Fabrication and Structural Properties of Ni_{50} Al_{50} Alloy by Mechanical Alloying

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Abstract

In the present study, mechanical alloying process was employed for preparation of the nanocrystalline $Ni_{50}Al_{50}$ alloy through ball mill method. The structure properties of the alloy at various milling times of 0, 2, 4, 6 and 8hr were studied by X-ray diffraction and scanning electron microscopy (SEM) measurements. Several phases was formed successfully after 4hr of milling. At 6hr of milling, new intermetallic compound type (Ni_3AI) was observed prospering, The particle size for various milling times decreased significantly, with increasing time of milling. The resulted morphology the milled powder shows a reduction of particle size which is in accordance with the XRD patterns. The results of EDX shows clearly atypical spectrums of both Ni and Al peaks.

Key Words: Ni–Al System, Mechanical Alloying, Microstructure Properties, Nanostructure.

DOI Number: 10.14704/nq.2021.19.7.NQ21091 **NeuroQuantology 2021; 19(7):110-114**

Introduction

A metal matrix composite like Nickel with Aluminum are a better and high-performance materials for industrial applications due to its acceptable properties over the presently available Ni and Al or its alloys (Enayati, et. al. 2004; Yoon, et. al., 1997). The composite is used in the fabrication of different components in electronics, aerospace applications, tubing, magnets and petrochemical industries (Krasnowski, et. al. 2007; Ragab and Salem, 2012). The researchers today are focused upon the powder metallurgy method in spite of casting towards the fabrication in engineering applications (Koch and Cho, 1992). Powder metallurgy method is a technique used for its particular characteristics such as lower sintering temperature low cost and uniformly homogenous distribution of the reinforcements inside the matrix elements (Koch and Cho, 1992). Mechanical alloying (MA) is typically used commercially and is capable of synthesizing materials with alloying phases in both equilibrium and non-equilibrium manners (Suryanarayana, 2001; Yazdian, et. al. 2010). MA is a solid-state powder processing technique that enables production of homogenous materials starting from blended elemental powders mixtures in a high energy ball mill (Mahmoudi, 2011). The advantageous of MA includes the refinement changes of the grain size down to nanometer range, disordering of ordered intermetallies and possibility of alloying of difficult alloy elements (Meng, et. al., 2007; Antolak, et. al., 2008). In this research work, structural of $Ni_{50}Al_{50}$ alloy, during mechanical alloying process at different milling times of 0, 2, 4, 6 and 8hr were conducted.

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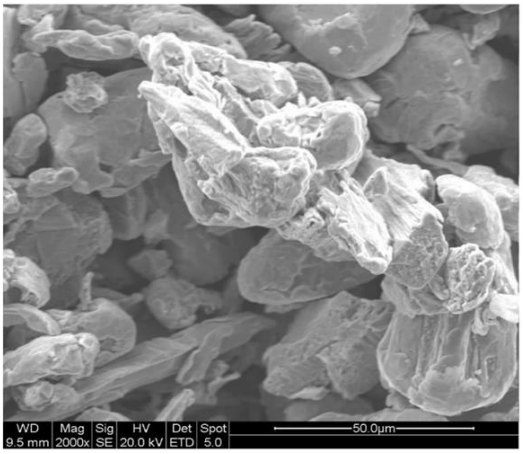
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received: 15 May 2021 **Accepted:** 19 June 2021

Experimental Procedure

Fluke Pure elemental powders (99.6% or better) of Ni(45µm), Al (50µm) were balanced to give the desired nominal composition of $Ni_{50}Al_{50}$. The binary metals of pure Ni and Al morphology shown in Figure 1. Mechanical alloying was carried out using a planetary ball mill (Fritsh Pulverisettep - 5) at a speed of 300rpm and ball to powder weight ratio of (8 :1). The stainless steel balls of 10µm in diameter applied in this study. The variable milling time was used from 0,2,4,6 to 8 hours. To check crystal structure and to determine the effective grain size, we used diffraction (XRD) measurements (Shimadzu-6000) with Cukα radiation (1.5406) A°. For each milling times, twice measurements were done. Morphology was observed via scanning electron microscopy (SEM) Model (XL30SFEG) coupled with energy dispersive X-ray spectroscopy (EDX).



