Barium Hexaferrite Thick Films for Microwave Absorbers and Circulators

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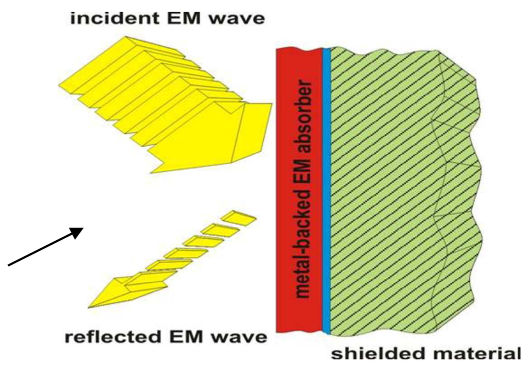
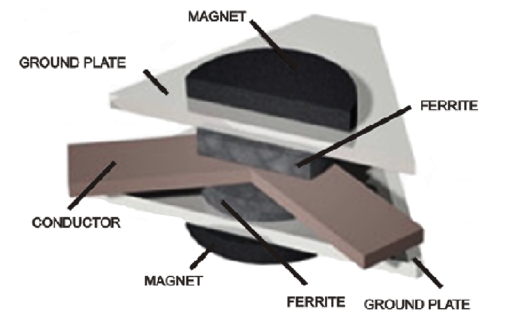
Introduction

1. Barium hexaferrite (BaHF) is a hard magnetic material with chemical formula $BaFe_{12}O_{19}$.
2. BaHF has high magnetic anisotropy field (17 kOe) and an easy direction of magnetization along (00l) crystallographic axis.
3. Dispersed BaHF hard magnetic particles in suspension can be oriented with a gravity field or an external magnetic field.
4. Electrophoretic deposition (EPD) is a process where charged particles from suspension are transported to the conductive substrate, where they agglomerate and deposit.

Application

1. BaHF has high a magneto anisotropy field and can be used as a **permanent magnet**.
2. Thick films of BaHF can be used for **absorbers at high-frequency** (above 40 GHz).
3. Oriented films of BaHF can be used for **millimetre-wave non-reciprocal device**, i.e. circulators, isolators or gyrators.

