Doctoral School of Physics - Eötvös Loránd University (ELTE)

Semester report
by **Vandri Ahmad ISNAINI** (vandri@caesar.elte.hu)
with Stipendium Hungaricum Fellowship
at ELTE Doctoral School of Physics, 1st semester
Supervisors: Prof. István Groma (ELTE) and Prof. Imre Bakonyi (Wigner RCP, HAS)

Ph.D. Thesis topic:
Magnetic and magnetotransport properties of nanoscale ferromagnetic heterostructures

Introduction: Spintronic and magnonic materials are two important classes of advanced materials the study of which is at the forefront of materials science. Such materials are typically composed of nanoscale ferromagnetic entities separated by either a non-magnetic metal, an air gap or another ferromagnetic metal of different magnetic characteristics. The interest in these materials arises, on the one hand, due to the already existing applications, e.g., in spintronics devices such as the giant magnetoresistance read heads of magnetic hard disk drives. The permanent demand for improving these existing applications necessitates further study of nanoscale magnetic heterostructures. On the other hand, there are prospective technological applications of such structures, e.g., information storage in magnonic crystals. Since the ferromagnetic elements Fe, Co and Ni as well as their alloys with each other are the basic ingredients of these magnetic nanostructures, it is important to have a reliable detailed knowledge of their electrical transport and magnetic properties since it appears from the literature that available data are not always satisfactorily accurate. This justifies revisiting the zero-field electrical resistivity, the magnetoresistance and the magnetization reversal characteristics of these ferromagnets in both the bulk form and in their various nanostructured form such as nanocrystalline state, thin films, nanoscale multilayers and nanowires, both homogeneous and compositionally modulated along their length.

My task for the Ph.D. work will be the preparation of nanoscale magnetic structures by using electrodeposition and the study of their electrical transport properties and their magnetic characteristics. For comparison and as reference materials, I will investigate also bulk homogeneous ferromagnets such as Fe, Co and Ni metals as well as their alloys produced by either electrodeposition or by my self or by metallurgical methods in other laboratories.

Description of research work carried out in current semester:

List of research training and work :

1. I have got trained to measure the resistivity of thin metallic foil samples in zero magnetic field by using the four-point method. The determination of the resistivity from the measured resistance on strip-shaped thin metallic foil samples requires a precise knowledge of the sample dimensions. The strips had a length of about 5 to 10 mm and a width of about 1 to 2 mm which are easy to measure with a mechanical caliper with sufficient accuracy. However, their thickness was in the range from 5 to 100 μm which could not be reproducibly and sufficiently accurately measured by the available mechanical calipers either analog or digital. Therefore, we had to turn to the determination of the strip thickness by measuring the strip mass, then in the knowledge of the material density and with the help of the length and width of the strips, the average thickness of the strip could be determined. Due to the not perfectly rectangular shape of

the strip-shaped samples (uneven width obtained while mechanically cutting them from a wider strip), I elaborated a new method for determining the average strip width. For this purpose, I have taken a photograph of the surface of the strip sample and by using an image evaluation software, I could determine precisely the actual strip surface area from which, by using the measured strip length, an accurate value of the average width could be determined. By adopting all these refinements, the resistivity of the investigated strip samples could be determined with an accuracy of about 3 %. As a test, we used a pure Ni metal foil sample for which we could reproduce the reported standard value of the resistivity of pure Ni within our accuracy. In this manner, we could trace out the composition dependence of the resistivity of Ni-Co alloys with an unprecedented accuracy.

2. I have got trained to operate the available vibration sample magnetometer (VSM) which allows the measurement of the magnetization of samples at room temperature in magnetic fields up to about 12.5 kOe. With the VSM, I have measured the saturation magnetization and the hysteresis loops of a nanocrystalline and a microcrystalline pure Ni sample. I have refined the currently available VSM user manual to facilitate the work of newcomers to the laboratory.
3. I have got trained to operate the available magnetoresistance measurement workstation at room temperature. This facility was developed to measure the variation of the electrical resisitivity of ferromagnetic samples with magnetic field up to about 9 kOe. I have measured the magnetoresistance of several pure Ni samples and of a series of Ni-Co alloy samples. I have composed a user manual for the magnetoresistance workstation to facilitate the work of newcomers to the laboratory.
4. I started my training for the electrochemical laboratory in order to practice how to make thin films with the electrodeposition method.

