magnetochemistry

Editorial

Synthetic, Natural and Natural-Synthetic Hybrid Magnetic Structures: Technology and Application

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The magnetic properties of various types of structures based on iron oxides and the other ferri- or ferromagnets strongly correlate with their origin. All of these magnetic structures can be divided into the two general groups: the natural and the synthetic. This Special Issue, entitled "Synthetic, Natural and Natural-Synthetic Hybrid Magnetic Structures: Technology and Application", considers these two types of magnetic structures and additionally firstly introduces natural–synthetic hybrid structures as a separate class, which can contain some elements of natural origin (biogenic or abiogenic) and/or can be obtained using some natural-like techniques, including biomimetic approaches. The goal of the current Special Issue was to attract scientists working on magnetic structures technologies, magnetic measurements, and theoretical modeling. It succeeded with 16 papers published, including 14 research articles and 2 reviews.

The first paper, published at the Special Issue's launch in January 2021, was "Magnetotactic Bacteria and Magnetosomes: Basic Properties and Applications", co-authored by Kamil G. Gareev and Petr V. Kharitonskii from Saint Petersburg Electrotechnical University "LETI", Russia; Denis S. Grouzdev from SciBear LLC, Tallinn, Estonia; Andrei Kosterov and Elena S. Sergienko from Saint Petersburg State University, Russia; Veronika V. Koziaeva from the Research Center of Biotechnology of the Russian Academy of Sciences, Moscow, Russia; and Maxim A. Shevtsov from the Institute of Cytology of the Russian Academy of Sciences, Saint Petersburg, Russia [1]. In this review paper, an attempt was made to summarize the current state of the art in the field of magnetotactic bacteria (MTB) research and applications.

The second paper, "Enriched Synthesis of Magnetosomes by Expanding the *Magnetospirillum magneticum* AMB-1 Culture at Optimal Iron Concentration", was co-authored by Yazhen Hong, Ranjith Kumar Kankala, Ruqi Yu, Huaqing Liu, and Yuangang Liu from Huaqiao University, Xiamen, China [2]. In this article, the authors developed a culture method that effectively provides a promising approach towards the culture of the MTB for the enriched production of magnetosomes.

The next contribution also relates to magnetosome formation and is entitled "Revisiting the Potential Functionality of the MagR Protein". The authors of the paper, Alexander Pekarsky, Herwig Michor, and Oliver Spadiut work at Technical University Wien, Austria [3]. Their results showed that MagR protein induces no measurable, permanent magnetic moment in *Escherichia coli* cells at low temperatures, indicating no usability for cell magnetization. Furthermore, the limited usability of magnetic bead-based protein purification was shown, thus closing the current knowledge gap between theoretical considerations and empirical data on the MagR protein.

The fourth paper, "Synthesis and Single Crystal Growth by Floating Zone Technique of $FeCr_2O_4$ Multiferroic Spinel: Its Structure, Composition, and Magnetic Properties" was co-authored by Ruslan Batulin, Mikhail Cherosov, Airat Kiiamov, Almaz Zinnatullin, Farit Vagizov, Dmitrii Tayurskii, and Roman Yusupov from Kazan Federal University, Russia [4]. The paper presents a new synthesis route for spinel-structure $FeCr_2O_4$ and its single crystal growth via the optical floating zone method, ensuring its single-phase and near-ideal

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Citation: Gareev, K.G. Synthetic, Natural and Natural-Synthetic Hybrid Magnetic Structures: Technology and Application. *Magnetochemistry* **2024**, *10*, 92. https://doi.org/10.3390/magnetochemistry10120092

Received: 11 November 2024
Accepted: 18 November 2024
Published: 22 November 2024

composition. The advantage of the proposed synthesis method is the creation of a reducing atmosphere in the oven needed for the preservation of the Fe^{2+} oxidation state via the decomposition of the iron (II) oxalate FeC_2O_4 used as one of the initial components.

The authors of the fifth paper, "Solid-State Self-Assembly of a Linear Hexanuclear Copper(II) Oxamate Complex with Alternating Antiferro- and Ferromagnetic Coupling", are Ana Luísa A. Lage, Luísa A. Ribeiro, Carlos B. Pinheiro, and Cynthia L. M. Pereira from Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil; Antônio C. Doriguetto from Universidade Federal de Alfenas, MG, Brazil; Wallace C. Nunes from Universidade Federal Fluminense, Niterói, RJ, Brazil; and Emerson F. Pedroso from Centro Federal de Educação Tecnológica de Minas Gerais, Belo Horizonte, MG, Brazil [5]. The paper describes the synthesis, structural characterization, and magnetic properties of a novel hexacopper(II) complex resulting from the molecular self-assembly in the solid state of two such tricopper(II) oxamate complexes prepared from the mononuclear precursors in water.