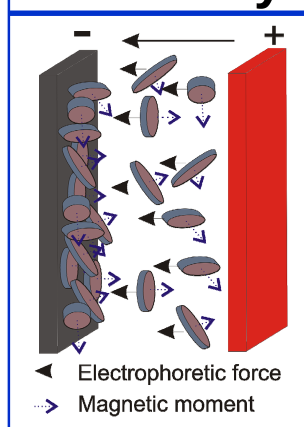
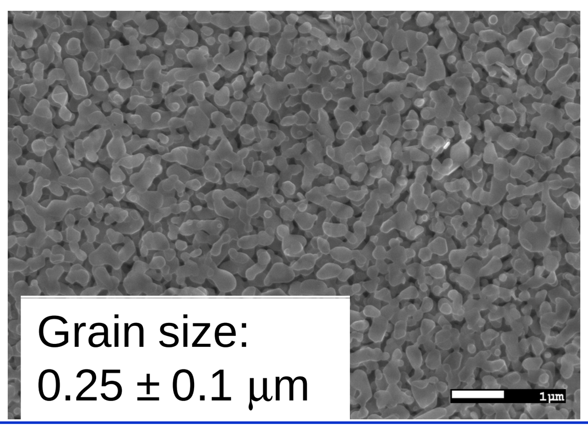
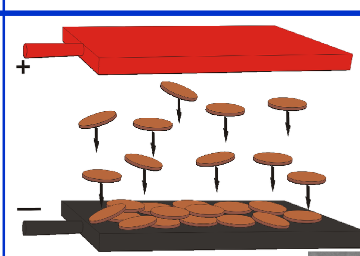
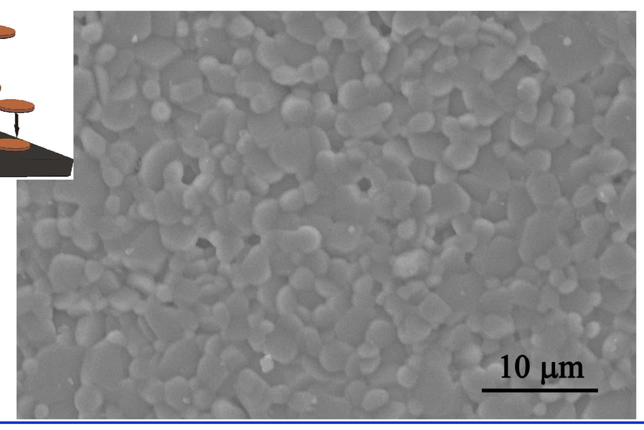
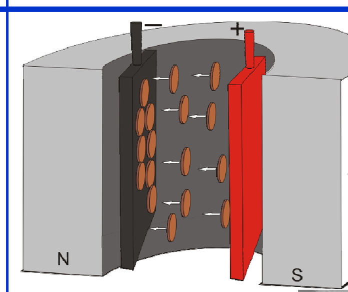
