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Structural and Thermal Unusual Properties in Invar Behavior of Ni-Mn Alloys

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Abstract

The Invar effect in 3D transition metal such as Ni and Mn, were prepared on a series composition of binary $Ni_{1-x}Mn_x$ system with x=0.3, 0.5, 0.8 by using powder metallurgy technique. In this work, the characterization of structural and thermal properties have been investigated experimentally by X-ray diffraction, thermal expansion coefficient and vibrating sample magnetometer (VSM) techniques. The results show that anonymously negative thermal expansion coefficient are changeable in the structure. The results were explained due to the instability relation between magnetic spins with lattice distortion on some of ferromagnetic metals.

Key words: Invar effect, Lattice distortion, Magnetic properties, Powder metallurgy**,** Thermal expansion.

Introduction:

Invar and the associated binary Fe-Ni alloys are known for their invariance of material properties over a range of temperatures. Invar alloy components are conventionally manufactured by machining. However, poor machinability is a serious problem associated with the use of Invar alloy in conventional manufacturing process (1). The most interesting of these compounds has an anomalously small thermal expansion below the Curie temperature (2, 3). It is in fact one of the most important problems of the 3d magnetic and structural properties (4, 5). These Invar characteristics are very closely related to the magnetic moment from the slater –Pauling curve with increasing Fe concentration in the Fe – Ni system (6). Various theoretical models have been proposed to explain the Invar effect on Fe-Ni alloys, which is believed to be a collapse of the local moments and structural properties (7,8). Recently, there have been microscopic techniques to elucidate the origin of the Invar effect , yet no clear Hander standing has been reached (9,10). In our study Invar $Ni_{1-Y}Mn_x$ binary alloys have been prepared by Powder technology technique when x=0.3, 0.5, 0.8. The purpose of this research of these series is to investigate the physical origin of the Invar phenomenon.

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Materials and Method:

The researcher used a new method of powder metallurgy technique (PMT) in spite of casting or electric arc methods. Ni_{1-x} M_n system where x=0.3, 0.5, 0.8 have been chosen to study the Invar effect. The raw powders of the 35-45µm with 98% purity and Mn 45-50µm with 98% purity were ball milled together with tumbler ball milling by hardens steel balls. Ball milling was carried out at a rotating speed of 60 rpm for 5hr to get homogeneous alloys with grain size around 40 µm. Microstructure and morphology of powder properties were investigated using a Philips XL30 scanning electron microscope (SEM) equipped with an energy dispersing X-ray analyzer (EAX). Figure 1 shows the morphology of the initial powder particles used.

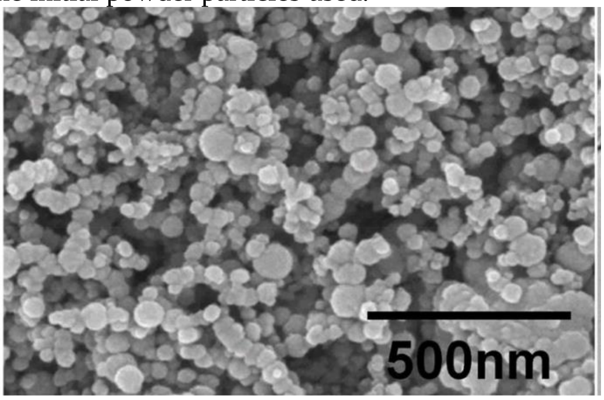

Figure 1. The Microstructure of the $Ni_{0.7}Mn_{0.3}$ alloys observed by SEM before sintering.

Phase compositions of the Ni-Mn samples were carefully analyzed by X-ray diffraction (XRD) in a Philips using filtered Cu Kα radiation λ =

0.1542nm. All the samples were pressed in the pellets form under cold pressing of 6 ton pressure. The sintering was done at 900 ^{o}C with temperature increasing rate by 5 ^{o}C/min, stayed 1hr and cooled inside the furnace slowly. The magnetic properties were measured using vibrating samples manometers (VSM). The instrument was calibrated firstly by using pure Nikel cylindrical shape 4x 2 mm. The thermal expansion measurements were measured by using continuous heating with Differential scanning colorimeter (DSC) .

Results and Discussion:

The result gives ferromagnetic behaviors, so in this composite; it has been recorded from the magnetic result. Figure 2 a and b shows that $Ni_{0.5}Mn_{0.5}$ and $Ni_{0.7}Mn_{0.3}$ after sintering at the same degree 900 ^{o}C/hr.

