Structural and Optical interpretations on KNN-based Transparent Ceramic Application in Optical Thermometry

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Abstract:

Luminescence thermometry has emerged as a powerful tool for non-contact temperature sensing, driven by significant advancements aimed at enhancing thermal sensitivity. In this study, we present Ta^{5+}-substituted $K_{0.5}Na_{0.5}NbO_3$:0.003Er^{3+} transparent ferroelectric ceramics as a highly promising material for advanced luminescence-based thermometric applications. The temperature-dependent fluorescence intensity ratio (FIR) between the thermally coupled $^2H_{11}/_2$ and $^4S_3/_2$ levels of Er^{3+} ions was utilized to achieve effective temperature detection across a broad 273–543 K range. By optimizing the Ta^{5+} concentration, a maximum absolute sensitivity of 0.0058 K^{-1} and a relative sensitivity of 0.0158 K^{-1} were achieved for the specific composition $K_{0.5}Na_{0.5}NbO_3$:0.65Ta^{5+}/0.003Er^{3+}. Notably, increasing Ta^{5+} substitution led to a structural evolution from orthorhombic to tetragonal, and finally to a cubic phase, with the highest thermometric sensitivity observed in the cubic phase region.

This phase transition directly influences the luminescence properties of the ceramics, with remarkable enhancements in sensitivity and clear changes in infrared luminescence around the transition temperature. These findings not only highlight the potential of Ta^{5+}-modified $K_{0.5}Na_{0.5}NbO_3$: Er^{3+} ceramics as a highly sensitive luminescent thermometer but also introduce them as a novel tool for simultaneous temperature sensing and phase transition monitoring. Consequently, this material represents a valuable candidate for applications requiring precise thermal sensing and structural diagnostics, particularly in fields where high sensitivity and the ability to detect phase changes are essential.