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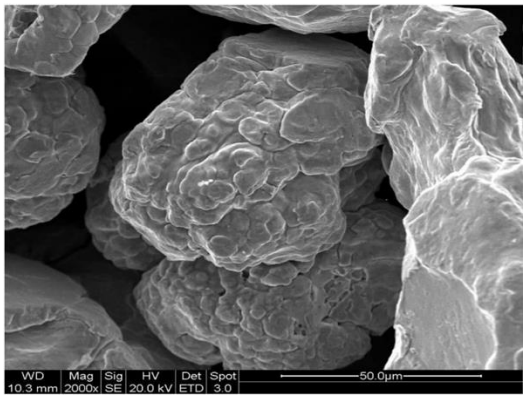

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Figure 1. SEM micrograph powder of: a- Al , b- Ni

Results and Discussion

XRD data shows in Figure 2, Patternas of $Ni_{50}Al_{50}$ powder before and after different milling times (0,4,6) hr. This XRD Patterns showed only the FCC-Ni and FCC-Al peaks dominated with increasing milling time. The results also received a higher intensity peaks that were clearly visible, identified with those of the standard peaks. It was observed also that anotable increase in their intensifies and an increase little broadening with the increasing milling hours. A significantly increasing intensity with diffraction peak of (220) at 6hr of ball milling Also found. The significant narrowing of Ni, Al peaks are very clear, may be due to the reduction of the grain size during the increasing the milling time. Further new structural expected due to change the Ni-AI solid solution forms as an intermediate compound and then very transforms to the Ni_3Al intermetallic compound, occurs after 2hr milling (Mahesh and Raman, 2014). The crystalline size of new Ni_3Al phase was obtained from XRD analysis by using the Scherer equation as calculated from average broadening of Ni_3Al (111) and Ni_3Al (220) peaks [Klug and Alexander, 1974]. The resulting show that Ni_3Al phase has at 4hr and 8hr a milling a crystalline size of (51 to 55) µm respectively comparison to its crystallite size to 108µm at 0hr. The variations of the particle size of the various milling times for Ni_{50} Al_{50} alloys are shown in Figure 3. It shows a significantly decreased until 4hr of milling. It remains almost constant above this milling time. This means that the present milling conditions formed only a FCC solid solution structure, consisting of the dominant Ni-Al intermetallies compound. Finally, No any peaks shifted at lower or higher diffraction analyses observed through milling times. This is May be due to the pure crystalline Ni and Al, which causes no any lattice deformation of a gradual increases of internal strains with increasing milling hours (Klug and Alexander, 1974, Elsayed, et. al., 2021).

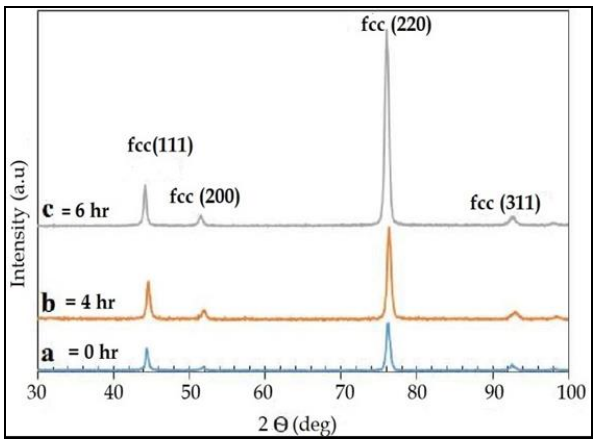


Figure 2. XRD patterns of $Ni_{50}Al_{50}$ alloy with various milling time

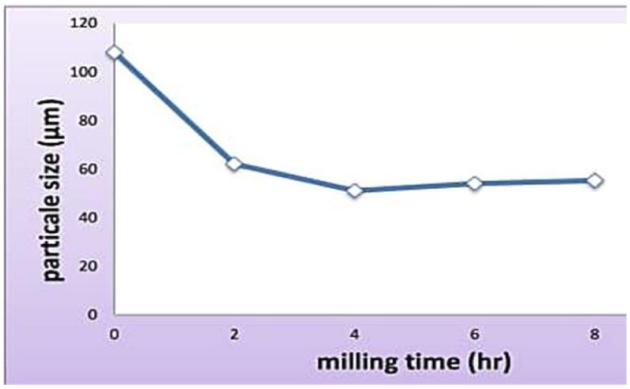
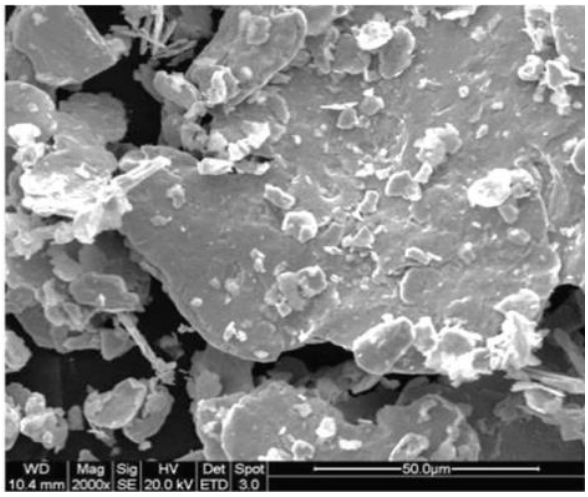


