Ferrite nanopartcles in borate glass matrix: first direct observation and correlation between particles characteristics and glass magnetic properties

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Direct high resolution transmission electron microscopy (HRTEM) observation of nanometer-sized magnetic particles dispersed in oxide glass matrix has been carried out for the first time. Particles formed during the process of additional thermal treatment in glasses of the basic composition Al_2O_3-K_2O-B_2O_3 doped with Fe_2O_3 and MnO in total concentration not higher than 5.0 mass. %. Thanks to the presence of the particles and low paramagnetic elements concentration glasses acquired unique property to be simultaneously magneto-ordered and keep optical transparency in the infrared and visible region. Additional information on the particle characteristics was obtained with X-ray diffraction (XRD) and differential dissolution (DD) phase analysis as well as with the Mössbauer, optical and magneto-optical spectroscopy, and magnetic measurements. It was shown that ferrite particles varied grossly size, shape, stoichiometry, structural perfection and space distribution in dependence on preparation conditions. The HRTEM images changed from well shaped isolated particles relatively uniform in size and quite evenly distributed in the matrix in some cases to a weak contrast aggregated particles showing no diffraction spots or polydisperse features in a lower contrast matrix in other cases. According to XRD, DD, and HRTEM data, the structure and composition of particles were typical for the manganese ferrite, at least, in the first case.

The Mössbauer study confirmed that the particles possess the magnetic order, and this order was close to that of the bulk manganese ferrite. Additionally, it was shown that the magnetic state like superparamagnetic or blocked was correlated with the ferrite particle size. A high magnetic susceptibility, magnetic saturation in low magnetic field, and magnetic hysteresis characterized the field dependencies of the magnetic moment of all glasses. The factors are discussed responsible for the lower particles magnetic moment comparatively with the bulk manganese ferrite single crystal.

For all glasses the decrease of the Faraday rotation (FR) value with an increase of the light wave λ was observed. The decrease went with practically equal rate for all glasses that was evidence of the same origin of transitions responsible for FR. The fairly large FR at $\lambda = 1.5$ μm was reached.

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