M.Sc. Eng. Marcin Krajewski

University of Warsaw
Faculty of Physics
Institute of Experimental Physics
Division of Solid State Physics

Structural and magnetic properties of iron nanowires, iron nanoparticles and multiwall carbon nanotubes covered by iron oxides

ABSTRACT OF DOCTORAL THESIS

Presently, iron nanoengineering is a rapidly developing branch of science and nanotechnology. Therefore, the iron-based nanostructures attract the attention of a vast amount of scientists from all over the world. Undoubtedly, it is related to the abundance of iron in the nature, what favourably influences the costs of iron nanomaterials. Moreover, the simple iron compounds as iron oxides exhibit the unique optical, magnetic and surface properties. Most of them are also low toxic and biocompatible. All of these features cause that iron-based nanomaterials are very promising from the viewpoint of the numerous amount of applications. But at the same time their fast development delivers more and more questions which are new or are still unclear and need to be explained. Hence, this work is entirely devoted to the structural, morphological and magnetic studies of iron-based nanomaterials including iron nanoparticles, iron nanowires and the nanocomposite composed of multiwall carbon nanotubes covered by iron oxides (Fe_xO_y). The properties of these nanomaterials have been determined using the various complementary experimental techniques such as: scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy (EDXS), transmission electron microscopy (TEM), powder X-ray diffractometry (XRD), Raman spectroscopy, transmission Mössbauer spectroscopy (TMS), thermogravimetric analysis (TGA), differential thermal analysis (DTA) and vibrating sample magnetometry (VSM).

Although in recent years plenty of publications have appeared showing how to manufacture iron-based nanostructures of different shapes and how to tune their physical and chemical properties depending on their different modifications, the forms of nanoparticles and nanowires are the most interesting from scientific and application points of view. This is related to their large surface-to-volume ratios and also their exceptional magnetic properties in comparison with other commonly produced nanostructures.

In general, it is difficult to find any publication where iron nanowires and iron nanoparticles are directly compared regarding to their magnetic properties. Therefore, it seems to be that this work shows one of the first reliable experimental results which are associated with the comparison of the magnetic properties of these two nanostructures because they have almost the same chemical compositions due to the similar conditions applied during their fabrication.

Besides the studies performed on as-prepared iron nanowires, they have been also thermally-oxidized in a constant flow of neutral argon atmosphere which has contained the traces of oxygen. This process has led to formation of the iron oxide shell covering iron nanowires, which structure has changed under the increasing annealing temperature. Thereby, the experimental results present in this work allow determining how magnetic and optical properties of iron nanowires alternate in respect to their structures. They also deliver the information about the phase transitions occurring in as-prepared sample under the thermal treatment.

This work also describes the preparation procedure and the characterization results of a new nanocomposite which consists of chemically-modified multiwall carbon nanotubes covered by randomly-deposited iron oxide nanoparticles. Furthermore, it is worth noting that the presence of residual catalyst inside carbon nanotubes originating from the fabrication process has been confirmed with use of the transmission electron microscope. These catalyst contaminants act as a source of weak magnetism of modified multiwall carbon nanotubes which in fact are a main part of investigated nanocomposite. Therefore, the diamagnetic contribution of the graphitic nanotubes and the encapsulated catalyst traces inside them as well as the deposited iron oxide as a whole nanomaterial exhibit very complex magnetic behaviour. Nevertheless, the magnetic properties of studied nanocomposite are briefly discussed in this work.

The results present in this work develop the current knowledge about the formation and the evolution of iron-iron oxide core-shell nanostructures and demonstrate how their physical properties change due to the thermal treatment in the slightly oxidized atmosphere. They also show that the new interesting nanocomposite can be simply fabricated via the proposed chemical method. Finally, all present experimental issues are very crucial in the case of possible applications of investigated nanomaterials.