Figure 3. Dependence of particle size on milling time for $Ni_{50}Al_{50}$ alloy

Figure 1(a-b) show the SEM images of pure aluminum and nickel powder before milling. Aluminum show exhibits the sub angular particles of various size, while nickel shows large lumps of spherical particles of uniform size. Figure 4 shows the SEM images of the synthesized $Ni_{50}Al_{50}$ alloy at various milling times of 2, 4,6, 8 hr. It is clear that at the case figure(4-a) after 2hr of milling, the compressive forces due to the collision of the milling. Balls flatten the powder particles (Elsayed, et. al., 2021). The material is usually soft at this stage Figure (4- b) correspond to 4hr of milling show the flattened particles cold welded together and forming a composite lamellar structure (Singh, 2021). It is also observed from Figure(4-c) correspond to 6hr of milling that the composite structure gets agglomeration of the welded particles. The fine Powders become convoluted rather than begin linear. Alloying begins to occur at this stage due to work hardening and the consequent fragmentation of the brittle particles (Singh, 2021). On Further milling 8hr, true alloying occured with uniform fine Particles which shown in Figure (4 -d).



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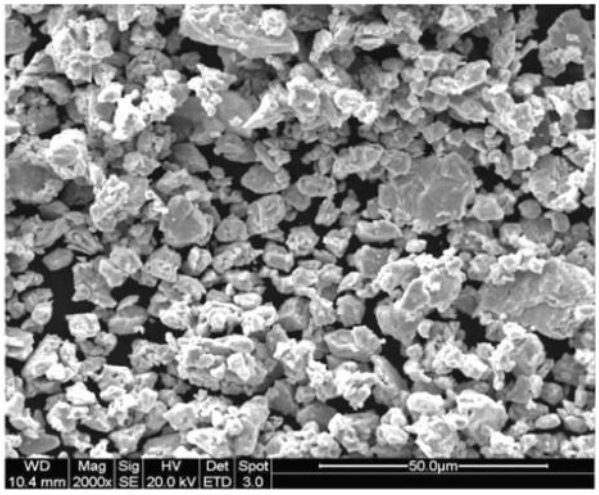

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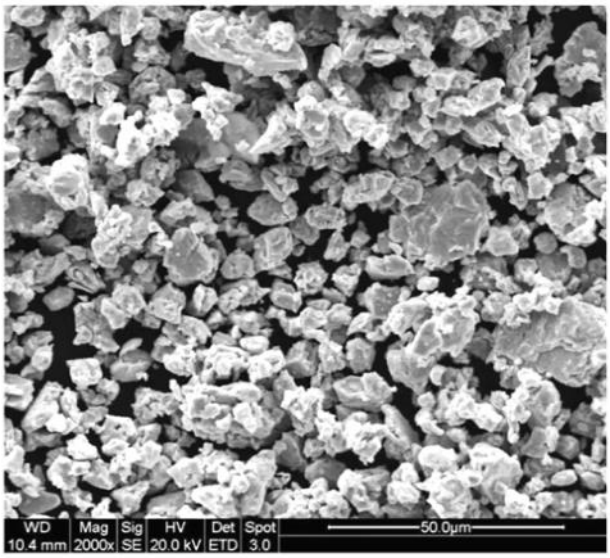