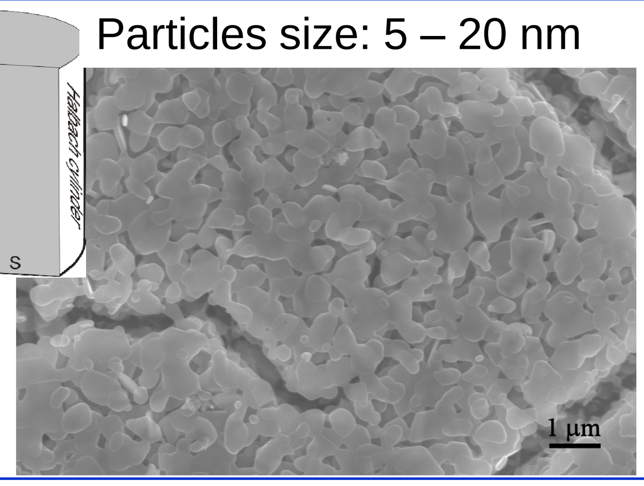
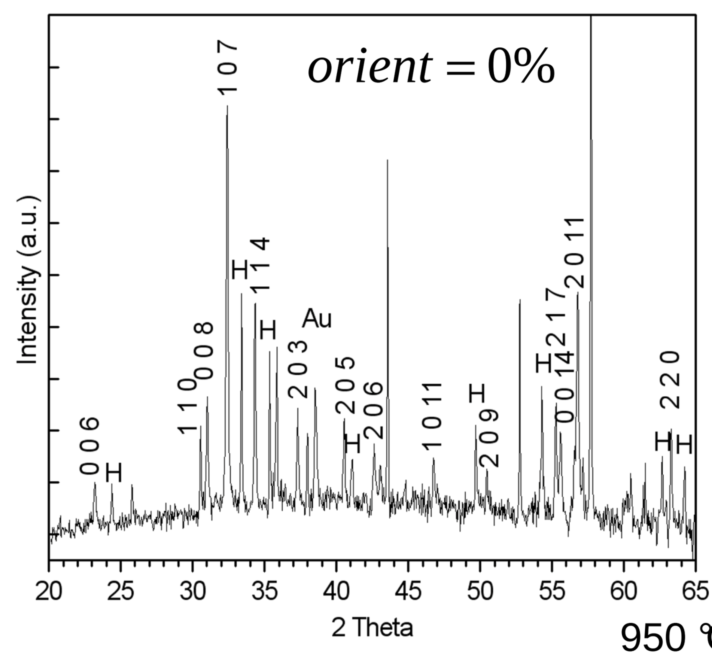
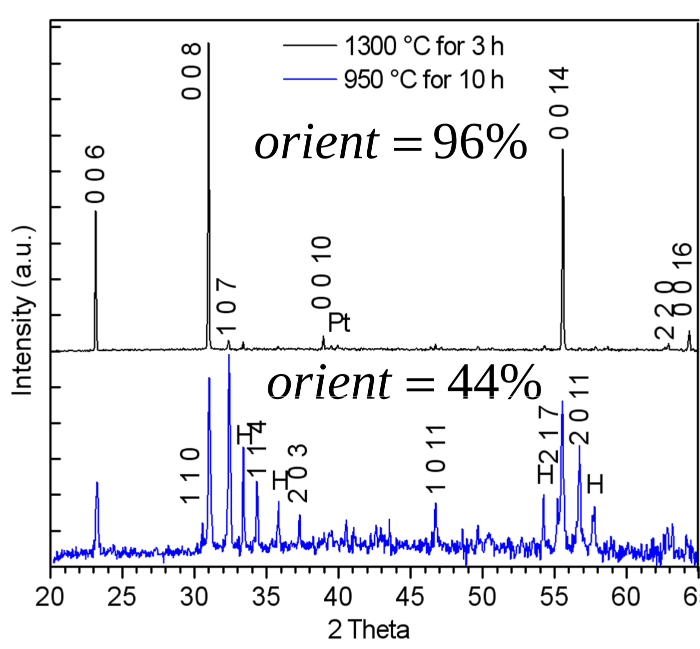
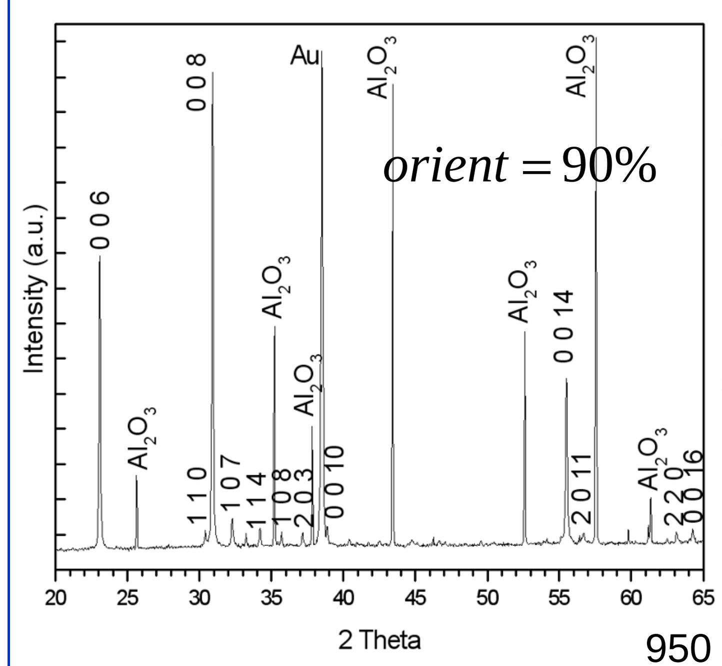