Publications: The experimental results (zero-field resistivity, magnetoresistance and magnetization isotherms) I obtained in the first semester at room temperature on several pure Ni metal foil samples and on a series of Ni-Co alloy foil samples which were placed at my disposal will be incorporated into three papers which are currently in preparation. The papers which are intended to be submitted to international peer-reviewed journals to be selected later are as follows:

1. V.A. Isnaini, T. Kolonits, S. Zsurzsa, L.K. Varga, E. Tóth-Kádár, L. Pogány, L. Péter, B. Jóni, H. Ebert and I. Bakonyi: Resistivity and magnetoresistance of Ni metal: influence of grain size. *(accomplishement level: 40 %)*
2. I. Bakonyi, F.D. Czeschka, L.F. Kiss, J. Gubicza, V.A. Isnaini, A. Krupp, E. Tóth-Kádár, L.K. Varga, L. Pogány, S. Zsurzsa, L. Péter, S.T.B. Goennenwein, R. Gross and H. Ebert: High-field magnetoresistance measurements at 300 K and 3 K on microcrystalline and nanocrystalline Ni metal. *(accomplishement level: 80 %)*
3. I. Bakonyi, J. Báskay, V.A. Isnaini, L.K. Varga, L. Pogány, L. Péter, F.D. Czeschka, A. Krupp, B. Jóni, Á. Révész, S.T.B. Goennenwein, R. Gross and H. Ebert: Resistivity and magnetoresistance of fcc Ni-Co alloys: room-temperature data. *(accomplishement level: 40 %)*

Educational activities in current semester:

1. Course in ELTE : Diffraction methods in Materials Science I with Prof. Jenő Gubicza (8 Credits). Exam is due after Jan 15, 2018
2. Course in ELTE : Analytical electron microscopy with Prof. János Lábár (8 Credits). Exam is due after Jan 15, 2018
3. Course in ELTE : Guided research work with Prof. István Groma and Prof. Imre Bakonyi (18 Credits).

Conferences in current semester:

List of attending department and institution seminars :

1. 2017. October 3 in MTA Wigner FK, Presenter : Szabolcs Csonka, Topic : Topologically protected ground state degeneracies in a two-spin system.
2. 2017. October 10 in MTA Wigner FK, Presenter : Katalin Kamaras, Topic : Nanocables based on Boron Nitride.
3. 2017. October 17 in MTA Wigner FK, Presenter : Matthias Droth, Topic : Electron-electron attraction in grapheme electromechanical systems.
4. 2017. November 15 in HAS Headquarters, Presenter : Dezso Horvath, Topic : Broken symmetries in particle physics.
5. 2017. November 15 in HAS Headquarters, Presenter : David Blaschke, Topic : Wigner and neutron star interiors.
6. 2017. November 15 in HAS Headquarters, Presenter : Norbert Kroo, Topic : Quantum coherence, Cooper pairs and high plasmonic fields.
7. 2017. November 27 in KFKI, Presenter : Magdolna Hargittai, Topic : Women scientists from around the world.
8. 2017. November 27 in KFKI, Presenter : Maria Lugaro, Topic : Experiences of a woman scientist from Australia to Hungary.
9. 2017. December 12 in MTA Wigner FK, Presenter : Prof. Tetsuo Hatsuda, Topic : From Quarks to Neutron Stars.
10. 2017. December. 19 in MTA Wigner FK, Presenter : Szipőcs Róbert, Topic : Handheld nonlinear microscope system comprising an Yb-fiber laser for in vivo biomedical imaging.