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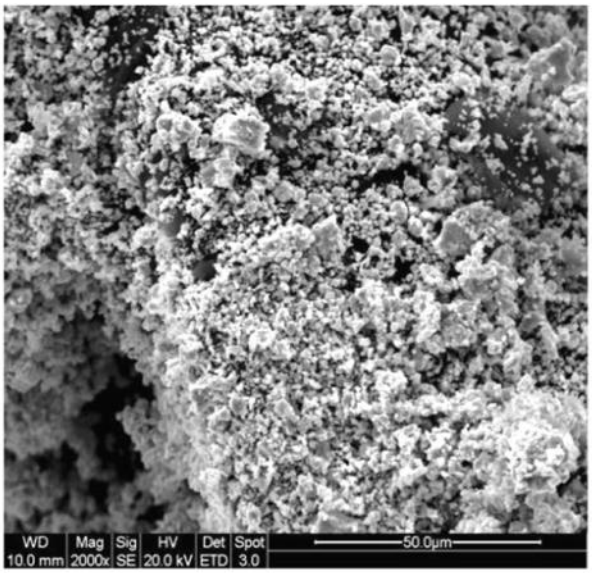
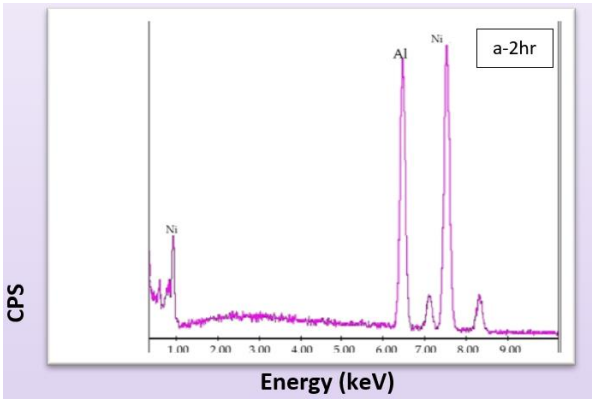


d

Figure 4 (a-b-c-d). SEM images of $Ni_{50}Al_{50}$ powder particles milled at different milling times (a)2hr, (b)4hr, (c)6hr and (d)8hr

The result of EDX analysis shows atypical spectrums for $Ni_{50}Al_{50}$ is shown in Figure 5(a-b). Both Ni and Al peaks are apparent clearly in the spectrum for 2 and 8 milling times. The EDX spectrum (Figure5–a) sample milled for 2hr show only the presence nickel and aluminum. In the case of 8hr milling (Figure 5-b) show that a small percentage of oxygen in $Ni_{50}Al_{50}$ spectrum. It could be that as the milling hours increased the percentage of oxygen also increases due to the formation of $Ni_{50}Al_{50}$ nanoalloy (Betancourt, et. al.,2021; Dhanal, et. al., 2020). However, the XRD data do not show any oxidation peaks for composition of $Ni_{50}Al_{50}$.



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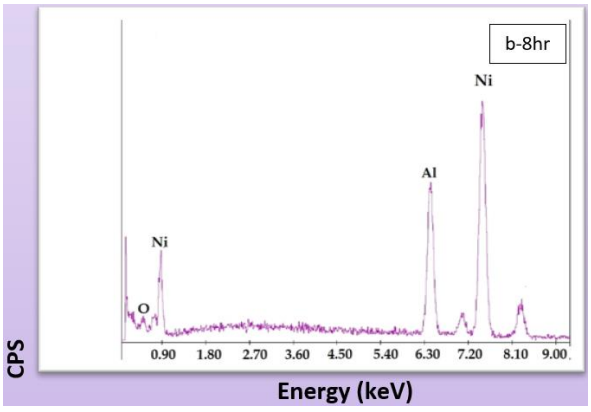

b

Figure 5(a- b). Typical EDX spectrums of $Ni_{50}Al_{50}$ at 2-8 hours milling

Conclusion

We have applied mechanical alloying (MA) to produce nanocrystalline $Ni_{50}Al_{50}$ alld by using a mixture of elemental of powders through ball mill method. The structural characterization of the alloy at various milling times of (0, 2, 4, 6:8) hr were studied by XRD, SEM and EDX measurements. Structural analyses show that, the solid interaction of the intermetallic powder occurs through milling times. The phase transformations and morphology changes during MA were conducted new intermetallic compound type (Ni_3Al) was detected prospering. The variations of the Particle size results are: decreased significantly with increasing milling times. The EDX mapping images confirms the elements of Ni and Al distribution, clearly in the spectrums at different milling times.

Acknowledgements

We particularly wish to acknowledge Prof. Dr. Ishmail K. Jassim and Prof. Amer. S. Mahmood, for giving us important contributions and valuable discussions. This work has been done at the University of Tikrit, Iraq, between physics and mechanical engineering departments I would also to thank the staff and skilled technical peoples for allowing me to use all apparatus test.

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