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MICROSTRUCTURES AND MECHANICAL PROPERTIES OF $Al_{85}Ni_{12.5}Si_{2.5}$ ALLOY

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ABSTRACT

In this study $Al_{85}Ni_{12.5}Si_{2.5}$ alloy was produced by arc melting method. The alloy was annealed at four different temperatures (200 ºC, 300 ºC, 400 ºC, 500 ºC). The microstructural, mechanical and thermal properties of as-cast and annealing alloys were analysed by X-ray diffraction (XRD), scanning electron microscopy (SEM) and differential thermal analysis (DTA). The XRD and SEM results revealed that the microstructure consisted of a mixture of Al, Si, and intermetallic Al_3Ni phases. DTA measurement showed that the as-cast alloy exhibit two endothermic reactions because of melting events. Mechanical properties of the as-cast and subsequently annealed alloys were examined by Vickers microhardness (HV) measurements. Results showed that microhardness of the as-cast alloy were about 144.6 HV and the micro-hardness of annealed alloys slightly decreased as the annealing temperature increased.

Keywords: Al-Ni-Si Alloy, Arc Melting, Microstructure, Mechanical properties.

INTRODUCTION

One of the alternative ways for providing fuel efficiency and improving vehicles performance is weight reduction of used materials that could be achieved via lightweight alloys [1]. Today, most of materials used in automobile industry are aluminum-based materials [2]. Al-based alloys also very popular in 3C (Computer, Communication and Consumer) industries because of their relatively low density, high corrosion resistance, good thermal conductivity and high tensile strength with respect to their density [3-4-5].

Al-Ni binary system has long been examined by various research groups. The eutectic systems of this binary phases have outstanding thermal stability below to 773 K. Moreover, hardness of this system does not seriously change up to 523 K [6,7]. It is revealed from conducted studies that Al-Ni intermetallic compounds also have excellent mechanical stability [8]. The formation mechanics and thermodynamic models of Al-Ni binary systems have been investigated by different research groups all around the world [7-8-9-11]. In literature, various ternary Al-based alloys systems Al-Ni-X (X=Ce, Y, La, Gd, Sm, Nd, Si) have been investigated [12-17]. Addition of silicon to Al improve fluidity of melt, so the speed of melt is increased that imply that Si element can reduced to cost of Al based alloys in casting [18]. By quenching of liquid Al-Ni-Si alloys that the composition of Al above 65% results in obtaining amorphous and nanocrystalline phases [19]. In the present study, the structural, morphological, thermal and micro-hardness properties of $Al_{85}Ni_{12.5}Si_{2.5}$ was investigated by X-ray diffraction (XRD), scanning electron microscopes (SEM), differential scanning calorimetry (DSC) and microhardness machine. The aim of present research was to investigate systematically effect of annealing temperature on microstructural and mechanical properties of the $Al_{85}Ni_{12.5}Si_{2.5}$ alloys.

EXPERIMENTAL STUDY

An ingot alloy with a nominal composition of $Al_{85}Ni_{12.5}Si_{2.5}$ was prepared by arc melting method, a mixture of high purity elements (99.99%) of Al, Ni and Si under argon atmosphere. The ingot alloy was cut appropriately shaped piece for the subsequent heat-treatments. The ingots were heat-treated at 200, 300, 400 and 500 ºC for up to 45 minutes followed by cooling to a room temperature under an air atmosphere. Structural characterization for all these samples was done by X-ray diffraction (XRD) using a Philips X`Pert PRO XRD with Cu Kα radiation (λ = 0.154056 nm), set at 40 kV and 30 mA. The morphological properties of the produced alloy were investigated by scanning electron microscopy (SEM) (ZEISS EVO LS10 SEM) device with voltage of 10 kV is used. Thermal behaviour of produced alloy was investigated by using differential thermal analysis (DTA) type Perkin- Elmer Diamond TG/DTA at a heating rate of 20 ºC/min under nitrogen atmosphere. Mechanical properties of the as-cast and the heat-treated alloys were measured by a Vickers Micro-Hardness. The Vickers micro hardness was used in a dynamic ultra-microhardness tester (Shimadzu, HMV). Vickers microhardness measurements were done by using a 0.98N load and the loading rate was 23.5 $mN.s^{-1}$. For a particular load at least five indentation tests were made and the experimental errors were also taken in to accounts.

