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Editorial

Special Issue: Soft and Hard Magnetic Materials: Latest Advances and Prospects

Cristina Favieres [1,2]

[1] Laboratory of Magnetism, Department of Science (Physics), Public University of Navarre (UPNA), Campus de Arrosadía, 31006 Pamplona, Spain; favieresc@unavarra.es
[2] Institute for Advanced Materials and Mathematics (INAMAT2), Public University of Navarre (UPNA), Campus de Arrosadía, 31006 Pamplona, Spain

The Special Issue *Soft and Hard Magnetic Materials: Latest Advances and Prospects* aims to provide researchers with an overview of some aspects of the current research in magnetic materials from theoretical studies to their applications, including their fabrication and characterization. Magnetic materials in the form of bulk materials, thin films, nanowires or nanoparticles are meticulously and proficiently optimized, including the control of their structure and morphology, which leads to interesting physical phenomena closely related to the magnetic properties used in a wide range of high-performance applications. This Special Issue includes nine contributions covering a wide variety of research on the topics described, a summary of which is provided below.

The first published review paper by Merve G. Ozden and Nicola A. Morley from the University of Sheffield, "Laser Additive Manufacturing of Fe-Based Magnetic Amorphous Alloys" [1], reviewe the manufacturing and use of Fe-based amorphous materials in a variety of magnetic sensors, actuators and transducers owing to their high saturation magnetostriction and low coercive field when compared with polycrystalline Fe-based alloys. They reviewed two additive layer manufacturing techniques, namely, selective laser melting (SLM) and laser-engineered net shaping (LENS). By using the SLM technique, the authors introduced two scanning strategies. Specifically, they showed that a double-scanning strategy gave rise to maximum relative density of 96% and a magnetic saturation of 1.22 T while improving the soft magnetic properties, i.e., decreasing the coercivity to ≈1590 A/m and increasing the magnetic permeability to ≈100 at 100 Hz and increasing the glassy phase content by an order of magnitude of 47%. The second novel scanning strategy, which comprised preliminary laser melting and short pulse amorphization, increased the amorphous phase fraction to a value of up to 89.6% and lowered the coercivity to 238 A/m.

The second contribution, "Estimation of the Electricity Storage Volume Density of Compact SMESs of a New Concept Based on Si Microfabrication Technologies", by Tomoyoshi Motohiro, Minoru Sasaki, Joo-hyong Noh and Osamu Takai from Nagoya University, Toyota Technological Institute and Kanto-Gakuin University [2], examines methods of improving electricity storage. For this purpose, and based on previous experimental results, the authors proposed a compact superconducting magnetic energy storage system (SMES) produced via Si microfabrication technologies to increase the electricity storage volume density values, w, of SMESs to rank with or surpass those of capacitors (and to mass-produce them at a low cost). In this work, for the first time in a series of trials, they considered the applied magnetic flux density, B, the dependence of the superconductive critical current density and the equivalent radius of a single circular current that generates the same B at the center of the circle as the single wafer coil (engraved with a spiral coil).

The third contribution, "A Ti/Pt/Co Multilayer Stack for Transfer Function Based Magnetic Force Microscopy Calibrations", by Baha Sakar, Sibylle Sievers, Alexander Fernández Scarioni, Felipe García-Sanchez, Ilker Öztoprak, Hans Werner Schumacher and Osman OÅNztürk of Gebze Technical University, Physikalisch-Technische Bundesanstalt and the

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University of Salamanca [3], presents the use of magnetic force microscopy (MFM) and the instrument calibration function (ICF). As the quality of the calibration depends critically on the calculability of the magnetization distribution of the reference sample, they discussed the use of a Ti/Pt/Co multilayer stack showing stripe domain pattern as a suitable reference material. This sample, with a very low degree of surface roughness and well-defined interfaces, was a suitable reference sample for quantitative MFMF and qMFM calibrations covering feature sizes from the 10 nm to the 100 nm range. The maximum stray field of the sample at 64 nm was found around $\pm$60 mT. They demonstrated that the sample's inherent stripe domain pattern provided a broad spectrum of Fourier components with sufficiently high amplitudes.