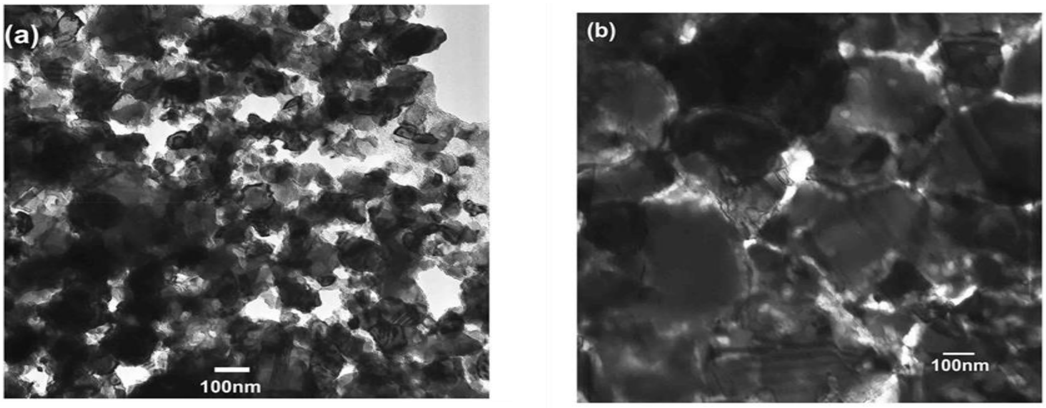

Figure 2. The Microstructure (SEM) after sintering of (a) $Ni_{0.7}$ $Mn_{0.3}$ and (b) $Ni_{0.5}$ $Mn_{0.5}$ alloys.

The particles became rounded and larger than Ni Mn roughly. This growing of the particles completely reduced porosity. Also, from ferromagnetic to antiferromagnetic behavior the phase structure expected the changeable to BCC structure accompanied with changeability. Figure 3 shows X-ray diffraction patterns of various Ni-Mn Phase ranging from 0.7, 0.5, and 0.2%. $Ni_{0.7}$ $Mn_{0.3}$ with high nickel concentration which were found to have a face –centered cubic (FCC) structure. Ni $_{0.5}$ Mn $_{0.5}$, Ni $_{0.2}$ $Mn_{0.8}$ with Lowe of nickel value we observed mixed FCC – BCC structure. (10).

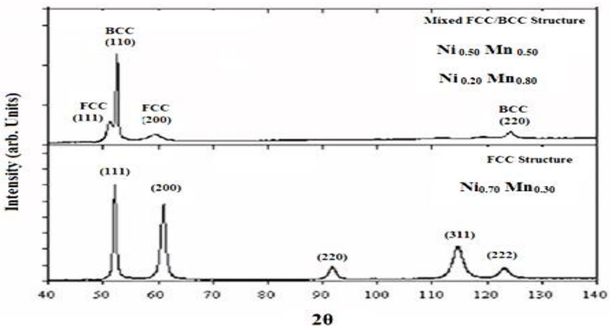

Figure 3. X-ray diffraction patterns of various concentration of Ni in Ni-Mn alloys

All the linear thermal expansion for series of dilatometric curves of Ni – Mn system are shown in Fig. 4. Interne stingily low thermal expansion was found in the dilatometric curve with high percentage of Ni (Ni $_{0.7}$ Mn $_{0.3}$), below Curie temperature around 950 K. This sample has an FCC (α – Phase) structure and negative thermal expansion. The influence of this ferromagnetic behavior is called in physics the INVAR effect. Above Curie temperature (Tc), the sample expansion appeared linearly with increasing in the temperature. This phenomenon is not Round in other alloys Ni $_{0.5}$ Mn $_{0.5}$ and $Ni_{0.2}$ $Mn_{0.8}$ as shown in Fig. 4. At Ni $_{0.5}$Mn $_{0.5}$ two distinct maxima were observed above 600 K. This Position range has an (α- β phases) with antiferromagnetic behavior, positively linear thermal expansion, where there is no Invar behavior (9).

The other sample Ni Mn also shows positive linear thermal expansion with one distinct maxima at about ~ 480 K. This result reveals that alloy is an antiferromagnetic behavior, BCC structure (β-phase), where there is no INVAR product. Finally the magnetic properties results obtained from (VSM) measurement are shows in Fig. 5.

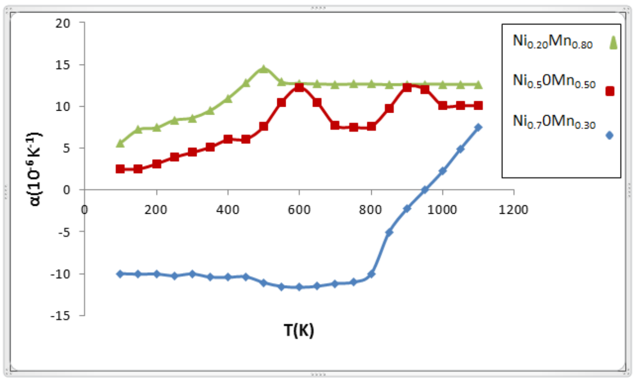

Figure 4. The linear thermal expansion coefficient of Ni – Mn alloys.

