Magnetic and dielectric properties of Electrospun $LiNbO_3$-$CoFe_2O_4$ Nanofibers

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Multiferroic nanostructured composites constructed by combining magnetostrictive and piezoelectric materials, possess not only ferroelectricity and ferromagnetism in each individual phase, but also exhibit a stress mediated coupling between their magnetic and electric properties, the so called magnetoelectric effect. In this context, sub-micrometer diameter electrospun nanofibers are particularly attractive, due to their low dimensionality, high aspect ratio and ease of production. By combining suitable piezoelectric and magnetostrictive compounds in the electrospinning precursor solutions, composite magnetoelectric nanofibers are achieved, with the potential to show very high coupling coefficients, broadening the prospects of potential applications. In this respect, lithium niobate (LNO-$LiNbO_3$), due to its high piezoelectric, pyroelectric, electro-optical, birefringent, photorefractive and photoelastic properties, presents a rich variety of favorable properties towards applications. While cobalt ferrite (CFO-$CoFe_2O_4$) presents a high magnetocrystalline anisotropy and magnetostriction, making it suitable for application in magnetoelectric composites.

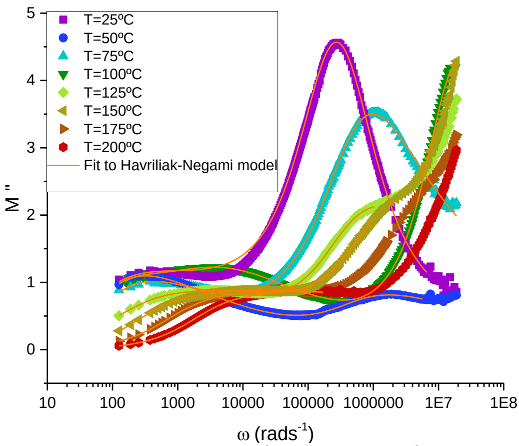

Figure 1: Imaginary component of electric modulus of composite sample with 40% of CFO at different temperatures and analytical fit using Havriliak-Negami model.

Here, multiferroic nanofibers composed by $LiNbO_3$ and $CoFe_2O_4$ were synthesized through the electrospinning technique, with different CFO concentrations (xCFO from 10% to 40%). Subsequently, they were annealed at 650°C, for ~3 hours, to vaporize the transporting polymer. X-ray diffraction measurements showed that the fibers were polycrystalline, presenting the CFO cubic spinel phase and the LNO rhombohedral ferroelectric structure, as envisaged. The lattice parameters of both phases showed a distortion compared to bulk values, which was associated with the presence of the mechanical coupling interaction between them. From the scanning electron microscopy measurements (SEM) the nanofibers presented diameters in the 100-400 nanometers range.

The dielectric properties of the produced composite nanofiber samples were determined through impedance spectroscopy, at various temperatures and frequencies. Two clear and distinct relaxations were observed at every temperature, arising from the electrical response of the LNO grains and grain boundaries. At high temperatures, a third relaxation was observed, arising from the presence of the CFO phase. The results were analyzed through fits of the experimental data to the Havriliak-Negami model (Figure 1), with the addition of an electrical conductivity contribution to the dielectric permittivity. As, such, in this work, the influence of the $CoFe_2O_4$ concentration on the determined relaxation times, activation energies, conductive behavior and magnetization dependence will be discussed and presented.