The sixth contribution, "Magnetic, Electric and Optical Properties of Ion Doped $CuCr_2O_4$ Nanoparticles", by Angel Todorov Apostolov from the University of Architecture, Sofia, Bulgaria; Iliana Naumova Apostolova from the University of Forestry, Sofia, Bulgaria; and Jilia Mihailowa Wesselinova from the University of Sofia, Bulgaria, reports on the theoretical study of the magnetic, electric, and optical properties of pure and ion-doped bulk and nano-sized $CuCr_2O_4$ [6].

The next paper, "Indocyanine Green-Containing Magnetic Liposomes for Constant Magnetic Field-Guided Targeted Delivery and Theranostics", was co-authored by Dmitry V. Korolev, Galina A. Shulmeyster, Maria S. Istomina, Alexey I. Nikiforov, Ilia V. Aleksandrov, and Michael M. Galagudza from the Almazov National Medical Research Centre, Saint Petersburg, Russia; and Valentin G. Semenov from Saint Petersburg State University, Russia [7]. The article aimed to develop a preparation method for indocyanine green-containing magnetic liposomes, followed by a detailed characterization of their physicochemical and magnetic properties.

The eighth article is a "Stability Analysis of Buoyancy Magneto Flow of Hybrid Nanofluid through a Stretchable/Shrinkable Vertical Sheet Induced by a Micropolar Fluid Subject to Nonlinear Heat Sink/Source", which is co-authored by Umair Khan and Anuar Ishak from Universiti Kebangsaan Malaysia, Bangi, Malaysia; Aurang Zaib from the Federal Urdu University of Arts, Science and Technology, Gulshan-e-Iqbal, Karachi, Pakistan; Abeer M. Alotaibi from University of Tabuk, Saudi Arabia; Sayed M. Eldin from Future University in Egypt, New Cairo, Egypt; Nevzat Akkurt from Munzur University, Tunceli, Turkey, Iskandar Waini from Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Melaka, Malaysia; and Javali Kotresh Madhukesh from Davangere University, India [8]. Its primary goal was to perform an analysis of the buoyancy flow of a shrinking/stretching sheet, whilst considering the fascinating and practical uses of hybrid nanofluids.

The ninth contribution, on the "Influence of the Preparation Technique on the Magnetic Characteristics of ε-Fe_2O_3-Based Composites", co-authored by Dmitriy O. Testov, Kamil G. Gareev, Ivan K. Khmelnitskiy, and Victor V. Luchinin from Saint Petersburg Electrotechnical University "LETI", Russia; and Andrei Kosterov and Leonid Surovitskii from Saint Petersburg State University, Russia, reports on the results paving the way to modify existing ε-Fe_2O_3 synthesis methods, aiming to increase the content of the epsilon phase in the final product and, consequently, improve its physicochemical properties [9].

The next, tenth, paper is "Investigation of the Prospects for the Use of Iron-Containing Nanocomposites Doped with Rare Earth Elements as Catalysts for the Purification of Aqueous Media", which is co-authored by Kayrat K. Kadyrzhanov, Artem L. Kozlovskiy, Kamila B. Egizbek, and Maxim V. Zdorovets from the L.N. Gumilyov Eurasian National University, Astana, Kazakhstan; and Sholpan N. Kubekova and Inesh E. Kenzhina from Satbayev University, Almaty, Kazakhstan [10]. The paper was aimed to study the prospects of applying a method of mechanochemical synthesis to the creation of iron-containing nanocomposites doped by the rare-earth elements Gd, Ce, Y, and Nd in order to obtain optimal catalysts for cleaning water media.