RESULTS AND DISCUSSIONS

The X-ray diffraction patterns of the as-produced $Al_{85}Ni_{12.5}Si_{2.5}$ alloy are presented in Figure 1. As shown in Fig. 1, the XRD patterns indicated that $Al_{85}Ni_{12.5}Si_{2.5}$ alloy have three different phases, α-Al solid solution, Si and intermetallic Al_3Ni. Although the content of Si in the alloy was rather small, the Si phase was also observed; this is probably because the solid solubility of Si in Al is very limited. It is also important to mention that no evidences of pure Ni peaks were observed by XRD. Therefore, XRD results are in agreement with other results [6,20-22]. X-ray diffraction patterns of the annealed samples are given in Figure 2. As seen from Figure 2, each annealing temperature are given in different colour and the Al, Si and Al_3Ni phases reference pattern were given in Figure-2. XRD patterns of all annealed samples are similar but crystalline intensities were increased with annealing temperature. This increase seems to result from the growth of the crystal grain size.

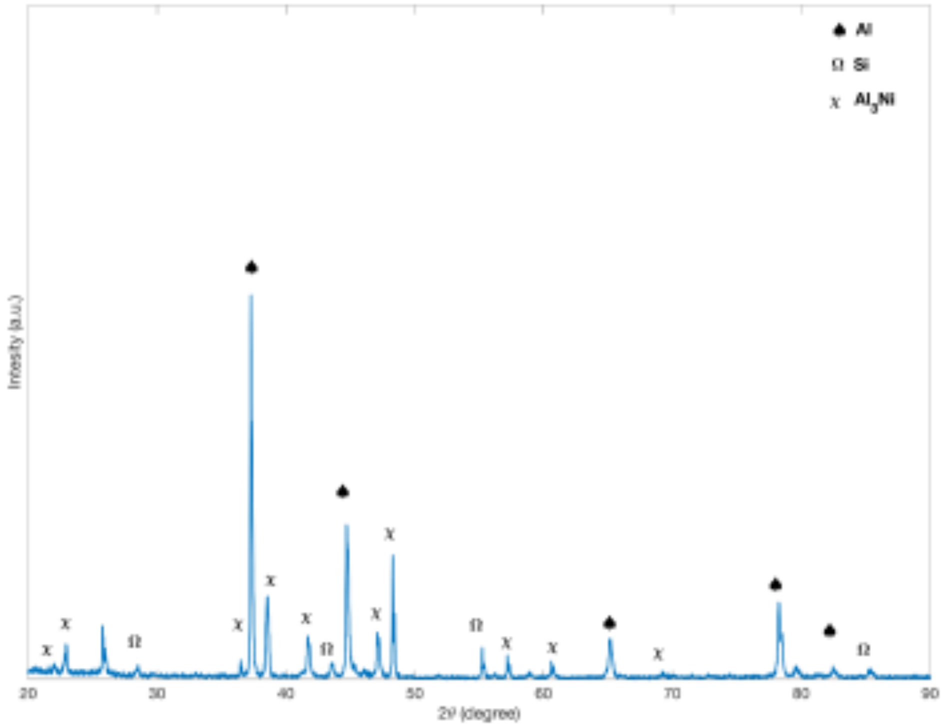

Fig.1. X-ray diffraction pattern of the as-produced $Al_{85}Ni_{12.5}Si_{2.5}$ alloy

