Barium Hexaferrite Thick Films Prepared by Electrophoretic Deposition

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Barium hexaferrite (BaHF) with a chemical formula $BaFe_{12}O_{19}$ is a hard magnetic material and has high magnetic anisotropy field, 17 kOe. The easy direction of magnetization corresponds to the crystallographic c-axis and BaHF particles orient in this direction when an external magnetic field is present. Because of the high magnetic anisotropy field a ferromagnetic resonant frequency appears from 45 to 50 GHz. For these reasons BaHF can be used for permanent magnets, electromagnetic absorbers (above 40 GHz) or for millimetre-wave non-reciprocal devices (i.e., circulators, isolators, or gyrators). Today, most of hexaferrites for microwave and millimetre-wave electronic components are prepared using ceramic technologies. Because of the technology trend to minimize the electronic component new techniques for thin and thick films were developed. One of the simplest and cheapest techniques is electrophoretic deposition (EPD). In EPD process the individually dispersed particles are transported to the electrode of opposite charge. At the electrode particles agglomerate and the deposit is formed. In case where the external magnetic field is applied during EPD the particles with magnetic anisotropy orient and magnetically oriented deposits are produced.

The individually dispersed particles are one of the most important conditions for the preparation of homogeneous and dense deposits. The stabile magnetic suspension of BaHF with particles size from 5 to 20 nm was prepared with surfactant dodecylbenzensuphonic acid in 1-butanol. The suspension was deposited on the cathode (Al_2O_3 coated with gold) by EPD with and without external magnetic field. The electric and the magnetic fields were parallel to each other and perpendicular to the cathode. The EPD was made at different electric fields with the magnetic field fixed to 0.6 T. After that, deposits were dried and sintered at 1000 °C for 10 hours. The magnetic measurements were obtained with the vibration-sample magnetometer (VSM) and the orientation was calculated from the XRD pattern.

Significant differences in magnetic properties were obtained for randomly oriented and magnetically oriented films. In case of magnetically oriented films the magnetic properties were different, when the magnetic field was applied parallel or perpendicular to the film plane. The remanent magnetization was higher when magnetic field was applied perpendicular to the film plane, because most of the particles had their magnetic moments already oriented in the field direction and, at the same time, a higher magnetic field was needed to reverse the magnetic moments in the opposite direction than in the case of parallel applied magnetic field. The orientation of particles in deposit was also observed from the XRD pattern. The intensities of (00l) peaks were enlarged in the oriented film, because the easy direction of magnetization coincides with the crystallographic c-axis.

We can conclude that, the oriented deposits of hard magnetic BaHF can be formed with the application of magnetic field applied during the EPD.