Wydział Inżynierii Produkcji i Technologii Materiałów

Faculty of Production Engineering and Materials Technology

Czestochowa University of Technology

Investigation into the effect of the cooling rate on the magnetic properties of alloys that are based on the FeCoB matrix

J. Garus[a]*, S. Walters[b], A.V. Sandu[c], M.M.A.B. Abdullah[d], F.F. Zainal[d], M.F. Omar[d], A. Seifoddini[e], P. Mousavi[e]

[a]Czestochowa University of Technology, Al. Armii Krajowej 19, 42-200 Czestochowa

[b]Advanced Engineering Centre, University of Brighton, BN2 4GJ, Brighton, United Kingdom

[c]Gheorghe Asachi Technical University of Iasi, Faculty of Materials Science and Engineering, Iasi, Romania

[d]Centre of Excellence Geopolymer and Green Technology (CEGeoGTech), Universiti Malaysia Perlis (UniMAP), 01000Kangar, Perlis, Malaysia

[e]Department of Mining and Metallurgical Engineering, Yazd University, 89195-741, Yazd, Iran

Abstract

The paper presents the results of tests carried out on samples of FeCoB-based alloys. The samples were produced by a technique involving the injection of each liquid alloy into a copper water-cooled mould. The investigated materials are characterised by much better properties than their crystalline counterparts with the same chemical composition. It has been shown that the cooling rate has a significant impact on the magnetic properties of the produced alloy. Alteration of the production parameters of FeCoB alloys has a decisive influence on the resulting properties of these alloys. The research has revealed evidence that changes in the structural characteristics are related directly to changes in the magnetic properties.

Introduction - essence

Development of physics, chemistry, metallurgy and materials engineering is conducive to obtaining new materials. Way of their production method may determine their values [1-3]. Further stages of refinement their properties are different treatment methods, e.g. soaking, heating, interference with a current pulse or a laser beam of different power [4-8]. In the 90's of the last century a new group of amorphous materials called bulk amorphous alloys was born [9-11]. Interestingly, these materials differed from their predecessors (classic amorphous materials in the form of tapes [12, 13]) only in thickness. Later studies have shown that the thickness have great importance in the case of properties [14]. In order to produce bulk amorphous alloys, three criteria developed by A. Inoue and colleagues from the Tochoku University in Japan should be used [15]. They assumed that the alloy should consist of more than three components whose atomic radii (at least the main components) will differ by more than 12% and the alloying components will have a negative heat of mixing. All these criteria are limiting migration of atoms in the volume of the solidifying alloy, which in turn inhibits the formation of energetically privileged systems.

Experimental procedure - highligts

Samples prepared in this way were tested for structure with use of x-rays. X-ray diffractometer by BRUKER, model ADVANCE 8 was used. Measurements were made in the range of 2 theta angle 30 - 100 degrees, with measuring step of 0.02 degrees and exposure time 7 s per step. Measurements were made for low energy crushed samples in agate mortar within toluene. Performing measurements for crushed samples makes it possible to obtain information from the entire volume. Measurements of magnetic properties were made with the use of a LAKESHORE 7307 vibrating sample magnetometer, operating in the range of magnetic field strength up to 2 T. Both structure and magnetic properties measurements were performed at room temperature.

Results

Fig. 2. X-ray diffraction patterns for the alloy samples: a) rapidly-cooled sample , b) crystal ingot

