Effect of J-aggregates' Formation in Liquid Crystal Matrix on Their Optical Properties

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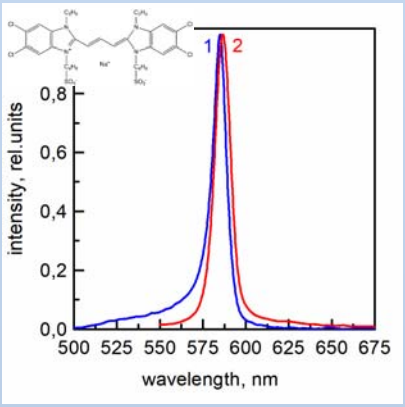
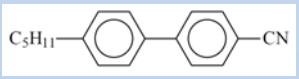


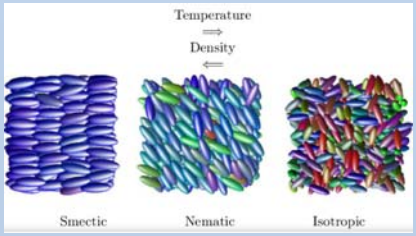
Absorption (1) and fluorescence (2, λ_{exc} = 530 nm) spectra of TDBC J-aggregates in aqueous solution (spectra are normalized for clarity). On inset – the dye structure.

Ordered luminescent molecular aggregates of dyes (so-called J-aggregates), primarily cyanine, merocyanine and porphyrin, form a wide class of luminescent nanoclusters, which are characterized by ultrahigh extinction coefficients, efficient energy migration and electron excitation, extremely high coefficients of cubic susceptibility etc. The unique optical properties of J-aggregates are related to the exciton nature of their electronic excitations of the Frenkel type. This phenomenon is possible only due to the high degree of ordering of molecules in chains, in fact translational symmetry, which is achieved due to the flat structure of molecules from which J-aggregates are formed. In fact, J-aggregates can be attributed to low-dimensional molecular crystals. Unlike bulk crystals, the exciton properties of J-aggregates are highly dependent on the degree of molecules disorientation in the chains or static disorder. Thus, the structure, and hence the optical properties of J-aggregates are largely determined by their microenvironment, which can be used to create J-aggregates with specified optical properties. At the same time, a number of studies have shown that in nanostructured media the J-aggregates luminescence can be significantly quenched due to the growth of static disorder.

In this work, the J-aggregate formation of anionic cyanine dye TDBC in the liquid crystal (LC) matrix 5CB has been studied using optical spectroscopy.

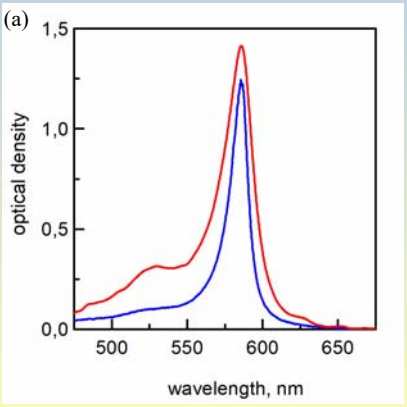


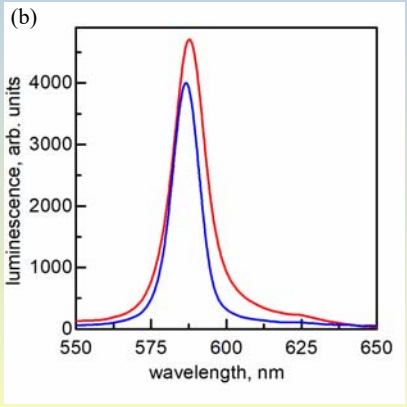
4-cyano-4′-n-pentylbiphenyl (CB5)



Molecular arrangement in liquid crystals depending on temperature

Results:





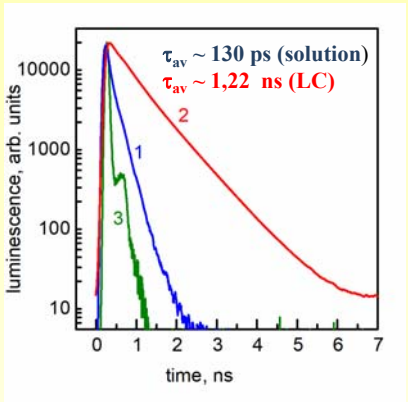
Absorption (a) and luminescence (b, λ_{exc} = 530 nm) spectra of the TDBC J-aggregates in aqueous solution (blue spectra) and in 5CB LC matrix (red spectra).

	Solution	LCs
$\Delta\nu_J$ (cm^{-1})	430	720
N_{coh} (mon)	9	3

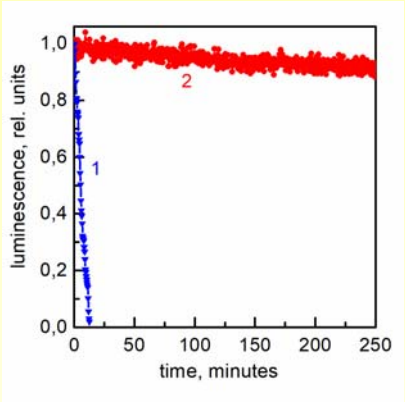
$$N_{coh} = \frac{3 \cdot (\Delta\nu^{mon}_{FWHM})^2}{2 \cdot (\Delta\nu^{J}_{FWHM})^2} - 1$$ the exciton coherence length

where $\Delta\nu^{mon}_{FWHM}$ and $\Delta\nu^{J}_{FWHM}$ – are full widths at half maximum of the monomer and J-bands, respectively

$\eta \sim 9\%$ (TDBC solution)
$\eta^{LC} \sim 10\%$ (TDBC LCs) the luminescence quantum yield



The luminescence (λ_{exc} = 531 nm, λ_{reg} = 590 nm) decay curves the TDBC J-aggregates in aqueous solution (1) and in 5CB LC matrix (2). 3 – IRF.



Time dependence of the luminescence intensity (λ_{reg} = 590 nm) of TDBC J-aggregates in in aqueous solution (1) and in 5CB LC matrix (2) at continuous illumination. The dependences are normalized to the initial value for clarity

Conclusions:

Features of TDBC J-aggregates' formation in liquid crystal matrix have been studied using steady-state absorption and luminescence spectroscopy and time-resolved luminescence spectroscopy. The spectral and structural features of the J-aggregates formed in liquid crystal matrix change significantly as compared with J-aggregates in aqueous solutions. We have shown that introduced in this work strategy of incorporating dyes like TDBC, exhibiting the strong emission in aggregated form, into LC matrices may be beneficial for the emissive LC materials. Moreover, presented system proves ultra-high photostability. Such feature is desired for development of opto-electronic devices.

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