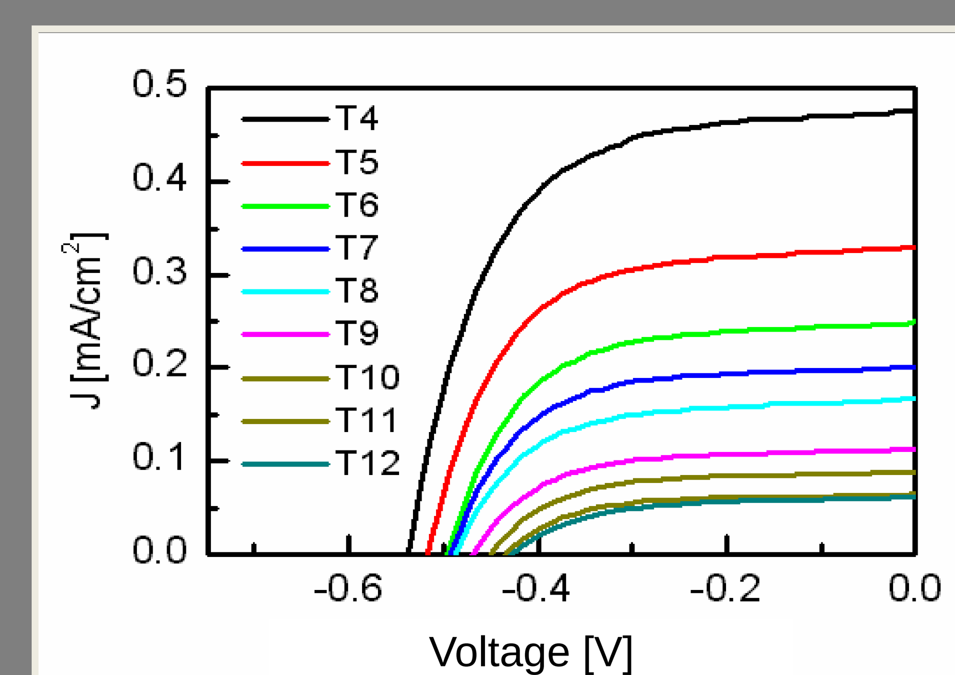
Optics Express, 2008, 16

(19 focused Issue: optics for energy)

