Synthesis of Silica-Coated YAG Nanocrystals for Applications in Luminescent Nanothermometry

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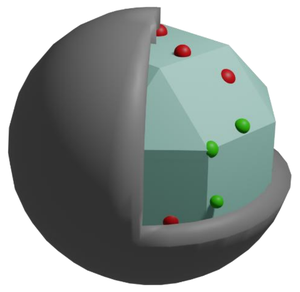


Context

Rare-earth doped Yttrium Aluminum Garnet (YAG), emerges as a highly promising candidate for applications in ratio-metric luminescent nano-thermometry. The solvothermal synthesis method yields individual nanocrystals (<100 nm) suitable for diverse biological applications.[1] However, the photoluminescence is hindered by the presence of organic residues. To combat this limitation, a silica shell, capable of further surface functionalization, is strategically coated onto YAG nanocrystals.[2] This shell allows protected annealing without inducing particle agglomeration, leading to an exceptional 30-fold increase in nanocrystal brightness. These advancements prove YAG nanocrystals to be ideal candidates for precise nanothermometry measurements in various applications. The significant improvement achieved through this protected annealing approach shows its potential for advancing temperature-sensing applications and nanoscale studies.

YAG@SiO_2 Nanocrystals

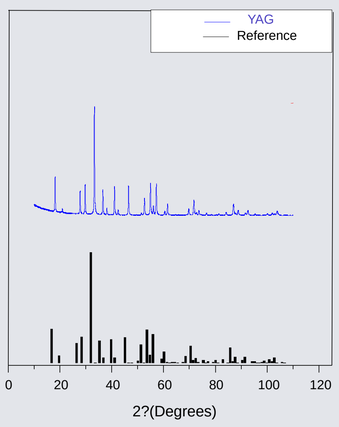
1-YAG:Nd-Yb Synthesis: Solvothermal Method

Mixing of precursors in solvent using a sonicator

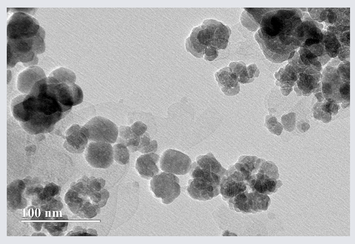
O2 Bubbling

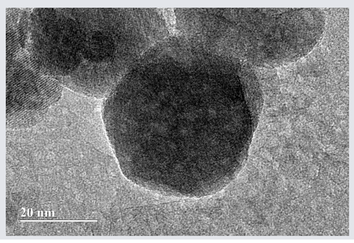
Placing Solution in Autoclave

Pure YAG Phase obtained

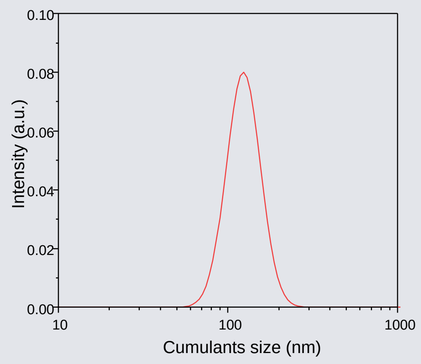


Individual YAG nanocrystals (size≈40nm)



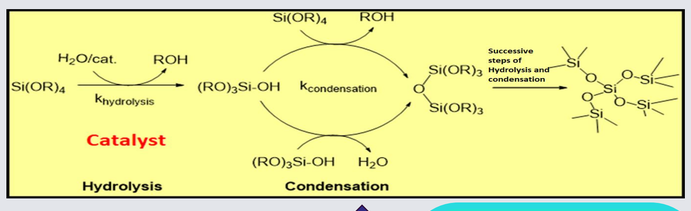


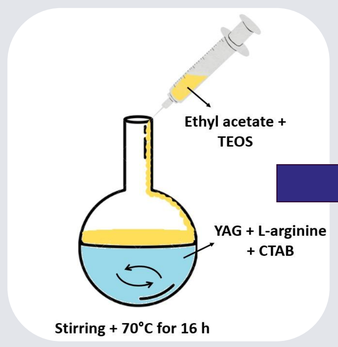
DLS size ≈100 nm



DLS measures state of stability and aggregation of colloidal solutions, not actual particle size.

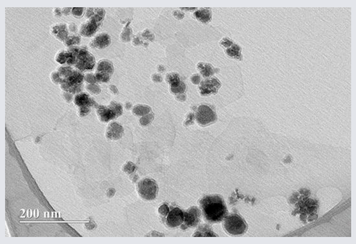
2-Silica shell: Biphasic Method

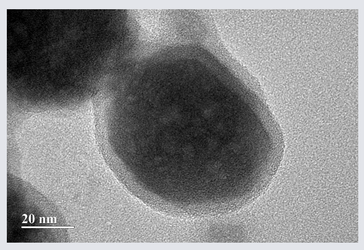




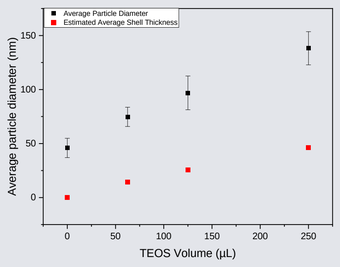
Significance of Biphasic Setup: Agglomeration Prevention in One-Core, One-Shell YAG Nanoparticles through Slow Hydrolysis at the Interface.

