Effect of Annealing Temperature on Magnetic and Structural Properties of Alnic0-5 Alloy

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Abstract

The crystal structure of an Alnico-5 Alloy during different annealing temperature up to 1050 °C for 1 hour has been monitored by measuring the magnetic hysteresis loop.X-ray diffraction and vibrating sample magnetometer (VSM) were used to characterize the phase composition and magnetic properties. The results found that, the effect of the annealing degree is the major parameter on particle size, phase transition and magnetic properties. The results also showed that particle size decreased with the increasing temperature from 18.3 nm at room temperature to 12.2 nm at 950 °C. The maximum coercive force (Hc) with residual magnetization (Br) also increased with increasing temperatures above RT. The oxidation of the alloy with new crystalline phase leads to change the magnetic and structure properties at 1050 °C were found. A good correlation has been established between the structure and magnetic properties.

Introduction

Alnico alloys are very important group of Permanent magnetic alloys which are used in wide range of electrical and electronic devices [1, 2].

They contain Fe, Co, Ni and Al with minor addition of Cu and Ti [3, 4]. This alloys have attracted considerable work, both theoretical and experimental because of their magnetic properties, good corrosion resistance, heat treatment, high curie temperature and the highest saturation magnetistation [5]. More recently the structure of some titanium and niobium adding to the Alnico composition have been examined in an attempt to find the reason for their high coercivity and saturation magnetization [6, 7].

These Alnico alloys can be divided into more than nine types, depending on atypical nominal composition and improvement in magnetic properties during a suitable method of preparing [3, 5].

Most of the studies and all attention in the literature have been focused in magnetic, electrical and mechanical properties, and the understanding the effect of heat treatment on magnetic and structural properties of Alnico-5 is still insufficient. The major reasons of our work is to get better understanding, the correlation between the variations of the magnetic and structure values at different annealing temperature.

Experimental Work

Laboratory ingots (1 Kg) of Alnico-5 magnetic alloy was prepares as abulk using high purity materials (≥99.97%) of Co, Ni, Cu, Al and Aramco Iron. The materials were melted in high frequency induction furnace using acrucible of pure alumina. The aluminium was added during the final stages of melting to prevent excessive losses of this element. The alloy was then given thermomagnetic treatment at 1200 °C then slow cooling in a magnetic field of 3500 Oe for 30 minutes, followed by aging at 600 °C for 2 hr. Compositional analysis of the bulk specimens determined by Atomic absorption flame emission (ABE) type (shimad 24, AA-670) and compared with the Energy dispersive X-ray analysis (EDSX) type (Quanta 200, FEI 2003). Samples were annealed at various temperatures 700, 950 and 1050 °C for 1 hr and then slow cooling by using Carbolite furnace type 201. The temperature during the annealing was stabilized to better than ±2 °C.

The samples were characterized structurally for different annenl temperatures by X-ray diffraction using Co K_α, λ= 0.179 nm radiations on a Philips diffractometer type 1729.

The average particle size estimated from Scherrer formula which is connected to the XRD line width [8].

Magnetic measurements were obtained by using vibrating sample magnetometer (VSM) and portable χ_m susceptibility system. The coercive force H_c, remanent magnetization B_r have been measured from (B-H) hysteresis loops at different annealing temperature.

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The thermal stability were studied also by differential thermal analysis (DTA) using equipment type (Netzsch, Sta, 409) at heating rate 5 °C/min in continuous heating experiment.

Results and Discussion

The alloys have been prepared for this work having the chemical compositions given given in table (1). The composition alloys presented by different methods are similar values, showing that atypical close to the standered values [8]. Atypical energy spectrum for this alloy (EDSX) is shown in figure (1). Analysis of this spectra have measured after background subtraction and separation of the overlapping peaks.

