DyFeO$_3$ is an interesting multiferroic material. Multiferroic materials exhibit magnetic, ferroelectric and ferroelastic behaviour simultaneously. A giant magnetoelectric effect has also been reported on DyFeO$_3$ [1]. However, there is very little work reported on the magnetic properties of DyFeO$_3$. In addition, the physical and chemical properties of DyFeO$_3$ are thought to be interesting to investigate, as they would then be employed for any possible nanodevices. With this in mind, some of us studied magnetic properties of DyFeO$_3$ nanoparticles [2]. It was found that hydrothermally synthesized DyFeO$_3$ (DFO) nanoparticles (size $\sim 50-60$ nm) not only exhibit huge temperature dependent exchange bias but also a coercivity as large as $\sim 580$ Oe at $\sim 70$ K (see Fig. 1). This was explained in terms of temperature dependent spin orientation and interactions between Fe$^{3+}$-Fe$^{3+}$, Fe$^{3+}$-Dy$^{3+}$ and Dy$^{3+}$-Dy$^{3+}$. The valence states Fe$^{3+}$ and Dy$^{3+}$ are expected in DyFeO$_3$ structure and inferred from photoelectron spectroscopy using Al K$\alpha$ (1486.6 eV), low resolution ($\sim 0.9$ eV) laboratory source.

![Graph](image1.png)

**Fig. 1:** Coercivity and exchange bias in dysprosium ferrite nanoparticles as a function of temperature.

Exchange bias, a phenomenon in which a hysteresis loop in the magnetization versus applied magnetic field shifts (i.e. does not appear symmetric around the origin) along the field axis, has been observed in many nanostructures (Fig. 1 and its reference). The exchange bias has been attributed to the antiferromagnetic and ferromagnetic interface in thin films as well as in nanoparticles. Origin of ferromagnetism in otherwise antiferromagnetic materials (core) can be explained by the existence of ferromagnetic shell which may form due to canting of the spins or strain in the surface region. It is also suggested that the chemical state of the core and shell may change giving rise to variation in the magnetic order in the core and shell. In our previous experiment on bismuth ferrite nanoparticles we had obtained metallic bismuth, not seen with soft X-ray photoemission, using HXPES on the P09 beamline, at the interface of antiferromagnetic core and ferromagnetic shell of bismuth ferrite.
Therefore, we performed HXPES experiments at HXPES facility on the P09 beamline at PETRA III (DESY, Hamburg). The powder sample of well-characterized DFO nanoparticles was dispersed on the sample holder using silver paste. The photon energy was varied between 3.5 keV to 7.5 keV. The data was recorded at normal photoemission geometry with photon incidence angle at 5° to the surface of sample. The spectra obtained on DFO nanoparticles depicting Dy 3d\textsubscript{7/2} and Dy 3d\textsubscript{5/2} are shown in Fig. 2.

![HXPES spectra of DFO nanoparticles](image)

**Fig. 2**: HXPES spectra of DFO in Dy 3d\textsubscript{5/2} - Dy 3d\textsubscript{3/2} range.

Similarly, HXPES spectra for SmCrO\textsubscript{3} nanoparticles also were recorded.

**References**