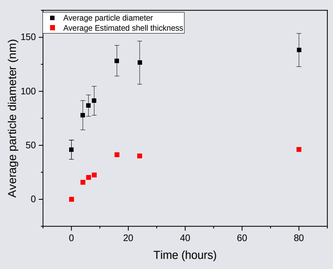
Individually-coated YAG@SiO2 (size≈ 70 nm)



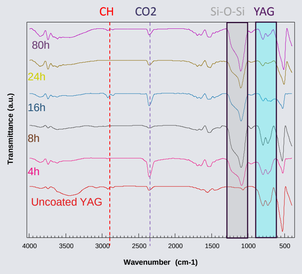


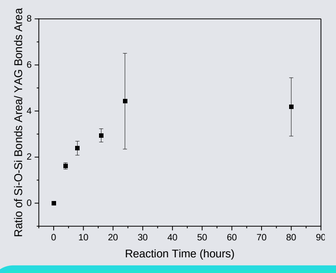
Parameters : Silica precursor amount and time





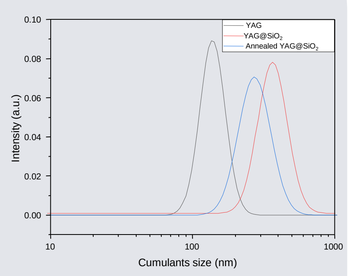
Degree of Condensation of Silica by FT-IR





Adequate condensation at 16h, reaction can be stopped.

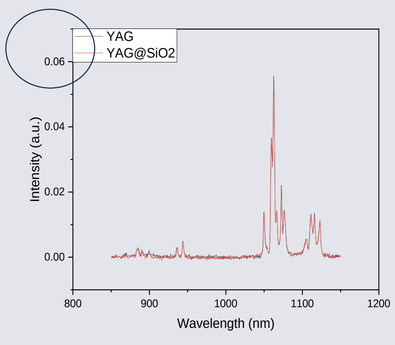
DLS size ≈200 nm

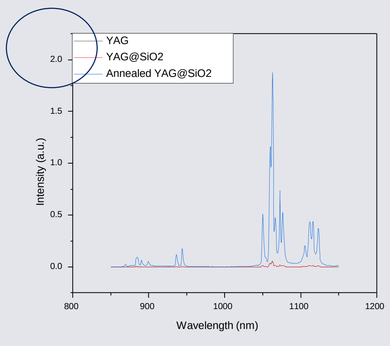


Particles remain dispersible even after annealing, showing little to no agglomeration.

3- PL & Thermometry Measurements:

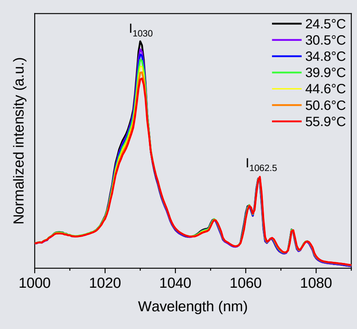
Nd^{3+} emission spectrum/ excitation at 808 nm

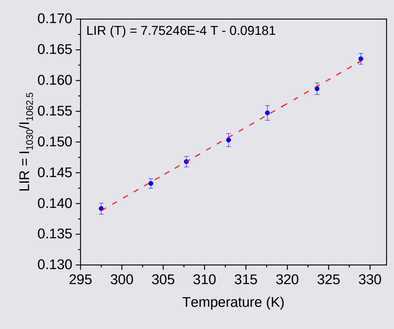




30-fold increase in PL following protected annealing!

First thermometry results:





At 34.8°C
Sr = 0.53%.K^{-1}
δT = 0.16K

$$S_r = \frac{1}{LIR}\frac{dLIR}{dT} \qquad \delta T = \frac{1}{S_r}.\frac{\delta_{LIR}}{LIR}$$

Perspectives

1. Optimize YAG synthesis to get rid of the smallest nano-crystals
2. Further shell surface modification by adding different functional groups.
3. Nanothermometry measurements, both in the solid state and in colloidal suspensions and simulated body fluids

References

1. Dantelle et al. *Physical Chemistry Chemical Physics,* vol. 21. no. 21, 2019, pp. 11132-11141.
2. Cichos and Karbowjak. *J. Mater. Chem. B*, vol 2, no. 05, 2014, pp. 556-568.