The magnetic properties for europium doped BiFeO$_3$

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The crystallographic and magnetic properties of europium doped Bi$_{0.9}$Eu$_{0.1}$FeO$_3$ prepared by a sol-gel method have been studied by x-ray diffraction, superconducting quantum interference device (SQUID) magnetometer, and Mössbauer spectroscopy. X-ray diffraction pattern for Bi$_{0.9}$Eu$_{0.1}$FeO$_3$ was analyzed by the Rietveld refinement using FULLPROF computer program, which fitted well with Bragg factor $R_B = 3.44$ and $R_F = 2.12$. The crystals were determined to be a rhombohedrally distorted perovskite-like structure with a space group of $R3c [1-3]$. The lattice parameters of Bi$_{1-x}$Eu$_x$FeO$_3$ ($x = 0.0, 0.1$) were $a_0 = 5.581$, $c_0 = 13.876$ Å [4] and $a_0 = 5.570$, $c_0 = 13.810$ Å, respectively, according to the ionic radius of Bi$^{3+} = 1.170$ Å and Eu$^{3+} = 1.087$ Å. SQUID measurements showed the antiferromagnetic behavior with Néel temperature ($T_N$) of 640 K. Mössbauer spectra of the sample have been obtained from 4.2 K to $T_N$. Mössbauer spectrum at 4.2 K shows six-line 1-sextet having the hyperfine field ($H_f$) values of 546 kOe. A least-squares fitting program was used to determine the Mössbauer parameters by assuming Lorentzian line shapes. The valence state of Fe ion is Fe$^{3+}$ relative to the Fe metal, according to the isomer shift ($\delta$) value = 0.39 mm/s at 4.2 K. In determining the interatomic binding force in Bi$_{0.9}$Eu$_{0.1}$FeO$_3$, the Debye temperature was calculated from the temperature dependence of the resonant absorption area and was 486 K. Also, the spin state ($S$) was 5/2, from the molecular field model using the Brillouin function.