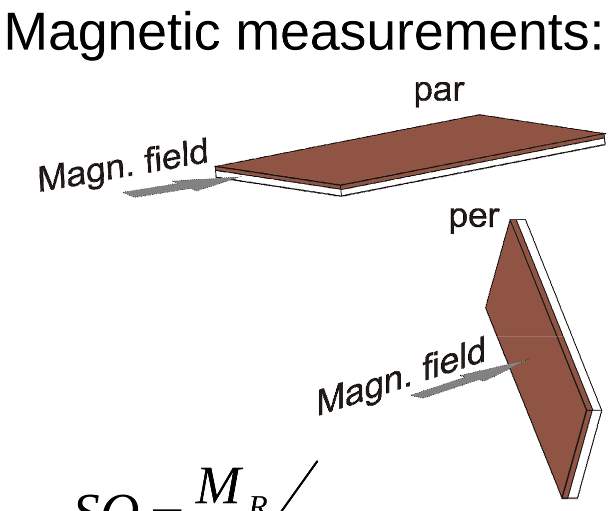
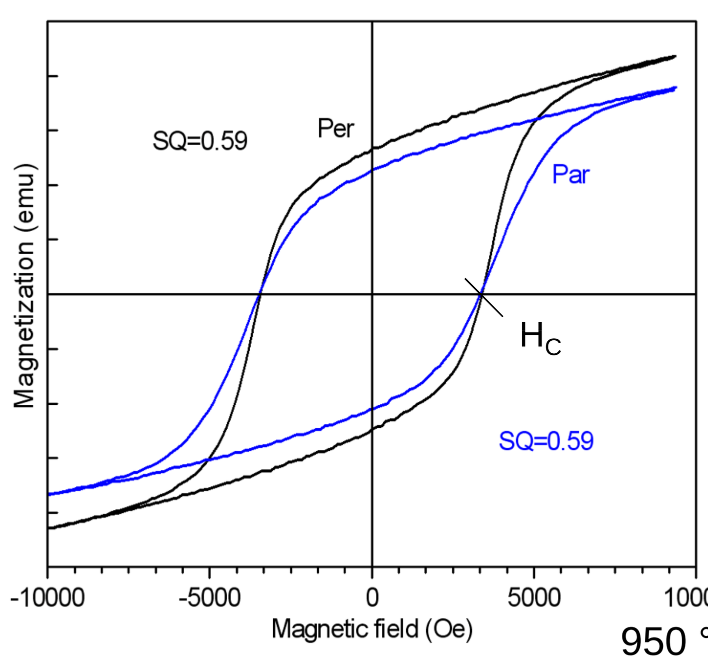
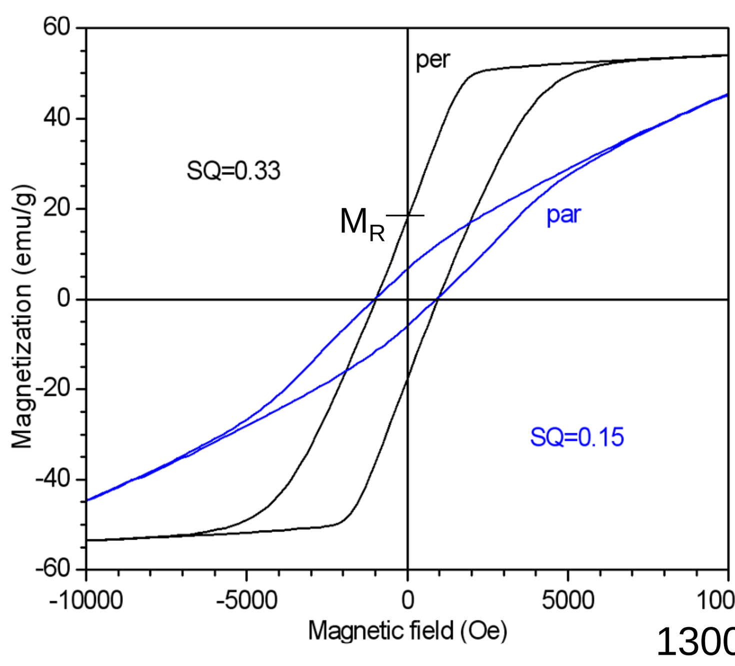
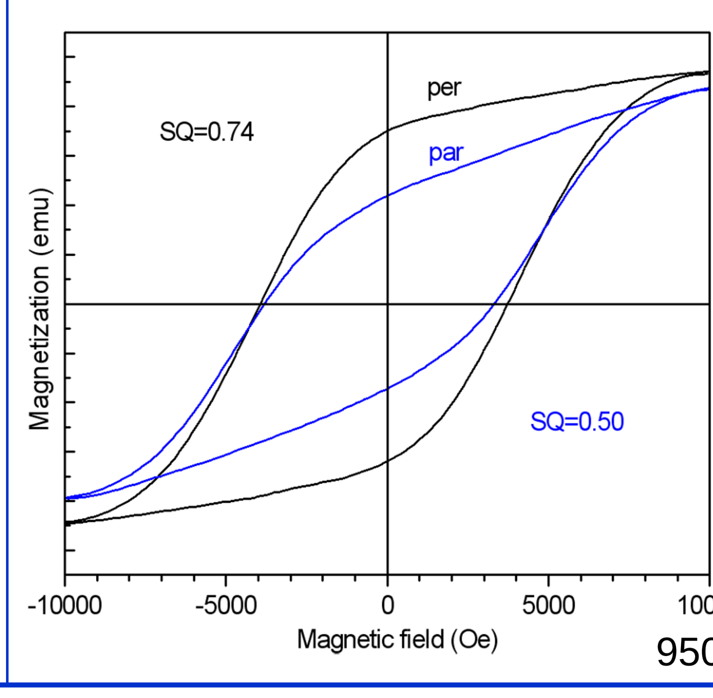
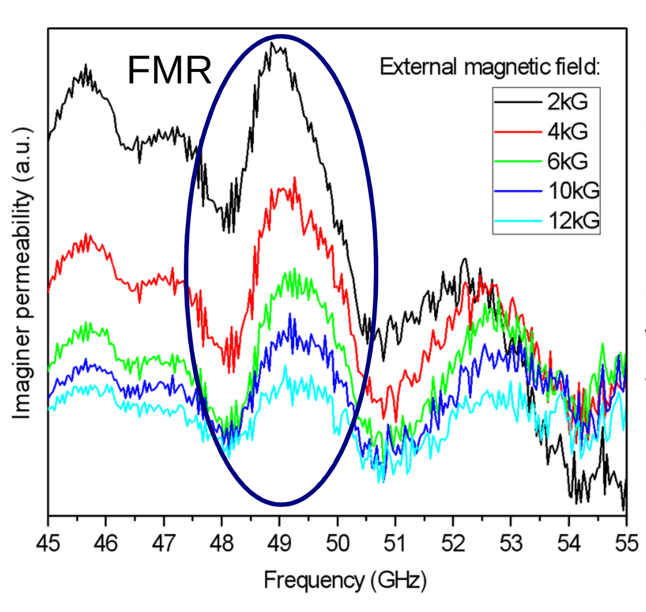




