Novel magnetic fluorescent nanofluids obtained by a colloidal approach

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Ferrofluids (FFs) and Carbon Nanodots (CDs) have been gathering worldwide attention due to their broad range of applications as promising solutions to many current global issues. More recently, magneto-photoluminescent colloidal systems have been intensively investigated considering their versatility by unifying these very compelling characteristics in a single adaptive and responsive smart material. However, the approaches for obtaining such materials often involve encapsulation and/or layering, which hinder the colloidal stability of the final product due to the increased size of the nanocomponents. In this study, we propose a solution to this issue by introducing a novel fluorescent magnetic liquid (FML) synthesized by combining aqueous FFs based on core-shell $CoFe_2O_4$@γ-Fe_2O_3 magnetic nanoparticles (MNPs) with fluorescent nitrogen-rich carbon nanodots (N-CDs) in a colloidal approach. We investigate the hybrid nanofluid in acidic (pH $\sim$ 2.5) and neutral (pH $\sim$ 7.0) conditions, allowing us to probe the effects of different interparticle interactions in the colloidal stability, under the light of the speciation diagrams of each component. Notably, in neutral conditions, (in which an additional citrate coating of the MNPs is required) the FML is visually homogeneous, even under field, as shown in the figure where the samples are shown suspended by a magnet under visible and UV light. The observed macroscopic stability was further confirmed at smaller scales by optical microscopy and small-angle X-ray scattering (SAXS). In addition, the magnetic properties of the stable FML were checked in a wide range of temperatures and magnetic fields, in which no significant changes were observed compared to unmixed FFs. Nonetheless, the FML's fluorescence emission was considerably modified by the presence of the MNPs, if compared with N-CDs alone. The reduction of the fluorescence emission was mostly attributed to optical absorption and quenching effects. These results demonstrate that in controlled conditions a stable FML can be achieved by mixing FFs and CDs, while largely preserving the individual properties of each nanocomponent. For this reason, the presented hybrid multifunctional fluid successfully combines highly appealing assets into a single product showing a substantial potential for technological applications.