

New insights into the limitations of solar cells sensitized with ruthenium dyes revealed in time-resolved spectroscopy studies

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Dye-sensitized solar cells (DSSC) using ruthenium dyes still possess the highest certified sunlight conversion efficiency (11.9%). However, employing cobalt-based electrolyte instead of iodine one led recently to much higher efficiencies (>13%) with porphyrin^[1] and all-organic dyes.^[2] Therefore, in the current studies we compared the performance of solar cells sensitized with the most popular ruthenium dye N719 using two different electrolytes. Electrochemical impedance studies showed the expected^[3] increased recombination of injected electrons with cobalt redox pair than with the iodine/iodide redox shuttle, resulting in lower photovoltage and fill factor for Co-based cells. However, our transient absorption studies, performed according to the previously proposed protocol,^[4] revealed that there exists additional, pronounced recombination between injected electrons and the oxidized dyes on sub-ns time scale, responsible for smaller photocurrent in Co-based cells (Fig. 1). Another problem with ruthenium dyes in DSSC is their lower absorption coefficient with respect to organic dyes, which requires thicker titania nanoparticles layer to sufficiently absorb sunlight. In our studies with N719 dye we found that increased number of titania layers (and also stronger TiCl₄ treatment) results in the lowering of titania conduction band energy, faster electron injection, and higher titania-electrolyte recombination. As a consequence, despite higher photocurrent, the charge separation efficiency and photovoltage drop.

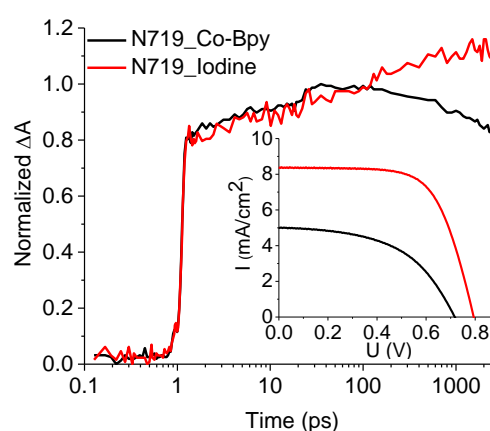


Figure 1. Transient absorption rise due to electron injection from N719 triplet state, and decay observed in cobalt electrolytes due to back electron transfer. Inset shows C-V curves of the cells.

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References:

- [1] S. Mathew, A. Yella, P. Gao, R. Humphry-Baker, B. F. E. Curchod, N. Ashari-Astani, I. Tavernelli, U. Rothlisberger, M. K. Nazeeruddin, M. Grätzel, *Nat. Chem.*, **2014**, 6, 242
- [2] K. Kakiage, Y. Aoyama, T. Yano, K. Oya, J.-i. Fujisawa, M. Hanaya, *Chem. Comm.*, **2015**, 51, 15894
- [3] E. Mosconi, J.-H. Yum, F. Kessler, C. J. Gómez García, C. Zuccaccia, A. Cinti, M. K. Nazeeruddin, M. Grätzel, F. De Angelis, *J. Am. Chem. Soc.*, **2012**, 134, 19438
- [4] J. Idígoras, G. Burdziński, J. Karolczak, J. Kubicki, G. Oskam, J. A. Anta, M. Ziólek, *J. Phys. Chem. C*, **2015**, 119, 3931