The contribution "Magnetic Properties of a Ni Nanonet Grown in Superfluid Helium under Laser Irradiation" by Oksana Koplak, Elizaveta Dvoretskaya, Maxim Stepanov, Alexander karabulin, Valdimir Matyushenko and Roman Morgunov from the Institute of Problems of Chemical Physics, the First Moscow State Medical University, Joint Institute for High Temperatures and the Semenov Federal Research Center of Chemical Physics, all of them in Russia [4], demonstrated the growth of a nanonet consisting of ultrathin Ni nanowires (diameter < 4 nm) and Ni nanoballs (diameter < 20 nm) via the laser ablation of a Ni target in superfluid helium. The magnetic properties were studied. The main importance of the work is the observation of the evolution of the magnetic properties of the ferromagnetic nanonet while its composition varied from nanowires to a combined nanowire–nanoball system. Indeed, the authors showed that at a low concentration of Ni, the nanonet consisted mainly of nanowires exhibiting a rectangular magnetic hysteresis loop, while an increase in the Ni concentration resulted in an increase in both the concentration and diameter of the nanoballs. A decrease in hysteresis loop rectangularity was observed as the concentration of the nanoball increased. The composition of the system was determined from the changes in the magnetic hysteresis loop and the temperature dependence of magnetization.

An additional contribution, "Tailoring Magnetic and Transport Anisotropies in Co_{100-x}–Cu_x Thin Films through Obliquely Grown Nano-Sheets", by Cristina Favieres, José Vergara and Vicente Madurga of the Public University of Navarre [5], dealt with the magnetic and transport properties of pulsed-laser-deposited nanostructured Co_{100-x}–Cu_x thin films properly tailored through their oriented nano-sheet nano-morphology. The generation of an in-plane uniaxial magnetic anisotropy controllable in both direction and magnitude was shown during the oblique growth of the films. The magnetic anisotropy field H_k remained constant for x = 0, 5 and 10, $H_k \approx 35$ kAm^{-1}, and decreased to 28 and 26 kAm^{-1} for x = 20 and 30. This anisotropy had a magnetostatic origin due to a tilted nano-sheet morphology whose top edges were directly observed via scanning tunnelling microscopy. The coercive field H_c decreased from 1500 (x = 0) to 100 Am^{-1} (x = 30) as x increased. Moreover, activation energy spectra corresponding to structural relaxation phenomena in these films were obtained from transport property measurements. They revealed two peaks which also depended on their nano-morphology and composition. These properties were compared with those exhibited by normally-deposited Co_{100-x}–Cu_x thin films.

In the work "Magnetic Properties and Microstructure of Ce-Cu-Al Low Melting Alloy Bonding $Sm_2Fe_{17}N_3$ Magnet Fabricated by the Hot-Pressing Method" by Jingwu Zheng, Shitong Yu, Heng Huang, Rongyao Li, Wei Cai, Haibo Chen, Juan Li, Liang Qiao, Yao Ying, Wangchang Li, Jing Yu and Shenglei Che from the University of Technology of Hangzhou and Hangzhou Chase Technology Co. [6] showed that $Ce_{72}Cu_{28-x}Al_x$ (x = 0, 3, 6, 9, 12) alloys were prepared and high-performance $Sm_2Fe_{17}N_3$-bonded magnets were fabricated via the hot-press sintering method. Their studies showed that the $Ce_{72}Cu_{28-x}Al_x$ alloys with lower densities and weak magnetic properties were more conductive to the fabrication of $Sm_2Fe_{17}N_3$-bonded magnets under high pressure and improvements in magnet performance. Despite the alloy powder having a very high oxygen content, the performance of its bonding magnets was better than that of the high-oxygen-content

Zn powder bonding magnet. When a 5 wt.% $Ce_{72}Cu_{22}Al_6$ alloy powder was used as a binder, the high-performance $Sm_2Fe_{17}N_3$-bonded magnet with remanence, coercivity, and a maximum magnetic energy product of 10.12 KGs, 5.63 KOe and 21.06 MGOe, respectively, was obtained.

