NIR fotonų konversija į matomą sritį: technologija leidžianti gauti našius rubreno sluoksnius

Technology to Produce Efficient NIR-to-Vis Photon Upconversion in Rubrene films

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Increasing research interest in photon energy upconversion (UC) utilizing organic compounds that can induce triplet-triplet annihilation (TTA) is associated with promising applications in photocatalysis, bioimaging, night vision, memory devices, targeted drug delivery and many others.[1-2] TTA-UC is particularly attractive because of efficient operation under incoherent excitation and at low power densities (~ mW/cm^2) such as those provided by the sunlight. This implies novel opportunities in photovoltaics to harvest weakly absorbed near-infrared (NIR) photons via their conversion to visible light.[2]

Typical UC system consists of a triplet sensitizer and an emitter. The sensitizer is responsible for lower energy photon absorption, triplet generation and their transfer to the emitter. Meanwhile the emitter ensures generation of higher energy photon via TTA. Commonly exploited TTA emitters for NIR spectral range are tetracenes, rubrenes perylenes or diketopyrrolopyrroles. Most of these emitters are efficient in the solution/liquid phase, yet in the solid-state they become poorly emissive.The best-performing NIR-to-vis UC systems demonstrated so far, both in solution and solid-state, rely on rubrene (**Rub**) emitter.[3] However, in the solid-state emissive properties of **Rub** are heavily influenced by the film morphology.

In this work we introduce straightforward UC film fabrication technique based on thermal evaporation in an inert atmosphere. In this way obtained highly concentrated **Rub** films (see Fig 1) display one order of magnitude higher fluorescence quantum yield (Φ_{FL}) compared to the films produced by solution-processing or sophisticated thermal deposition in vacuum. Additionally, we show that in these films sensitizer and emitter are well dispersed and intermixed to result in efficient triplet energy transfer ($\Phi_{TET} > 60\%$). As a result, the UC films demonstrate record-high NIR-to-Vis UC efficiency (Φ_{UC}) of 1.2%. The attained Φ_{UC} is at least 2-fold higher compared to that of other bicomponent NIR-UC films reported in literature so far. Moreover, we evaluate **Rub** potential as TTA emitter by calculating the statistical probability (f) to obtain one singlet from two triplets via TTA. In this case, by determining efficiency of each energy transfer step, we evaluate f to be ~19.7 %. The value is found to be similar to the previously estimated one for **Rub** in a solution (15.5%)[4]. This indicates that f of the Rub is not significantly influenced by the environment and is a more intrinsic property.

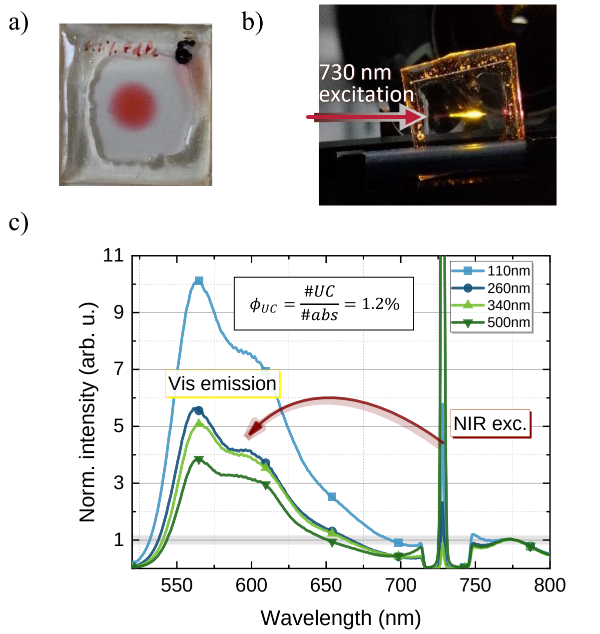

Fig 1. a – digital photo of thermally deposited UC film, b – UC film under NIR excitation, c – relative spectra of UC films with varying sensitizer thickness.

Key words: Rubrene, Triplet-triplet annihilation, TTA upconversion, NIR-vis UC.

Literature

[1]. J. Zhou, Q. Liu, W. Feng, Y. Sun and F. Li, Chem. Rev., **115**, 395–465, (2015).
[2]. B. S. Richards, D. Hudry, D. Busko, A. Turshatov and I. A. Howard, Chem. Rev., **121,** 9165-9195, (2021).
[3]. P. Bharmoria, H. Bildirir and K. Moth-Poulsen, Chem. Soc. Rev., **49**, 6529–6554, (2020).
[4]. E. Radiunas, S. Raišys, S. Juršėnas, A. Jozeliūnaitė, T. Javorskis, U. Šinkevičiūtė, E. Orentas and K. Kazlauskas, J. Mater. Chem. C, **8**, 5525–5534, 2020.