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50. Internationales Wissenschaftliches Kolloquium
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Y. Ludwig / W. Ertel-Ingrisch / K. Hartmann / P. Weih

Crystallization Inside High Magnetic DC Fields: Experiments regarding BHF as a model material between 0 and 5 T, and 800 to 1400 °C

ABSTRACT

Crystallization of Barium-hexaferrite (BHF) powders were investigated both in and outside of magnetic field. Variables under investigation were chemical composition, temperature, time, and magnetic flux density (1 to 5 T) while performing a systematic investigation altering only one variable at a time while keeping the other two constant. Powders synthesized without magnetic field function as reference material.
In general, hexagonal shaped BHF powders crystallized inside magnetic fields ranging from 1 to 5 T, at 800 to 900 °C and for 2 hours, exhibit an increased thickness of the single-domain BHF crystals (c-axis) with increasing magnetic flux density, while the diameter of the crystals (a, b-axis) increases only marginally.
Maximum determined coercivity in the obtained powders is 377 kA/m, and independent of applied magnetic field during crystallization. However, higher coercivities can be obtained at already lower temperature conditions in comparison to the reference material which is economically advantageous. Remanence of obtained powders are up to 10 % higher than observed in reference material.

Crystallization inside Strong Magnetic DC Fields using BHF as Model Substance

Ba-Hexaferrite (BHF: $BaFe_{12}O_{19}$) powder is a hard magnetic material of wide technical application, widely used in the production of industrial permanent magnets. Technically produced BHF powder, however, does barely reach 60 to 70 % of its theoretically possible maximum magnetic potential. For High-End applications, very homogeneous sub-micron single domain BHF powder is required. Starting compositions in the ternary system $BaO\text{-}Fe_2O_3\text{-}B_2O_3$ with more than 20 mole-% Fe_2O_3 tend, however, to crystallize spontaneously into numerous phases of vastly varying magnetic properties. One method to synthesize BHF nanocrystalline powder with satisfying magnetic properties is the glass crystallization technology [GCT: 1 to 4]. The GCT starts from melts prepared from oxide components in the $BaO\text{-}Fe_2O_3\text{-}B_2O_3$ ternary system, consisting of two separate melting processes at 1400 °C with a rapid quench after the second fusion resulting in glassy flake as intermediate run product. These amorphous flakes are starting material for all subsequent investigations.

Obtained glass flakes of a variety of chemical starting compositions are processed in subsequent systematic tempering experiments crystallizing homogeneous, nm-size BHF powders within the Ba-borate matrix. Parameters investigated are chemical starting composition of oxide components,

tempering temperature and duration, and magnetic field strength (between 0 to 5 T). Intermediate glass flakes and final BHF powders are analyzed and characterized using a wide range of analytical technologies (EMPA, DTA, XRD, optical microscopy, REM, TEM, VSM), and compared to the 0 T reference material.

The rationale behind these experiments is the common knowledge that macroscopic magnetic properties of any material are controlled by the size and magnitude of formed single magnetic domains, their number, orientation and other crystallographic and magnetic prerequisites of crystals. Additionally, the relative orientation of formed crystals towards eachother in the solidified structure plays an additional, major role determining the bulk magnetic properties of materials.

Little is known about crystallization processes inside strong magnetic DC fields and its influence on the processes during crystallization. Therefore, systematic experiments in a cryogen-free magnet (CFM) equipped with a high-temperature oven to control precisely the process and crystallization parameters like temperature (800 to 1400 °C), run duration (2 to 75 hours), and magnetic flux density (0 to 5 T) were performed to investigate the basic scientific question how strong magnetic fields can alter crystallization processes. Of special interest is the complex question whether and how magnetic fields can help control and improve the single domain crystal structure by influencing nucleation, domain and crystal growth, transport properties like ionic diffusion, growth and orientation of growing domains towards eachother, and, of course, magnetic bulk properties of obtained BHF powders. Understanding the fundamental processes governing the crystallization of magnetic material should, in return, help us to control and improve its crystallographic properties and its magnetic potential especially in respect to industrial application.

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Dipl.-Ing. Yvonne Ludwig, Dr. Werner Ertel-Ingrisch, Dr. Karsten Hartmann, Dipl. Ing. PetiaWeih
Junior Reseach Group: Electromagnetic Processing of Materials, TU Ilmenau, 98684 Ilmenau
0049-(0)3677-691510
0049-(0)3677-691552
E-mail: Yvonne.Ludwig@TU-Ilmenau.de