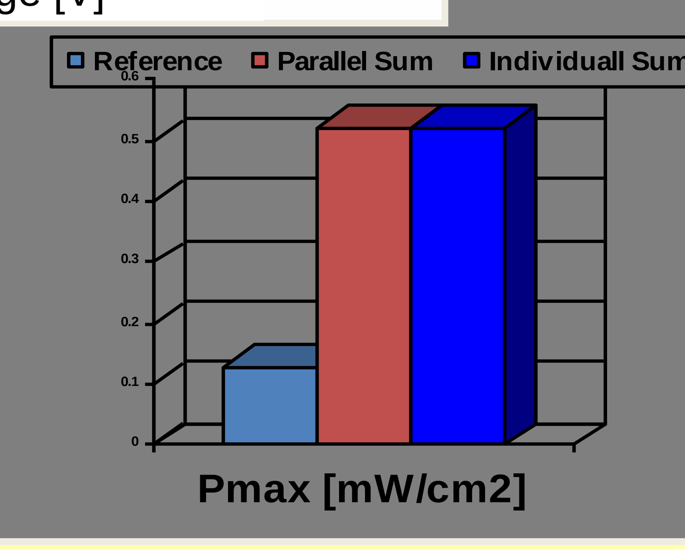


DSSC Results

Terminal IV Measurements



Enhanced power efficiency compared to illumination at normal incidence



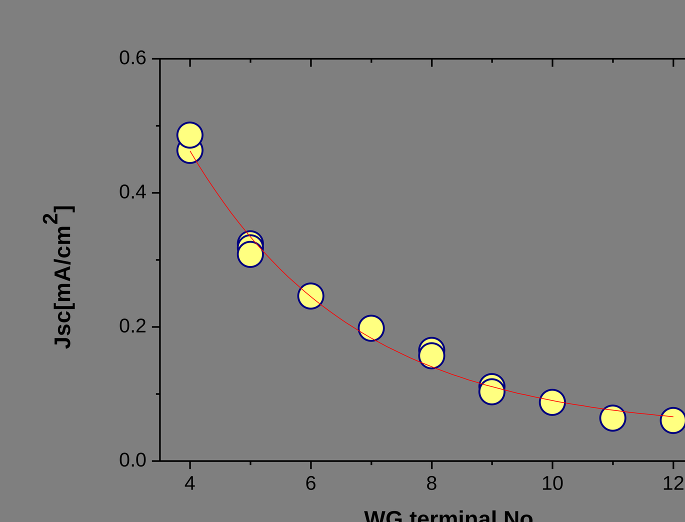
Current Vs. Terminal

The light absorption and charge carrier generation follow Beer-Lambert law

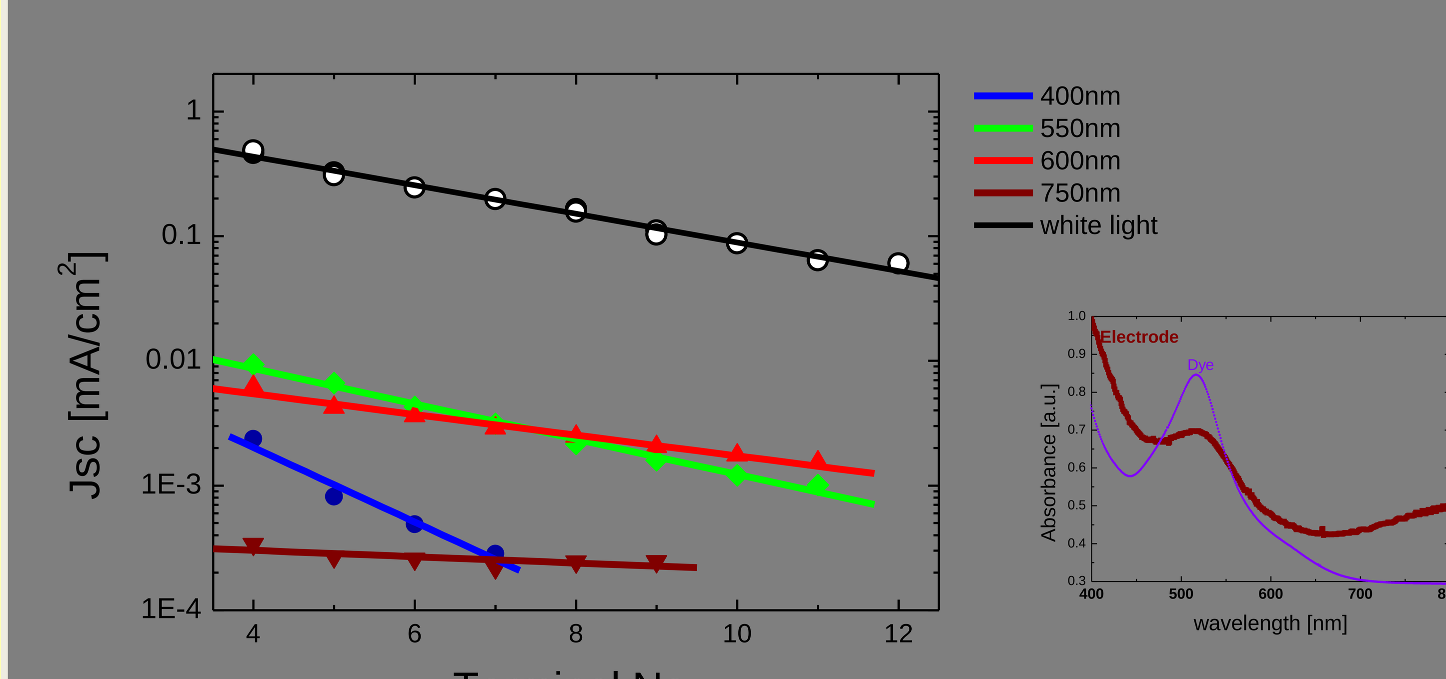
Current flux $J_{sc}(x) \sim \Phi$

Photon flux $\Phi(x) = \Phi_0 \exp(-\alpha x)$

α is an effective absorption coefficient which takes the waveguide structure into consideration



Photocurrent at Monochromatic Illumination



- The steepness of the exponential photocurrent decrease depends on the absorption coefficient of the dye, e.g. a larger α leads to a steeper decrease.
- Comparison of the absorption spectra of dye solution and the electrode shows that at 400nm also scattering occurs, which leads to a rapid decrease of J_{ph} at this wavelength.