On the Synthesis of Onion-Shell Type Multiferroic Nanocrystals

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Background

A Néel temperature of 643 K[1] and a ferroelectric Curie temperature of 1103 K[1] brands Bismuth ferrite $BiFeO_3$ (BFO) to date the only known room temperature multiferroic material. It should be noted that single phase BFO, neither in powder nor single crystalline form, is rare and hard to obtain. Recent studies even discuss phase impurities in BFO as the extrinsic source of the magnetic properties of BFO[2,3]. Both properties can be used to allow imaging in medical applications. Unfortunately, the antiferromagnetic component is not strong enough for its use as a contrast agent in magnetic resonance imaging. In order to enable a multimodal imaging process, this study shows the construction of an onion-shell around the core particle to boost its magnetization.

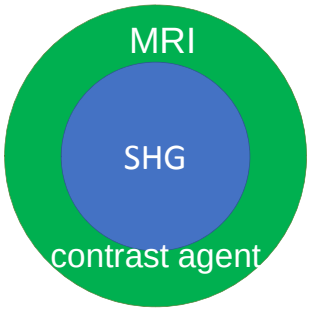
Multiferroic material

- Intrinsic ferroelectric and ferromagnetic
- One step synthesis
- Only one multiferroic material (BFO) at room temperature is known
- Week magnetization
- Extrinsic impurities to boost magnetization necessary

SHG + MRI contrast agent

Multiferroic particle

- Required properties can be build up
- Suitable ferroelectric and ferromagnetic material can be choosen
- Coating step is necessary
- Closed shell is hard to obtained
- Absorption of the shell material

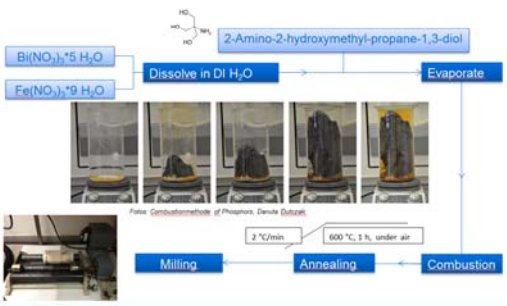


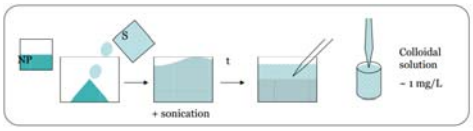
Synthesis

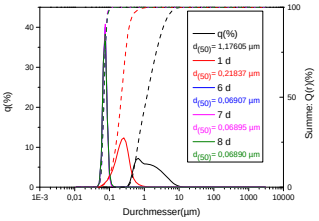
Nanocrystal synthesis
- Combustion synthesis [4]
- Hydrothermal

→ **Purification**
- Sedimentation

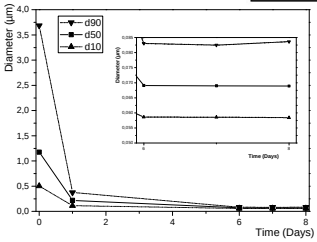
→ **Coating**
- Sol-Gel process

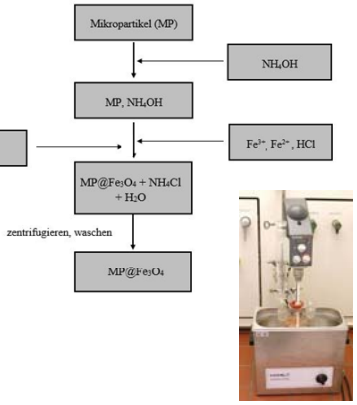






Particle size distribution over time for a typical sedimentation series





Conclusions

The resulting multiferroic nanocrystals were characterized by standard techniques (x-ray diffraction, dynamic light scattering, scanning electron microscopy and hyper-Rayleigh scattering[5]). The SHG signal measured by the Hyper Rayleigh scattering is still existing in spite of the iron oxide shell.

[1] Kumar, A.; Rai, R. C.; Podraza, N. J.; et. al.: "*Linear and nonlinear optical properties of $BiFeO_3$*", Appl. Phys. Lett. **92** (2008) 121915

[2] Guo, R.; Fang, L.; Dong, W.; et. al.: *"Magnetically separable $BiFeO_3$ nanoparticles with a γ-Fe_2O_3 parasitic phase: controlled fabrication and enhanced visible-light photocatalytic activity"*, J. Mater. Chem. **21** (2011) 18645

[3] Mazumder, R.; Sujatha Devi, P.; Bhattacharya, D.; et. al: "*Ferromagnetism in nanoscale $BiFeO_3$*", Appl. Phys. Lett. **91** (2007) 062510

[4] Schwung, S.; Rytz. D.; Jüstel, T.; et. al.: "*$BiFeO_3$ nanocrystals for bio-imaging based on nonlinear optical harmonic generation*" in press 2014

[5] C. Joulaud, PhD Thesis, Université de Savoie (Annecy, France, 2013)

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