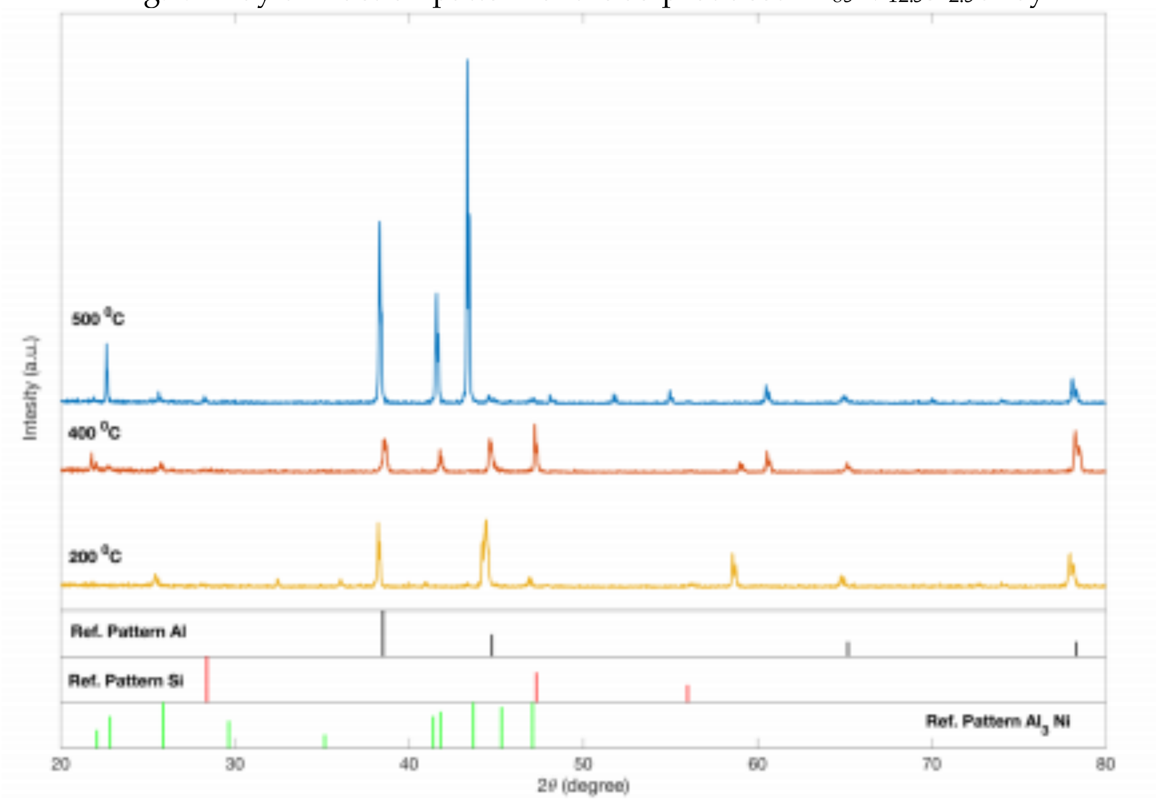

Fig.2. X-ray diffraction pattern of $Al_{85}Ni_{12.5}Si_{2.5}$ alloys at different annealing temperatures

In order to understand the microstructural evolution depending on the heat-treatment in conventionally solidified $Al_{85}Ni_{12.5}Si_{2.5}$ alloy, the samples were examined by SEM. Figure 3 shows the SEM micrographs for the as-cast and the heat-treated samples. All micrographs revealed the formation of Al, Si, and Al_3Ni phases. These results are good agreement with XRD analysis.