Another contribution of this Special Issue studied the use of magnetic nanoparticles for the healing of a human disease. Indeed, in the work "Dissolution of Lysozyme Amyloid Fibrils Using Magnetic Nanoparticles in an Alternating Magnetic Field: Design of an Effective Treatment for Cutaneous Amyloidosis", the authors, Natália Andrýsková, Hana Vrbovská, Melánia Babincová, Peter Babinec and Mária Šimaljaková, from Comenius University and Bratislava University [7], studied the possibility of using sodium oleate-functionalized magnetic nanoparticles generating heat in an external alternating magnetic field with a frequency 3.5 MHz to heal cutaneous amyloidosis. Specifically, they used lysozyme fibrils, and for the quantification of fibrillar status, they used Thioflavin T and Congo red, specific dyes which change their spectroscopic properties upon binding with the cross-beta structure of fibrils. They used different techniques, including fluorescence, polarization microscopy and absorption spectrophotometry, finding that the amyloid-like fibrils can be almost completely dissolved.

Another interesting work was of the paper by Diana Benea and Viorel Pop from Babes-Bolyai University [8], "Magnetic Properties of the Fe2B Alloy Doped with Transition Metal Elements", in which they conducted theoretical studies of doped Fe_2B with selected transition elements, M. They calculated the magnetic moment, magneto-crystalline anisotropy and Curie temperature of $(Fe_{1-x}M_x)2B$ alloys using the spin-polarized relativistic Korringa–Kohn–Rostoker (SPR-KKR) band structure method. The transition metal elements M (M = Co, Ni, Mo, Ta, W and Re) were reported to form stable M2B or FeMB alloys with a tetragonal Cu2Al structure type. They showed decreases in the total magnetic moments and Curie temperatures of the alloys by increasing the doping amount, which is more pronounced for non-magnetic *4d*/*5d* elements. They studied also the evolution of the direction of the anisotropy constant K_1, from planar for the Fe_2B alloy to axial, which was only found for M = Re, Co and Ta (for $x \leq 0.28$). The largest theoretical value of the anisotropy constant within the investigated alloys was K_1 = 1.5 MJ/m^3 for $(Fe_{0.76}Re_{0.24})_2B$, with magnetization $\mu_0 M_s$ = 1.22 T and an estimated Curie temperature T_c = 595 K. The intrinsic properties of $(Fe_{1-x}Re_x)_2B$ alloys with x = 0.2–0.24 were compatible with those of semihard alloys. In addition, they found disorder effects to have a strong influence on the MAE of the Fe_2B-based alloys.

The last contribution, "Transformation Pathways of Ferromagnetic Mn-Al-Ga-Ni", was made by Shane Palmer, John Martin, Paul Lindquist and Peter Müllnerof Boise State University [9], in which other interesting magnetic materials with hard magnetic properties were investigated. The effect of alloying Mn-Al-Ga with 3 at.-% Ni and the stability and formation mechanisms of the τ phase on the chemical composition and structural and magnetic properties, including the observation of magnetic domain structures, were studied. A new t phase reaction path was identified by first annealing the Mn-Al-Ga-Ni alloy at 800 °C for 24 h, which formed a nearly single κ phase, followed by a second anneal at 500 °C for 24 h, at which the τ phase formed with some κ phase remaining. The energy product of the Mn-Al-Ga-Ni alloy increased that of the ternary Mn-Al-Ga alloy: for Mn-Al-Ga, the BH_{max} was 0.4 kJ/m^3 and for Mn-Al-Ga-Ni, the BH_{max} was 1.8 kJ/m^3. The κ-phase particles in the Mn-Al-Ga-Ni alloy hinder magnetic domain boundary motion, thus providing a method for magnetic hardening and increasing the energy product.

Surely, this Special Issue is of interest for researchers investigating the fabrication and characterization of magnetic materials and some of their useful applications.

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Conflicts of Interest: The authors declare no conflict of interest.

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