Figure (2) shows the X-ray diffraction pattern at variable annealing temperatures, which approved that have phase in cubic structure. It is clear from the figure that the diffraction peak at 2θ= 51.08 becomes narrower than at room temperature, which indicates that the crystallized structure dominated bellow 950 °C, which could be due to BCC structure. This has been characterized as a strongly ferromagnetic by high iron or cobalt content (Fe Co) phase.

Appreciable difference pattern with small split was found when the alloy is annealed at 1050 °C, which indicated that Oxidation or a significant new structure change, probably a weakly ferromagnetic (Ni-Al) phase. This can be must clearly seen in figure (2).

The structure transformation also detected very clear from thermal analysis (DTA) as can be seen in figure (3).

The hysteresis loops (H-B) at different annealing temperature are given in figure (4). Increase in magnetic properties with increasing anneal temperature was observed. The coercivity force H_c and remanence magnetization B_r appeared to change more significantly and shifts sign above RT, which is related an improvement of soft magnetic behavior. Aremarkable increase of H_c at 1050 °C was observed but B_r was no sensitive effect to this anneal temperature. This could be due to transfer into another phase as mentioned earlier with the XRD results.

Finally, this changeable of these magnetic quantities can be explained as related to the degree of crystallization which governs by influence of average particle size. The grain sizes calculated from Scherer equation and it is found of 18.3 nm at RT, while reaches ~12.2 nm at 950 °C, which can play important role to control the mobility of domain walls of magnetic structure. Therefore, leading to conclusion that the magnetic prosperities must contain small particle size in order to keep a maximum of coercivity and remanence values.

Conclusions

Alnico-5 alloy was prepared using a high purity materials in high frequency induction furnance.

Changes in magnetic and structural properties were examined under the influence of different annual temperatures for 1 hr.

From the hysteresis loops, the coercivity force and remanence magnetization parameters were found increase up to 950 °C.

Aremarkable increase of coercivity force at 1050 °C was observed but the remanence was found to be independent, probably due to Oxidation or anew phase dominated.

Similar results have also obtained by X-ray diffraction. Appreciable difference pattern was found after annealing at this degree.

We investigated also the influence of particle size on the magnetic properties, and we found that the particle size strongly related with the magnetic properties.

To get more physical information of this alloy, we suggest for future work to get thick films by variety techniques such as rf. sputtering or laser deposition.

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الخلاصة

تم سراقبة خاصية البناء البلوري لسبيكة الالمنيوم-5 خلال درجات حرارة تلبيد مختلفة تصل الى 1050 م خلال ساعة واحدة وذلك من خلال اجراء فحوصات حلقة الهسترة المغناطيسية.

استخدمت فحوصات حيود الاشعة السينية والمغناطيسية باسلوب اهتزاز النماذج المحضرة داخل مجال مغناطيسي لغرض تشخيص الخواص التركيبية والمغناطيسية عند درجات حرارة تلبيد مختلفة.