The eleventh contribution, "MHD Hybrid Nanofluid Flow over a Stretching/Shrinking Sheet with Skin Friction: Effects of Radiation and Mass Transpiration", is co-authored by Angadi Basettappa Vishalakshi, Rudraiah Mahesh, and Ulavathi Shettar Mahabaleshwar from Davangere University, India; Alaka Krishna Rao from Government Degree College, Chodavaram, Andhrapradesh, India; and Laura M. Pérez and David Laroze from Universidad de Tarapacá, Casilla, Arica, Chile [11]. An investigation of inclined magnetohydrodynamics mixed with the convective incompressible flow of a fluid with hybrid nanoparticles containing a colloidal combination of nanofluids and base fluid is presented in this study.

The twelfth contribution, a review article on the "Diversity of Iron Oxides: Mechanisms of Formation, Physical Properties and Applications" by Kamil G. Gareev from Saint Petersburg Electrotechnical University "LETI", Russia, considers an attempt to classify all the information on different iron oxide compound formation mechanisms and their intended applications in biomedicine, catalysis, waste remediation, geochemistry, etc. An outlook on the perspectives for further iron oxide studies is provided [12].

The next paper is on the "Effect of an External Magnetic Field on the Hydrogen Reduction of Magnetite Nanoparticles in a Polymer Matrix" and is co-authored by Petr Chernavskii, Galina Pankina, and Nikolai Perov from Lomonosov Moscow State University; and Sveta Ozkan and Galina Karpacheva from A.V. Topchiev Institute of Petrochemical Synthesis, Russian Academy of Sciences, Moscow, Russia [13]. The authors investigated, for the first time, the effect of an external magnetic field on the reduction kinetics, not of free magnetite but of magnetite nanoparticles, which are part of a nanocomposite material.

The fourteenth paper, "Controlling the Magnetic Properties of $La_{0.9}A_{0.1}Mn_{0.9}Cr_{0.1}O_3$ (A: Li, K, Na) Powders and Ceramics by Alkali Ions Doping" is co-authored by Paweł Głuchowski, Ruslan Nikonkov, and Daniela Kujawa from Nanoceramics Inc., Wroclaw, Poland, Wiesław Stręk from the Institute of Low Temperature and Structural Research PAS, Wroclaw, Poland; Tomas Murauskas, Andrius Pakalniškis, and Aivaras Kareiva from the Institute of Chemistry, Vilnius University, Lithuania; Andrii Yaremkevych and Olena Fesenko from Institute of Physics NAS of Ukraine, Kyiv, Ukraine; and Aliaksandr Zhaludkevich and Dmitry Karpinsky from Namangan Engineering-Construction Institute, Namangan, Uzbekistan [14]. As they show, combustion synthesis can be an easy, fast, and, above all, scalable method for obtaining multiferroics based on manganese and rare earth ions. Additionally, it has been proven that the structural and magnetic properties of these materials can be easily modulated by the addition of various types and amounts of alkali ions, which change the Mn^{3+}-to-Mn^{4+} ratio.

The fifteenth contribution, "Some Magnetic Properties and Magnetocaloric Effects in the High-Temperature Antiferromagnet $YbCoC_2$", co-authored by Denis Alexandrovich Salamatin, Vladimir Nikolaevich Krasnorussky, Mariya Viktorovna Magnitskaya, Alexei Valeryevich Semeno, Alexander Vladimirovich Bokov, and Anatoly Vasilyevich Tsvyashchenko from the Vereshchagin Institute for High Pressure Physics, RAS, Moscow, Russia; Atanas Velichkov from the Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria; and Zbigniew Surowiec from the Institute of Physics, M. Curie-Sklodowska University, Lublin, Poland, reports on the results of studies of the magnetic H-T phase diagram and magnetocaloric effect in the $YbCoC_2$ compound in the field range of 0–9 T and temperature range of 2–80 K [15].

The final contribution is "Synthesis and Characterization of Hematite, Magnetite and Maghemite Supported on Silica Gel", co-authored by P. A. Chernavskiy, A. A. Novakova, G. V. Pankina, D. A. Pankratov, S. I. Panfilov, and G. A. Petrovskaya from Lomonosov Moscow State University, Russia [16]. In this work, a new method is proposed for obtaining nanosized particles of iron oxides using porous silica gel.

Summarizing the Special Issue, its goal to attract the specialists working in the areas of magnetic structures synthesis, natural (biogenic) magnetic structures research, and structures implementing natural mechanisms in synthesis technique was successfully accomplished. In addition to the experimental studies, theoretical modeling has also been considered. Thus, we believe that the chosen approach of not dividing natural and synthetic objects and of studying them through their interconnections can be further developed in future research.

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflicts of interest.

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