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Manufacturing and magnetic properties of Fe_xCo_{1-x} wire-like nanoalloys

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A novel manufacturing process of the magnetic Fe_xCo_{1-x} wire-like nanoalloys with various Fe-to-Co ratios is described in this work. In general, it is based on a chemical reduction reaction in presence of an external magnetic field in which the magnetically active nanoparticles tend to align along the magnetic field lines. This magnetic-assisted assembly causes that the as-prepared Fe-Co materials take a form of long almost straight chains with average diameters reaching the tenths of nanometers. It is also worth noting that the nanoalloys are amorphous considering their structural characterization. Referring to the magnetic measurements, the Fe-Co nanoalloys reveal typical ferromagnetic character. It is found that with increasing content of cobalt in the chains their saturation magnetization as well as their coercivity decrease.

For ages, the magnetic field have been studied as either an intrinsic material property or a parameter associated with attracting or repelling two or more materials. In the turn of 20th and 21st centuries the magnetic field has been started using as a reaction parameter. Since then, the approaches, which use the external magnetic field as a growth directing factor, are commonly called as magnetic-field-assisted (MFA) or magnetic-field-induced (MFI) processes [1, 2]. In general, a lot of scientific works show that the MFI method can be successfully applied in order to

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produce the wire-like nanostructures. Nevertheless, most of them concern the synthesis of metallic nanomaterials [2]. Only few MFI procedures, which allow manufacturing the alloy-type nanomaterials, have been demonstrated so far because their growth is hardly predicable [3, 4]. Therefore, this work aims to develop this branch of science associated with the MFI synthesis.

One of the most interesting magnetic materials is iron-cobalt alloy due to its high saturation magnetization (M_S) as well as Curie temperature (T_C) [5, 6]. Recently, the chemical procedures, which allows producing this material in a form of nanoparticles, have been established [6]. Taking the advantage of this method and the application of the external magnetic field (~ 0.05 T), it is proved herein that it is possible to manufacture efficiently the Fe_xCo_{1-x} wire-like nanoalloys with various iron-to-cobalt ratios.

The morphology, structure and chemical composition of as-prepared Fe-Co nanoalloys have been characterized using several complementary experimental techniques, including: scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy dispersive X-ray spectrometry (EDS), electron energy loss spectroscopy (EELS), energy dispersive X-ray fluorescence spectroscopy (EDXRF), and X-ray diffractometry (XRD). In turn, their magnetic properties at room temperature have been determined with a vibrating sample magnetometry (VSM).

The detailed morphological and structural investigations indicate that the as-formed Fe-Co samples reveal very complex structures. They consist of nanoparticles which are aligned in long and almost straight chains. In addition, they exhibit core-shell structures where the amorphous bimetallic alloy and the amorphous very thin oxide layer constitute the core and the shell, respectively. The obtained Fe-Co nanoalloys are also typical soft ferromagnetic materials. Considering their magnetic properties, it is found that their coercivity (H_C) values as well as saturation magnetizations (M_S) depend strongly on their chemical compositions. In general, the more iron in the chains the higher values of M_S and H_C are measured.

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