Design of luminescent materials – From basics to real applications

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Luminescent materials are ever important for various applications such as LED phosphors,[1] upconversion nanocrystals,[2] or luminescent thermometers[3] to mention just a few. For all of these applications, a firm understanding of the interplay between the radiative and non-radiative decay pathways is crucial for a better design. Within this tutorial lecture, I will demonstrate that for the case of two luminescent materials classes. In the first part, an overview of the requirements for phosphors for both phosphor-converted white-light LEDs and displays will be given. Special emphasis lies on the demonstration on how important control over the thermal crossover barrier in such phosphors is. It will then be followed up on why narrow-band phosphors are ideally suited for these applications taking the UCr_4C_4-type phosphors as a representative example. In some of them, subtle structural disorder features can occur. I will also shortly demonstrate how the photoluminescence of Eu^{2+} can help resolve such features in conjunction with ligand-field modelling [4].

Another emerging materials class are luminescent Boltzmann thermometers. They essentially rely on non-interacting emitting centers with two thermally coupled and radiatively emitting states. The luminescence intensity ratio then follows Boltzmann's law. Trivalent lanthanoids with their narrow line $4f^n$-$4f^n$ luminescence doped into micro- or nanocrystalline powders have emerged for this type of thermometry. The ultimate desire to design such thermometers for the application of interest requires, however, a careful understanding of both thermodynamic and kinetic concepts of their performance [5]. It will be demonstrated that precise temperature measurements with these thermometers are fundamentally limited to only a small temperature window and what are strategies to overcome this obstacle [6,7]. As it turns out, this approach has a much deeper connection to a fundamental understanding of the nature and control of non-radiative transition rates [8–10], which could open a whole new perspective on the control of the efficiency of inorganic phosphors quite generally.

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