Physiochemical properties of nanocomposites based on $M_xFe_{3-x}O_4$ magnetic nanoparticles and polythiophene

This dissertation establishes and presents an approach that may be taken, while designing and developing new conducting nanocomposites based on magnetic nanoparticles and conjugated polymers.

The main goal of the first phase of this research, was to study the influence of content of dopants on size, shape and magnetic properties of metal oxide nanoparticles. To achieve that the synthesis of iron oxide and zinc ferrite nanoparticles was realized with thorough analysis using numerous methods like vibrating sample magnetometry, X-ray photoelectron spectroscopy, transmission electron microscopy and more. In addition, the presence of a shell, made of capping agents used during the synthesis, was observed and studied. Such a shell adds additional interface which must be taken into consideration, while designing nanocomposites based on polymers and nanoparticles. This issue was further investigated in the following parts of the study.

In the next step, a unique measurement procedure was established. It was proposed that proper application of X-ray photoelectron spectroscopy combined with Gas Cluster Ion Beam allows to study the chemical composition of not only the surface of nanoparticles, but also the deeper layers of measured samples. What is more important, it was proven that here established procedure of sample's sputtering, allows to study subsequent shells of nanoparticles without changing the states of elements present in the sample, which sometimes may be an issue.

Then, I have proposed an altered method of synthesis of nanoparticles involving conjugated polymers during the whole process of nanoparticle formation to resolve the problem of additional layer covering nanoparticles. As a result, there was less control over the morphology, but the shell was modified, so that the electrical conductivity of pure nanoparticles was observed. What is more, two distinct nanocomposites, based on two different types of nanoparticles, were formed (using the classical and newly designed synthesis protocol), and enhanced electrical properties of newly designed nanoparticles were shown.

Finally, the study presents the comparison of resistance of six different nanocomposites. Namely, magnetite, cobalt ferrite and nickel ferrite nanoparticles, obtained following the classical and newly designed synthesis protocol, were mixed with poly(3-hexylthiophene-2,5-diyl). Subsequently, not only their electrical resistance was measured, but also the electric response in the external magnetic field, changing in the range of up to 1500 mT, was studied for four out of sixed samples. As a result, I have obtained over 5% change in the resistivity for the nanocomposite based on iron oxide nanoparticles synthesized in the presence of conjugated polymer. On the other hand, similar nanocomposite, but with nanoparticles coated with surfactant capping agents, showed only 1% of such alteration, proving that the interface engineering is a crucial point in nanocomposite materials of that type.

To sum up, during my doctoral studies I have modified and created a synthetic protocol which allows to obtain nanoparticles with two distinct shells – electrically insulating or conducting. What is more, the importance of interface between the nanocomposite's components was evidenced, which paves the way for enhancement of the electromagnetic response in the field of inorganic/organic nanocomposites.

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