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Remote temperature sensing using Eu-doped 3D-printed micropolymers at the tip of an optical fiber

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Temperature sensing using luminescence has become a prominent topic in recent years, particularly following the redefinition of the International System of Units (SI) by the International Committee for Weights and Measures, which assigned each basic unit to a constant of nature. Consequently, numerous studies have demonstrated how the luminescence phenomenon, particularly in rare-earth ions, can be described using a Boltzmann energy distribution model. In this work, we utilized a coordination complex $Eu(tta)_3(H_2O)_2$ to modify a commercial photopolymerizable resin (PPR), integrating Eu^{3+} luminescence into a 3D-printed micropolymeric structure at the tip of a multimode optical fiber to serve as luminescent thermometer in aqueous medium. To develop this material, it was essential to investigate: (1) how to chemically incorporate the complex in the PPR and optimize all printing parameters; and (2) how the printed luminescent structures at the tip of the optical fiber respond to environmental temperature changes. Figure 1(a) presents a SEM image of four different printed structures and their respective responses under UV light illumination. The red emission is assigned to the hypersensitive transition $^5D_0 \rightarrow {}^7F_2$ of Eu^{3+}. Figure 1(b) shows a conical-shaped structure printed at the tip of the optical fiber and 1(c) depicts the temperature dependency on Eu^{3+} lifetime of $^2D_0$ level, with values ranging from approximately 500 to 100 µs. Figure 1(d) shows the repeatable response against heating and cooling of the structure at the tip of the fiber.

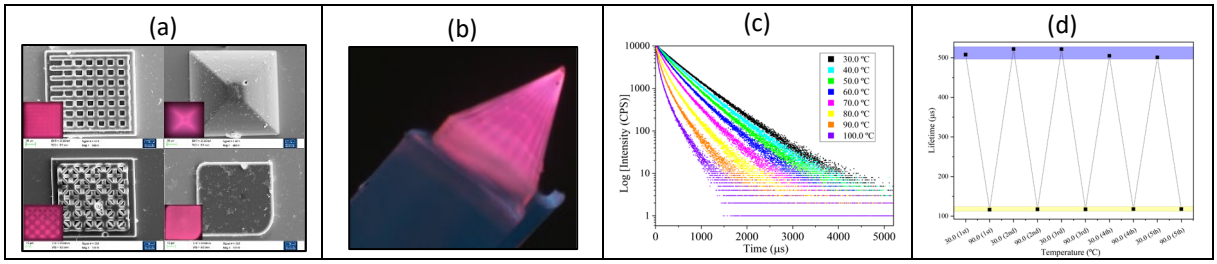

Figure 1 – (a)Different printed shapes; (b)structure at the tip of the optical fiber; (c)lifetime temperature-dependent measurements; and (d)heating/cooling cycle of temperature.

Given that luminescence in this context involves energy transfer from the ligand (tta) and PPR to Eu^{3+}, it is significantly influenced by thermal processes. As observed, the luminescence lifetime decreases with increasing temperature due to the increase of non-radiative rate facilitated by increase of vibrational energy of the system. The results show that the polymer actively participates in the luminescence mechanism, likely due to its strong interaction with the ligand and the ion. The lifetime response as a function of temperature, within the analyzed range (30 °C to 100 °C), exhibits an R^2 of 0.997. The system presented a maximum absolute (S_A) and relative sensitivity (S_R) of 7.03 µs.K^{-1} and 3.4%.K^{-1}, respectively. Furthermore, the repeatability of the measurements in 30 and 90 °C demonstrates a robust response of 0.99 and 0.97, respectively across multiple cycles with minimal error, indicating substantial potential for practical applications.

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