

## DOCTORAL THESIS

# Local Field Effect and Photoluminescence Properties Study of Organic and Inorganic Materials

HUANG, Anjun

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## ABSTRACT

The spectroscopy study of organic and inorganic luminescence materials lay a good foundation for developing their practical applications. In the past decades, improving the optical performance of a material has always been a topic of concern. Local field effect refers to a phenomenon that the local electric field surrounding the emitter is different with the average field of medium, which can be employed to effectively improve the optical properties of a material. In this thesis, the photoluminescence properties of several typical inorganic and organic materials are investigated, and the influence of local field effect on their optical performances are studied.

Garnet is one of the most common inorganic luminescence hosts, and lanthanide ions-doped garnets have received lots of interest in the past few decades.  $\text{Ce}^{3+}$  ions-doped  $\text{Y}_3\text{Al}_5\text{O}_{12}$  nanoparticles are prepared by a glycothermal method in this work, and their structure and morphology are well-characterized. The emission spectrum of the nanoparticles in the visible region is due to the electric dipole allowed transitions of  $\text{Ce}^{3+}$  ions, involving  $\text{Ce}^{3+}$  ions with 8- or lower coordination numbers in  $\text{Y}_3\text{Al}_5\text{O}_{12}$  host. When the  $\text{Ce}^{3+}$ -doped  $\text{Y}_3\text{Al}_5\text{O}_{12}$  nanoparticles are dispersed in a series of alcohols, the temperature-dependent local field effect on  $\text{Y}_3\text{Al}_5\text{O}_{12}:\text{Ce}^{3+}$  nanoparticles are explored. The variation of decay rates of the samples with the refractive indices of alcohols is matched with the local field model, and the derived radiative rate and nonradiative rate are obtained. The change of derived nonradiative rate with temperature can be explained by the strong electron-phonon coupling model.

Recent years, lead-free double perovskite halides materials attract great attention due to their potential application in fields of white LEDs, photovoltaics, Li-battery anodes, and so on. This thesis focuses on the  $\text{Cs}_2\text{NaBiCl}_6$  matrix and systematically investigate its photoluminescence properties. A series of emission bands from ultraviolet to infrared regions are observed at low temperature. The blue emission at 360 nm corresponds to the  $^3\text{P}_{1,0} \rightarrow ^1\text{S}_0$  transition of  $\text{Bi}^{3+}$  ions in  $[\text{BiCl}_6]^{3-}$ , and the red emission bands correspond to the transitions of  $(\text{Bi}^*-\text{Bi})$  pair; the ultra-broad near infrared and infrared emission bands may be attributed to the transitions of  $\text{Bi}^+$  ions and  $\text{Bi}^0$  atom. When  $\text{Er}^{3+}$  is doped in  $\text{Cs}_2\text{NaBiCl}_6$  host, a striking downshifting luminescence is observed. There is a sharp near infrared emission band due to the  $^4\text{I}_{13/2} \rightarrow ^4\text{I}_{15/2}$  transition of  $\text{Er}^{3+}$  ions. The  $^4\text{I}_{13/2}$  emitting level is populated by at least two channels, the cross-relaxation of  $^2\text{H}_{11/2}$  level of  $\text{Er}^{3+}$  and the energy transfer from a perturbed  $\text{Bi}^{3+}$  site to  $\text{Er}^{3+}$ . Additionally, the emission intensity of  $\text{Cs}_2\text{NaBiCl}_6:\text{Er}^{3+}$  nanoparticles can be tuned by selection of an appropriate solvent.

The luminescence of organic molecules consists of emissions from the singlet and triplet states. The spin and electric dipole allowed transitions between singlet states are considered in this study. Using pyranine (HPTS) and porphyrin derivative (POR) as luminescence centres, the chemical interaction and local field effect are explored. Two kinds of silica-coated organic dye nanoparticles are fabricated by the reverse micro-emulsion method and dispersed in various alcohols. For silica-coated HPTS nanoparticles, samples with distinct size are synthesized for comparison. The variation of fluorescence lifetimes of smaller HPTS nanoparticles with refractive index is

consistent with the predicted trend by the local field model, but this model is not applicable for larger HPTS nanoparticles and POR nanoparticles. The chemical interaction of dyes-dyes and/or dyes-solvents may be mainly responsible for the change in their fluorescence lifetime.