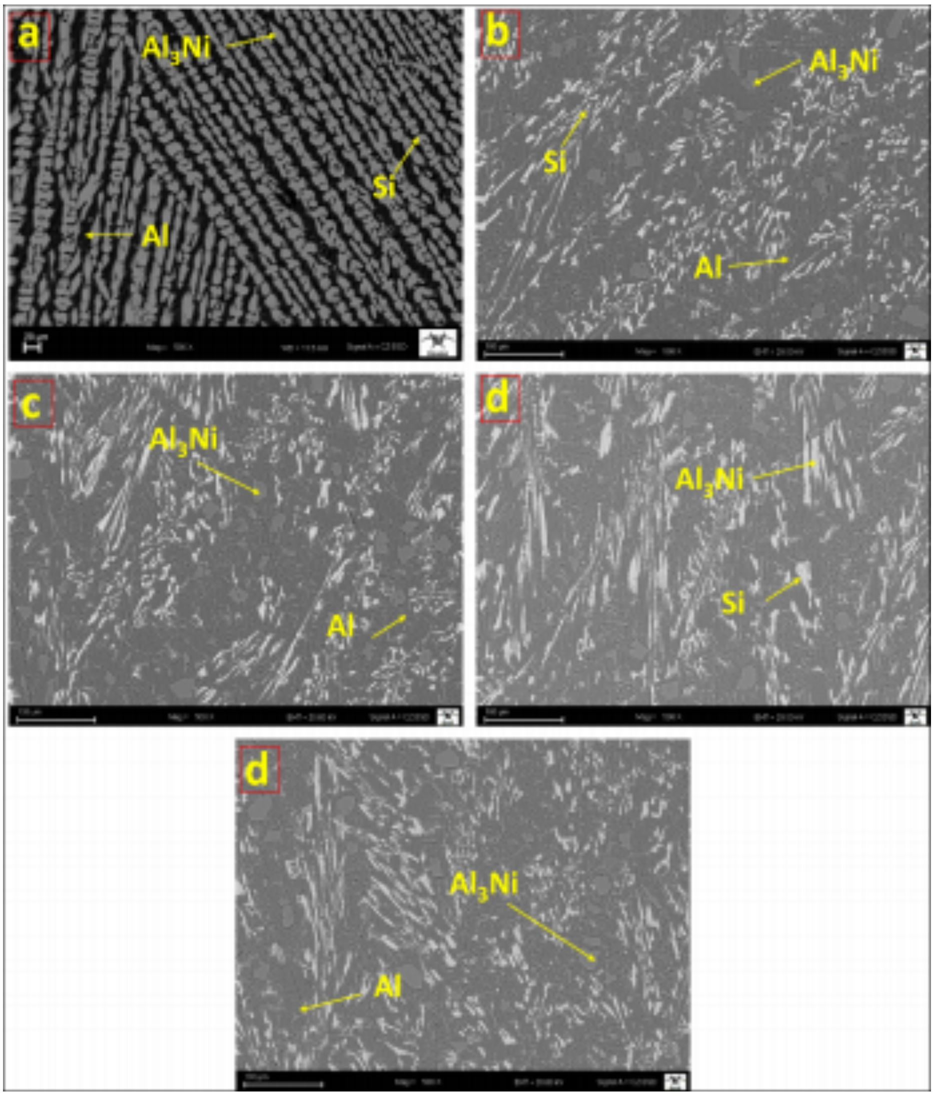

Fig. 3. SEM micrographs for $Al_{85}Ni_{12.5}Si_{2.5}$ alloy before and after heat-treatments: (a) as-cast, (b) 200 °C, (c) 300 °C, (d) 400 °C and (e) 500 °C

The thermal behaviour of the $Al_{85}Ni_{12.5}Si_{2.5}$ alloy was determined using the DTA during continuous heating at a heating rate of 20 °C/ min, and the corresponding DTA trace is shown in Fig. 4. The continuous heating DTA traces of the investigated alloys exhibit two endothermic reactions because of phase transformation events such as melting. As can be seen from Figure 4, the first endothermic effect at around 575 °C is considered corresponds to the dissolution of the Al phase and it is suitable with literature [23,24]. The second peak at around 616 °C is caused by melting point of Al-

Ni eutectics [25]. Therefore, DTA results given in Fig. 4 of the investigated alloys are consistent with the XRD results given in Fig. 2.