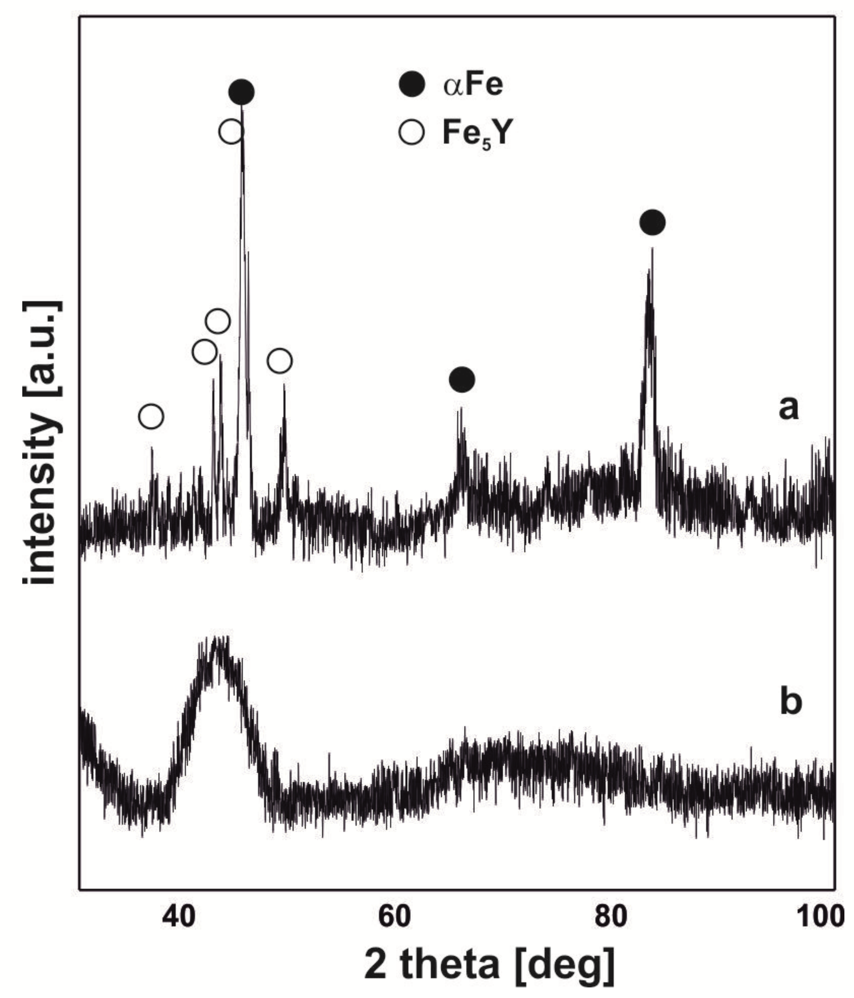
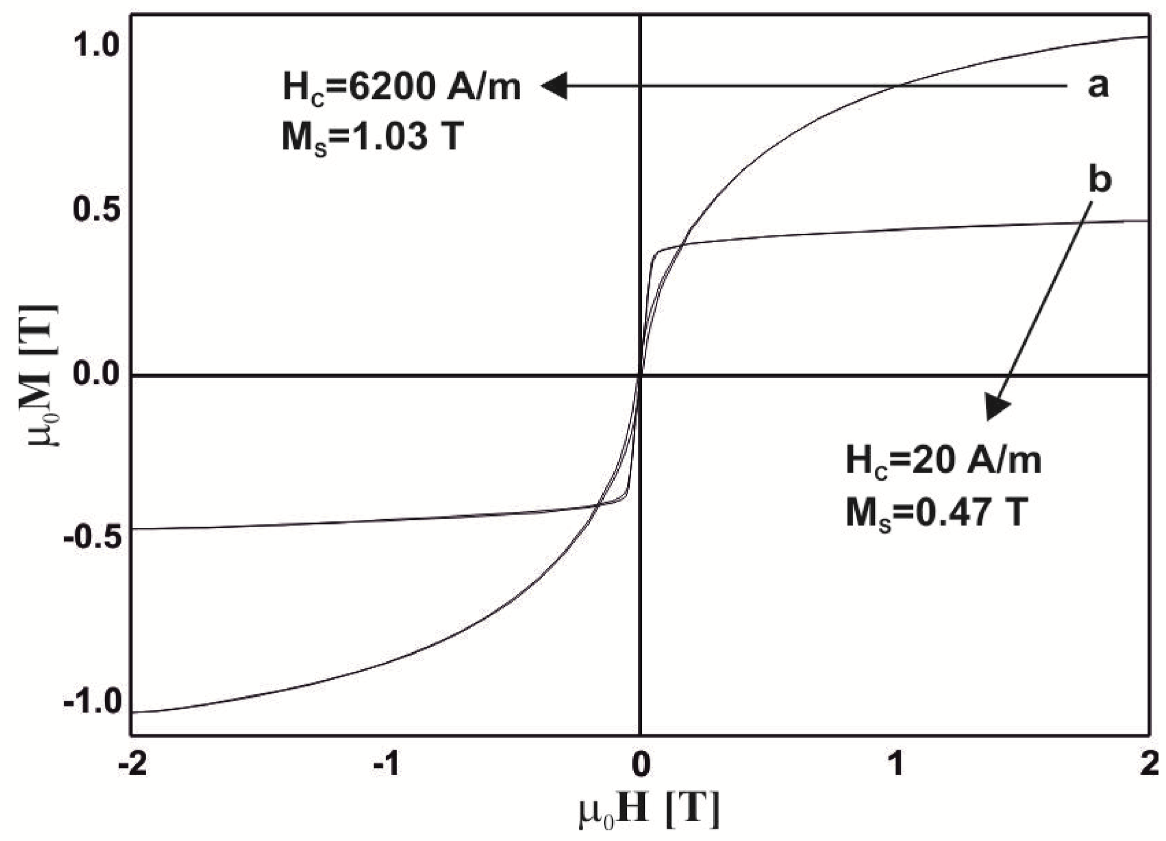


Fig. 3. Static magnetic hysteresis loops for the alloys: a) cooling on a copper plate, b) rapidly-cooling

Conclusions

Process of producing rapidly-cooled materials determines the evaluation of structure and has a direct impact on ferromagnetic alloys properties. Appearance of a well-developed crystal structure without directional texturing significantly deteriorates the soft magnetic properties of this type of alloys.