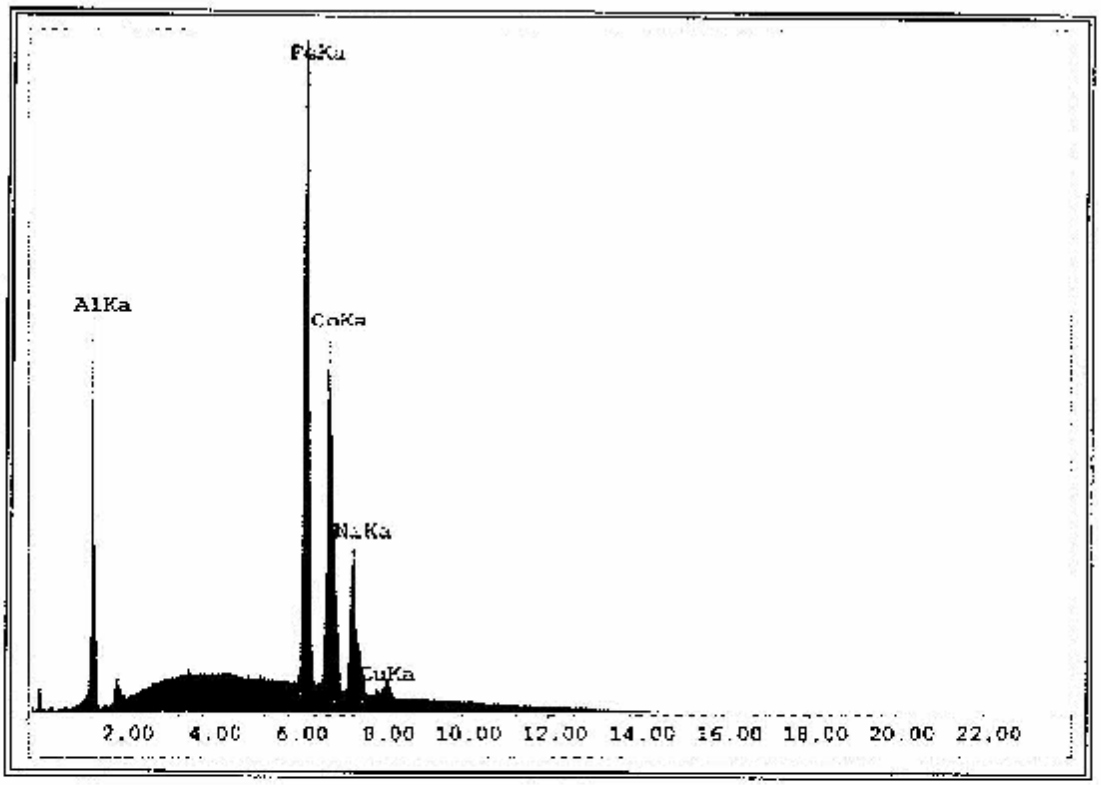
اكدت النتائج التجريبية الى ان درجة حرارة التلبيد تلعب دورا مؤثرا على الحجم الحبيبي الاطوار التركيبية والخواص المغناطيسية.

اظهرت النتائج بان قيم الحجم الحبيبي تقل مع ازدياد درجة حرارة التلبيد من 18.3 نانومتر عند درجة حرارة المختبر الى 12.2 نانومتر عند 950 م. كما لوحظ اقتران هذا التغير بازدياد قيم القوة القهرية (Hc) والمغناطيسية المتبقية (Br) مع زيادة درجات حرارة التلبيد.

اما عند درجة حرارة التلبيد 1050 م فقد لوحظ تغير مفاجئ في خصائص البناء التركيبي والمغناطيسي يعود الى احتمالية ظهور طور جديد او نشوء طور تركيبي جديد.

Table (1): Chemical compositions of the experimentally studied of Alnico-5 alloy.

Method	Chemical Composition, % wt				
	Co	Ni	Al	Cu	Fe
EDSX (Ingot)	23.21	14.60	8.74	3.63	Rem
ABE (Ingot)	23.81	14.13	8.60	2.98	Rem
Standard Values (2)	24	14.5	8.5	3	Rem



Element	Wt %	At %	K-Ration	Z	A	F
Alk	8.74	16.91	0.0422	1.0967	0.4400	1.0002
Fek	49.82	46.57	0.5062	0.9928	0.9981	1.0254
Cok	23.21	20.56	0.2268	0.9725	1.0001	1.0047
Nik	14.60	12.98	0.1422	1.0074	0.9670	1.0000
Cuk	3.63	2.98	0.0335	0.9591	0.9622	1.0000
Total	100.00	100.00				

Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
Alk	102.21	11.70	0.86	8.73
Fek	219.55	6.75	0.54	32.51
Cok	78.31	5.73	0.94	13.66
Nik	38.33	5.15	1.42	7.45
Cuk	6.85	4.26	4.47	1[.61

Figure (1): EDAX for a Alnico – 5 Alloy showing elemental spectral peaks.