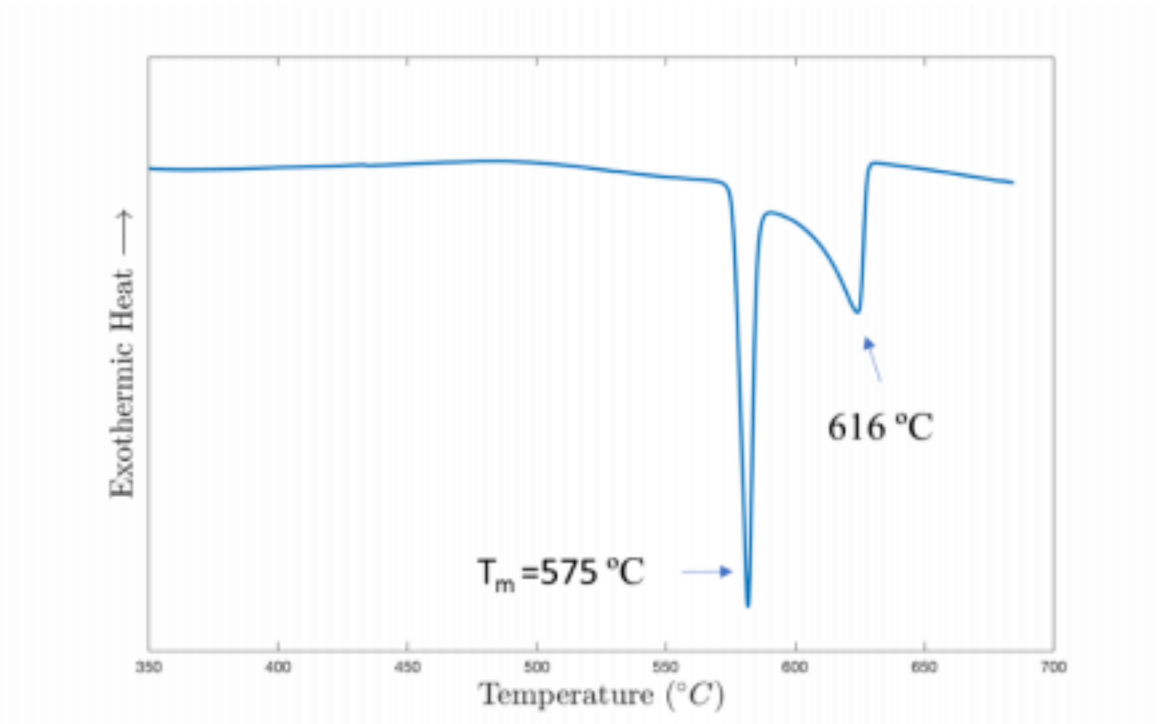

Fig 4. DTA curve of conventionally solidified $Al_{85}Ni_{12.5}Si_{2.5}$ alloy.

Mechanical properties of the as-cast and subsequently annealed alloys were determined by Vickers HV measurements. The micro-hardness values of as-cast and annealed alloys are presented in Figure 5. The micro hardness of samples was determined by means of the average of five different measurements. The hardness of as-cast sample is 144.6 HV, after annealed at 200 °C it was reduced to 141.8 HV. The micro hardness values of sample annealed at 300 °C, 400 °C and 500 °C were 135.8, 135.2 and 130 HV respectively. According to result of hardness measurements, micro hardness values of $Al_{85}Ni_{12.5}Si_{2.5}$ alloy were gradually decreased with increasing annealing temperature, and this situation is found in literature [26,27].

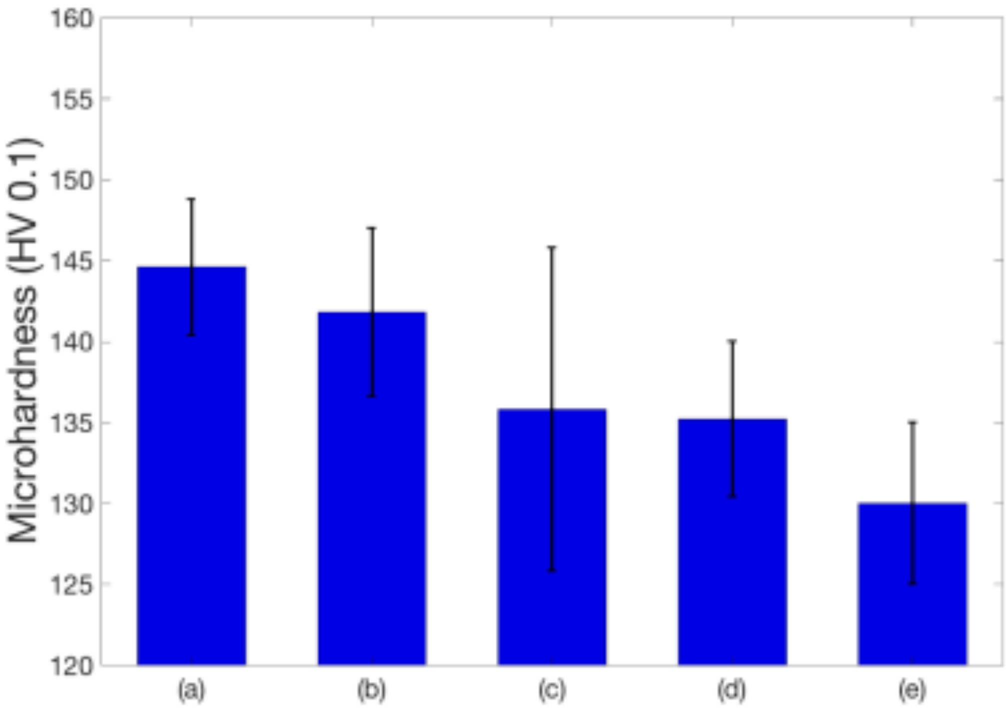

Fig. 5. Micro-hardness of $Al_{85}Ni_{12.5}Si_{2.5}$ alloy before and after heat-treatments: (a) as-cast, (b) 200 °C, (c) 300 °C, (d) 400 °C and (e) 500 °C

CONCLUSIONS

In the present study, microstructures, mechanical and thermal properties of $Al_{85}Ni_{12.5}Si_{2.5}$ alloy
were investigated and the results were summarized as follows.

