Study on Pulsed Electron Deposition as an effective method for thin films growth of room temperature multiferroic $BaFe_2O_4$

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Multiferroics are materials showing the coexistence of two or more primary ferroic orderings. The exploitation of components with coexisting electric and magnetic domains has led to significant advances in various innovative fields. However, to date very few single-phase materials are known being characterized by stable electric and magnetic states at room temperature. γ-$BaFe_2O_4$, a non-centrosymmetric stuffed tridymite-type compound (space group *Cmc21*), is an interesting example of a previously unrecognized single-phase multiferroic material with high ordering temperatures [1]. Thanks to the synergic use of single-crystal X-ray and powder neutron diffraction, we found out that this barium ferrite is an antiferromagnetic improper ferroelectric (G-type spin ordering and *PCca21* magnetic space group). Conversely, macroscopical magnetic measurements performed by SQUID vibrating sample magnetometry highlighted the presence of weak ferromagnetism, being apparently at odds with the more phase-sensitive neutron powder diffraction analysis.

In order to get a more ideal sample both in terms of purity degree and suitability for devices fabrication, a thin film growth method was attempted by Pulsed Electron Deposition (PED). The γ-$BaFe_2O_4$ films were grown on various substrates in the temperature range 700-850° C. Powder X-ray diffraction (XRD) patterns, combined with Raman spectroscopy and energy dispersive X-ray analysis, allowed to identify the formation of the target phase over all the tested substrates, without significant amounts of impurities. The additional magnetic measurements collected for a micrometric film showed the absence of saturation magnetization and coercive field, thus excluding any ferromagnetic component, this time in agreement with the structural characterization. Moreover, partial control of the crystalline orientation was achieved through the proper choice of the substrate, growth temperature and deposition parameters, as confirmed by texture coefficients determined from XRD data and pole figures measurements. The relevance of this step is related to the strong anisotropy of the polar *mm2* point group, so that the device applicability strongly depends on the orientation of crystals with respect to the substrate surface. In conclusion, the present results suggest that PED is a promising technique for producing high-purity barium ferrite films compatible with key materials in the electronic device industry.

References

[1] Orlandi, F. et al. γ-BaFe2O4: a fresh playground for room temperature multiferroicity. Nat Commun 2022; 13: 7968