Experimental

1. Stabile magnetic suspensions from 5–20 nm and 10-250 nm BaHF plates were prepared with dodecylbenzensulphonic acid in 1-butanol.
2. Different positions of electrodes and external magnetic field were used.
3. Electric field 71 V/cm and deposition time 15 min
4. The films were prepared by sintering at 950 ℃ fo r 10 h or 1300 for 3 h.

Results

Orientation of particles / Figure of EPD / SEM image / Film properties	Randomly oriented	Oriented with gravity field	Oriented with magnetic field
	 Particles size: 5 – 20 nm  Grain size: 0.25 ± 0.1 μm 950 ℃ for 10h	 Particles size: 10 – 250 nm  Grain size: 1.6 ± 0.6 μm 1300 ℃ for 3h	 Particles size: 5 – 20 nm  Grain size: 0.5 ± 0.2 μm 950 ℃ for 10h
Thickness:	13 μm	15 μm	2 μm
XRD pattern: $orient = \frac{\frac{\sum I_{00l}}{\sum I_{hkl}} - \frac{\sum I^o_{00l}}{\sum I^o_{hkl}}}{1-\frac{\sum I^o_{00l}}{\sum I^o_{hkl}}}$	 H – hematite Non-identified peaks – Al_2O_3 950 ℃ for 10h	 Orientation increases with sintering temperature	 Particles coated with Bi-phase. ↓ Enhanced sintering process 950 ℃ for 10h
Magnetic measurements:  $SQ = M_R / M_S$ Ideal oriented film SQ_{per}=1	 0% of orientation par = per 950 °C for 10h	 ← M_S Multi domain grains - Low H_C - Low M_R 1300 °C for 3h	 Single domain grains - High H_C - High M_R Poor total orientation 950 °C for 10h
Microwave measurements: The ferromagnetic resonance (FMR) = Shift of imaginary permeability maximum to a higher frequency by increased external magnetic field Natural ferromagnetic resonance (0 Oe) = 48 Gz	 orient = 16% Partly oriented film with thickness of 5 μm		

Conclusion

1. Higher density of oriented films, due to anisotropic grain growth.
2. The intensities of (00l) peaks in oriented films were enlarged.
3. For oriented films the magnetic properties were different with measuring them parallel than perpendicular to the film plane.
4. The natural FMR for partly oriented film appears at 48GHz, which makes this material interesting for microwave applications.

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Reference: 1. S.Ovtar, D. Lisjak, M. Drofenik, J. Colloid Interface Sci., **2009** (337), 456
2. S. Ovtar, D. Lisjak, M. Drofenik, Surf. Interface Anal., in press