- Three crystalline phases Al, S_i and Al_3Ni were determined from the result of X-ray diffraction patterns of $Al_{85}Ni_{12.5}Si_{2.5}$ alloy,
- The three crystalline phases identified from SEM morphological investigation for both as-cast and heat-treated alloy,
- The micro hardness of as-cast sample is 144.6 HV, and after annealed at different temperature the hardness values of the alloy were gradually decreased with increasing annealing temperature.

REFERENCES

[1] R. K. Gupta, B. Murty, N. Birbilis. *An Overview of High-energy Ball Milled Nanocrystalline Aluminum Alloys.* Springer; 2017.

[2] S. Shaha, F. Czerwinski, W. Kasprzak, J. Friedman, D. Chen, *Materials Science and Engineering: A* 684, 726-736 (2017)

[3] L. Yang, W. Li, J. Du, K. Wang, P. Tang, *Thermochimica Acta* 645, 7-15 (2016)
[4] K. Song, X. Bian, J. Guo, et al., *Journal of alloys and compounds* 440, L8-L12 (2007)
[5] Y. Shen, J. Perepezko, *Journal of Alloys and Compounds* 707, 3-11 (2017)
[6] J. Kim, S. Hong, J. Park, J. Eckert, K. Kim, *Journal of Alloys and Compounds* 749, 205-210 (2018)
[7] C. Tiwary, S. Kashyap, D. Kim, K. Chattopadhyay, *Materials Science and Engineering: A* 639, 359-369 (2015)
[8] L. Hou, B. Li, R. Wu, et al., *Journal of Materials Science & Technology* 33, 947-953 (2017)
[9] W. Huang, Y. Chang, *Intermetallics* 6, 487-498 (1998)
[10] J. Qian, J. Li, J. Xiong, F. Zhang, X. Lin, *Materials Science and Engineering: A* 550, 279-285 (2012)
[11] G. Purja Pun, Y. Mishin, *Philosophical Magazine* 89, 3245-3267 (2009)
[12] A. Inoue, Y. Horio, T. Masumoto, *Materials Transactions, JIM* 33, 669-674 (1992)
[13] F. Guo, S. Poon, G. Shiflet, *Scripta materialia* 43, 1089-1095 (2000)
14] A. Inoue, K. Ohtera, A.-P. Tsai, T. Masumoto, *Japanese Journal of Applied Physics* 27, L479 (1988)
[15] V. Ronto, L. Battezzati, A. Yavari, M. Tonegaru, N. Lupu, G. Heunen, *Scripta materialia* 50, 839-843 (2004)
[16] L. Battezzati, S. Pozzovivo, P. Rizzi, *Materials Transactions* 43, 2593-2599 (2002)
[17] M. Gögebakan, M. Okumus, *Materials Science (0137-1339)* 27, (2009)
[18] B. McKay, P. Cizek, P. Schumacher, K. O'Reilly. Heterogeneous Nucleation of α-Al in Al-Ni-Si Alloys. In: *Essential Readings in Light Metals.* Springer; 2016:375-380.
[19] O. Muratov, O. Roik, V. Kazimirov, et al., *Journal of Molecular Liquids* 200, 213-222 (2014)
[20] A. Aversa, M. Lorusso, G. Cattano, et al., *Journal of Alloys and Compounds* 695, 1470-1478 (2017)
[21] O. Senkov, J. Scott, D. Miracle, *Journal of alloys and compounds* 337, 83-88 (2002)
[22] X. Sauvage, G. Dinda, G. Wilde, *Scripta Materialia* 56, 181-184 (2007)
[23] U. Böyük, *Metals and Materials International* 18, 933-938 (2012)
[24] B. McKay, P. Cizek, P. Schumacher, K. O'Reilly, *Materials Science and Engineering: A* 304, 240-244 (2001)
[25] Baghdasaryan, A. M., et al. Chemical engineering journal 188, 210-215 (2012)
[26] *M. Huo, J. Zhao, H. Xie, et al., Materials Characterization 148, 142-155 (2019)*
[27] *H. Feng, H. Jiang, D. Yan, L. Rong, Trends Journal of Sciences Research 4, 1-8 (2019)*