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Masaru Matsuo
Dalian University of Technology, China

Dielectric properties of the composites containing superparamagnetism particles

Superparamagnetism particles have been applied to magnetic fluids, microwave absorption materials, drug delivery systems and pigments. The high magnetization under external applied magnetic field could be obtained by using Zn-doped Fe_3O_4 nanoparticles. By the replacement of Fe^{3+} ions by Zn^{2+} ions in A-site of Fe_3O_4 crystal unit with inverse-spinel ferrite, the super-exchange interaction between spins of Fe^{3+} existing in A-site and B-site becomes weakened, while the double-exchange interaction between Fe^{3+} and Fe^{2+} in B-site remains. This indicates that the magnetization increases with Zn doping. Different from the general concept, however, the highest magnitude was x=0.2 when Zn-doped Fe_3O_4 is represented as $Zn_xFe_{3-x}O_4$ ($0 \leq x \leq 1$). To investigate such contradiction, the crystallinity and crystal size of Fe3O4 by the doping were evaluated using X-ray and dielectric measurements. The crystallinity and crystal size decreased with increasing x up to 0.4 but they increased beyond 0.5 inversely. This indicated that Fe_3O_4 crystal cannot accept further doping by Zn^{2+} to maintain $ZnxFe_{3-x}O_4$ crystal. This is since Zn doping resulted in the damage of the Fe_3O_4 crystal, since the atomic size (74 pm) of Zn^{2+} is bigger than that of Fe^{3+} (64 pm). As for Mg doping represented as $MgxFe_{3-x}O_4$, Fe_3O_4 crystal accepted Mg^{2+} up to x=1 because of similar size of Mg^{2+} (65 pm). In this case, Fe^{3+} ion in A-site becomes zero and crystal structure of Fe_3O_4 crystal was collapsed. The crystallinity and crystal size were sensitive to their dielectric properties. The complex impedance for $Mg_{0.6}Fe_{2.4}O_4$ and $MgFe_2O_4$ with no crystal domain can be represented by Kramers-Kronig relation which has been utilized for amorphous materials, while that for Fe_3O_4 and $Zn_{0.2}Fe_{2.8}O_4$ can be represented by the equivalent circuit model with three units relating to suppressed circle by Cole-Cole plots. The three units correspond to particle (grain) resistance, grain boundary resistance and interface resistance between electrode and grains indicating the existence of crystal particles. The dielectric behaviors of superparamagnetism particles were in good agreement with X-ray diffraction profiles. The DC component of conductivity (frequency→0) was highest for $Zn_{0.2}Fe_{2.8}O_4$ with the highest magnetization.

Biography

Masaru Matsuo has completed his PhD at Kyoto University in Japan and he was a Professor of Nara Women's University. After his retirement, he became a full time Professor of Dalian University of Technology in China. Since 2014, he is a Visiting Professor of Dalian University of Technology. He has published more than 200 papers in refereed journal articles. He is IUPAC Fellow and Certificate of Membership Award of ACS (2015-2018). He has received Award of Society of Fiber Science and Technology of Japan and Certificate of Friendship Award of Liaoning Province in China on September 2011.

mm-matsuo@live.jp