Tiny Titans: Exploring The Power of Upconverting Nanoparticles and Copper Complexes in Multifunctional Sensing

Marylyn S. Arai[1], Leandro P. Ravaro[1,2], Gabriel V. Brambilla[1], Lauro J. Q. Maia[3], M. Reza Dousti[2] and Andrea S. S. de Camargo[4,5]

1 São Carlos Institute of Physics, University of São Paulo,13566-590, São Carlos, Brazil
2 Graduate Program on Physics Engineering, Federal Rural University of Pernambuco, 54518-430, Cabo de Santo Agostinho, Brazil
3 Physics Institute, Federal University of Goiás, 74690-900, Goiânia, Brazil
4 Federal Institute for Materials Research and Testing (BAM), 12489 Berlin, Germany
5 Friedrich-Schiller University (FSU), 07743, Jena, Germany
E-mail: marylyn.setsuko@gmail.com

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Multifunctional nanoplatforms integrate diverse material properties to fulfill a wide range of application needs and enable the development of highly customizable systems. These platforms have been extensively investigated, and in this rapidly advancing field, this work introduces a novel multifunctional nanomaterial designed for oxygen sensing, optical thermometry, and emission color tuning, based on the synergy between Tm^{3+}-doped upconverting nanoparticles (Tm-UCNPs) and a Cu(I) complex (CuCom). The Tm^{3+}-doped UCNPs were synthesized using a co-precipitation method, while the Cu(I) complex was prepared via ligand coordination chemistry. Various concentrations of the CuCom complex were electrostatically integrated into a mesoporous silica shell on the surface of the UCNPs (UCNP@mSiO_2), optimizing the system to UCNP@mSiO_2@CuCom-10. The optimal concentration was determined through systematic photophysical and chemical analysis, ensuring maximal performance across all applications. Upon excitation at 980 nm, a portion of the UCNP's UV-blue emission was transferred to CuCom via Luminescent Resonance Energy Transfer (LRET), initiating emission from the molecule in the red region. The residual Tm^{3+} emissions were utilized for optical thermometry, while the CuCom band served as a sensitive oxygen sensor. The optimized nanoplatform achieved a Stern-Volmer constant of 1.64 for oxygen sensing and demonstrated thermometric relative sensitivities of 0.9% and 1% K^{-1} at room temperature, with a linear response ranging from 193 to 373K. Moreover, the emission of UCNP@mSiO_2@CuCom-10 can be readily modulated by varying the excitation and temperature, adding further functionalities to the system. This multifunctional platform holds significant promise for applications in biology, medicine, environmental monitoring, and industry. Compared to existing materials, this nanoplatform offers enhanced sensitivity and versatility due to the unique properties of the Tm3+-doped UCNPs and Cu(I) complex. Specific potential applications include real-time monitoring of cellular oxygen levels in biological research, precise temperature measurement in medical diagnostics, and environmental monitoring of oxygen levels in various settings.

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