# Barium hexaferrite thick films prepared by electrophoretic deposition

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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. Individually dispersed BaHF hard magnetic particles in suspension can be oriented with 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.

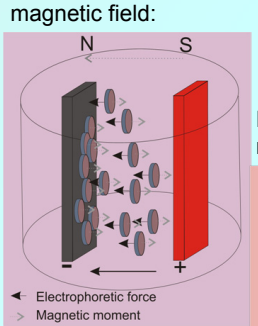
## Application

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.

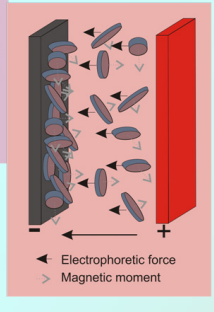
## Experimental

1. Stabile magnetic suspension from 5–20 nm BaHF was prepared with dodecylbenzensulphonic acid in 1-butanol.
2. Stabile magnetic suspension was deposited by EPD with and without external magnetic field.
3. For the cathode (substrate) $Al_2O_3$ coated with Au was used and for the anode an Al plate was used.
4. The electric and the magnetic fields were parallel to each other and perpendicular to the substrate. The thickness of deposits was few a micrometers.
5. The films were prepared by sintering at 1000 °C for 10 h.
6. The orientation of films was obtained from XRD pattern and magnetic measurements.

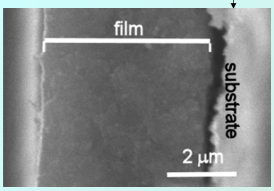
EPD with external magnetic field:




EPD without external magnetic field:



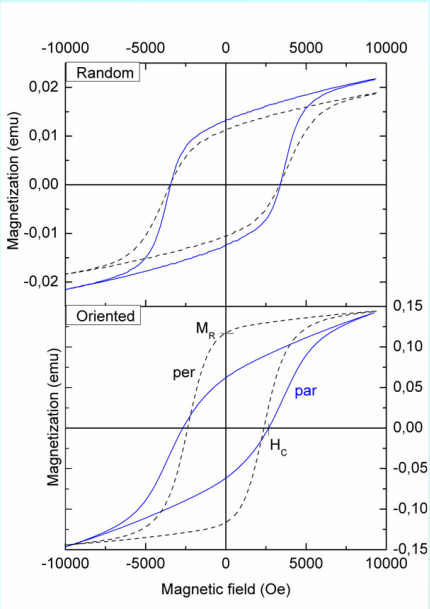

Magnetic moment of particles are along easy direction of magnetization.




SEM image of deposit thickness

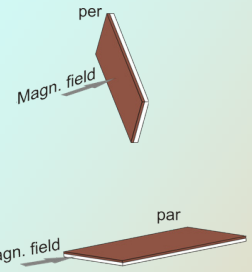
## Results

Magnetic measurements:

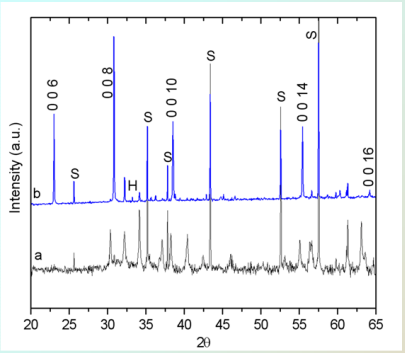



Magnetic hysteresis loop of randomly oriented and oriented BaHF film.

Position of magnetic field and film plane during measurements:




XRD pattern:




a) Randomly oriented

b) Magnetically oriented BaHF film

S – substrate ($Al_2O_3$)

H – hematite (present also in raw powder)

Magnetic orientation of deposits = $\dfrac{\dfrac{\sum I_{00l}}{\sum I_{hkl}} - \dfrac{\sum I^o_{00l}}{\sum I^o_{hkl}}}{1 - \dfrac{\sum I^o_{00l}}{\sum I^o_{hkl}}}$,

where $I_{00l}$ and $I_{hkl}$ are peaks intensities of sample and $I^o_{00l}$ and $I^o_{hkl}$ are peaks intensities of raw powder.

Orientation calculated from above XRD pattern is 82 %.

## Conclusion

1. During EPD in external magnetic field the magnetically oriented deposits were produced.
2. Magnetic properties were different with measuring magnetic properties parallel than perpendicular to the film plane for oriented film.
3. The intensities of (00l) peaks in oriented film were enlarged.