References

[1] K. Błoch, M. Nabiałek, Acta Physica Polonica A 127(2), 413-414 (2015). DOI: 10.12693/APhysPolA.127.413

[2] M. E. Mchenry, M. A. Willard, D.E. Laughlin, Progress in Materials Science 44, 291-433 (1999). DOI: 10.1016/S0079-6425(99)00002-X

[3] P. Rezaei-Shahreza, A. Seifoddini, S. Hasani, Journal of Non-Crystalline Solids 471, 286–294 (2017). DOI: 10.1016/j.jnoncrysol.2017.05.044

[4] P. Vizureanu, M. Nabiałek, A. V. Sandu, B. Jeż, Materials 13, 835 (2020). DOI: 10.3390/ma13040835

[5] J. Gondro, J. Świerczek, J. Olszewski, J. Zbroszczyk, K. Sobczyk, W. Ciurzyńska, J. Rządki, M. Nabiałek, Journal of Magnetism and Magnetic Materials 324, 1360-1364 (2012).DOI: 10.1016/j.jmmm.2011.11.038

[6] T. Alam, T. Borkar, S.S. Joshi, S. Katakam, X. Chenc, N.B. Dahotre, R.V. Ramanujan, R. Banerjee, Journal of Non-Crystalline Solid s428, 75–81 (2015). DOI: 10.1016/j.jnoncrysol.2015.08.001

[7] L.Y, Guo, S.N. Geng, J. Pang, Y.H. Hu, S. Lan, C.M. Wang, W.M. Wang, Materials and Design 160, 538–548 (2018).DOI:10.1016/j.matdes.2018.09.045

[8] P. Rezaei-Shahreza, A. Seifoddini, S. Hasani, Journal of Alloys and Compounds 738, 197-205 (2018). DOI: 10.1016/j.jallcom.2017.12.135

[9] J. Olszewski, J. Zbroszczyk, K. Sobczyk, W. Ciurzyńska, P. Brągiel, M. Nabiałek, J. Świerczek, M. Hasiak, A. Łukiewska, Acta Physica Polonica A114, 1659-1666(2008). DOI:10.12693/APhysPolA.114.1659

[10]A. Inoue, T. Zhang, T. Masumoto, Materials Transactions JIM 31, 177-183 (1990). DOI: 10.2320/matertrans1989.31.177

[11] A. Inoue, A. Kato, T. Zhang, S.G. Kim, T. Masumoto, Materials Transactions JIM 2, 609-616 (1991). DOI: 10.2320/matertrans1989.32.609

[12] P. Pietrusiewicz, K. Błoch, M. Nabiałek, S. Walters,Acta Physica Polonica A 127(2), 397-399 (2015). DOI:10.12693/APhysPolA.127.397

[13]A. Wang, C. Zhao, H. Men, A. He, C. Chang, X. Wang, R. Li, Journal of Alloys and Compounds 630, 209–213 (2015).DOI: 10.1016/j.jallcom.2015.01.056

[14]M. Nabiałek, S. Garus, Acta Physica Polonica A 130, 1010-1012 (2016) DOI: 10.12693/APhysPolA.130.1010

[15]A. Takeuchi, A. Inoue, Materials Transactions 46(12), 2817-2829 (2005). DOI: 10.2320/matertrans.46.2817

[16] V. Pop, Formation and characterisation of nanostructured metastable alloys, Ecole Franco –Romanie: Magnétisme des systémesnanoscopiques es structures hybrides –Brasow, Romania, 2003.

[17] J. Gondro, K. Błoch, M. Nabiałek, S. Garus, Materiali in Tehnologije 50(4), 559-564 (2016). DOI: 10.17222/mit.2015.148

[18] B. Jeż, Revista de Chimie 68(8), 1903-1907 (2017). DOI:10.37358/RC.17.8.5788

[19] P. Jia, E. Wang, K. Han, Materials 9, 899 (2016). DOI: 10.3390/ma9110899

[20] K. Sarlar, I. Kucuk, Journal of Magnetism and Magnetic Materials 374, 607–610 (2015). DOI:10.1016/j.jmmm.2014.08.060

[21] K. Jeż, B. Jeż, P. Pietrusiewicz, Revista de Chimie 70(9), 3158-3162 (2019). DOI:10.37358/RC.19.9.7507

[22] P. Vizureanu, Metalurgia International 14, 5-9 (2009)

[22] M. Nabiałek, B. Jeż, K. Błoch, J. Gondro, K. Jeż, A.V. Sandu, P. Pietrusiewicz, Journal of Alloys and Compounds 820, 153420 (2020).

[23] P. Pietrusiewicz, M. Nabiałek, B. Jeż, Revista de Chimie 69(8), 2097-2101 (2018). DOI: 10.37358/RC.18.8.6481

www.wip.pcz.pl

Katedra Fizyki

Al. Armii Krajowej 19
42-200 Częstochowa