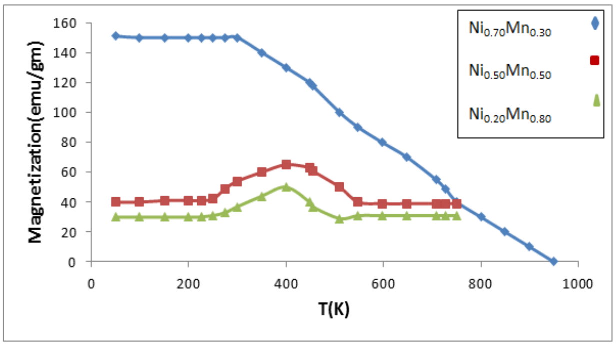

Figure 5. The magnetization properties of Ni – Mn alloys.

Ni $_{0.7}$ Mn $_{0.3}$ alloy shows the ferromagnetic behavior below curie temperature T_c due to the interaction between parallel spins. Above this curie degree all spin change randomly which is paramagnetic structure. This alloy also shows negative thermal expansion below curie temperature. The other alloys Ni $_{0.5}$Mn $_{0.5}$ and Ni $_{0.2}$Mn $_{0.8}$ are antiferromagnetic behavior below Neel Temperature T_N due to the interaction between ant parallel spins. Above T_N all spins also move randomly to paramagnetic state. These alloys show positive thermal expansion and magnetic transformation occurs from ferromagnetic (α-phase) FCC to antiferromagnetic (β-α phase) BCC structure produce normal expansion. Similar effects have been seen in other Invar alloys of Fe $_{0.8}$ Ni$_x$ Cr$_{0.2}$ system (11). They found that phase instability play an important role in the thermal and magnetic properties. Also the reason of negative thermal expansion of system Fe_{1-x} Ni_x is explained as the interaction between lattice vibration and magnetic degrees of freedom (12, 13).

Conclusions:

In this work, the effect of nominal composition on thermal, magnetic and structure properties of Ni_{1-x} Mn_x alloys with x=0.3 ,0.5, 0.8 is investigated. It is found that, $Ni_{0.7}$ $Mn_{0.3}$ alloy shows FCC structure ferromagnetic behavior with negative thermal expansion below curie temperature T_c, which is Invar phenomenon, The other alloys Ni $_{0.5}$ Mn $_{0.5}$ and Ni $_{0.2}$ Mn $_{0.8}$ are mixing structures (FCC – BCC) and (BCC) respectively. Both alloys have Antiferromagnetic structure with Neel temperature T_N, Positive thermal expansion and no Invar behavior. For (SEM) it is found that the particles become rounded and larger than Ni Mn roughly. This growing of the particles completely reduces porosity. The linear thermal expansion coefficient is found above Curie temperature (T_c), the sample expansion linearly with increasing the temperature. Also the other sample Ni Mn shows positive linear thermal expansion with one distinct maxima at about ~ 480 K. This result reveals that alloy is antiferromagnetic behavior.

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Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Tikrit.

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الخصائص التركيبية والحرارية النادرة لسلوك سبائك الانفار Ni-Mn

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الخلاصة:

ان تأثير الانفار يكون للمعادن الانتقالية بثلاثة ابعاد مثل Ni و Mn والمحضرة بسلسلة من المتراكب ذو النظام الثنائي $Ni_{1-x}Mn_x$ مع x = 0.3, 0.5, 0.8 تم باستخدام تقنية ميتالورجيا المساحيق. في هذا العمل تم تناول توصيف الخصائص التركيبية والحرارية والتي تم اختبارها تجريبياً بواسطة حيود الأشعة السينية ومعامل التمدد الحراري وتقنيات مقياس المغنطيسية الاهتزازية (VSM). أظهرت النتائج أن معامل التمدد الحراري السلبي المجهول متغير في التركيب. وقد اوضحت النتائج ان هناك علاقة بين عدم الاستقرارية والبروم المغناطيسية مع تشوه الشبيكة على بعض المعادن الفيرومغناطيسية.

الكلمات المفتاحية: تأثير الانفار، تشوه الشبيكة، الخصائص المغناطيسية، ميتالورجيا المساحيق، التمدد الحراري.