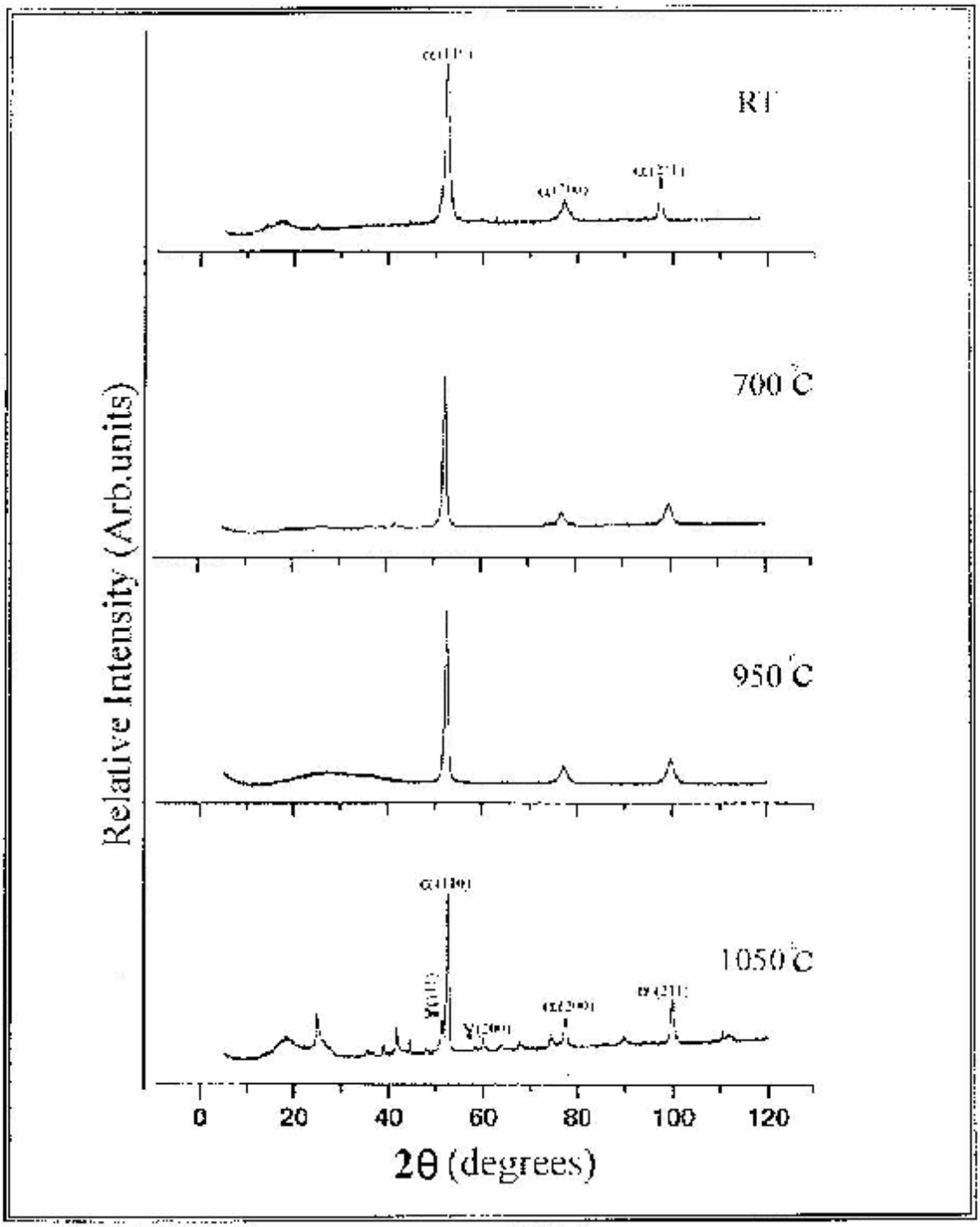


Figure (2): X-ray diffraction of Alnico-5 sections

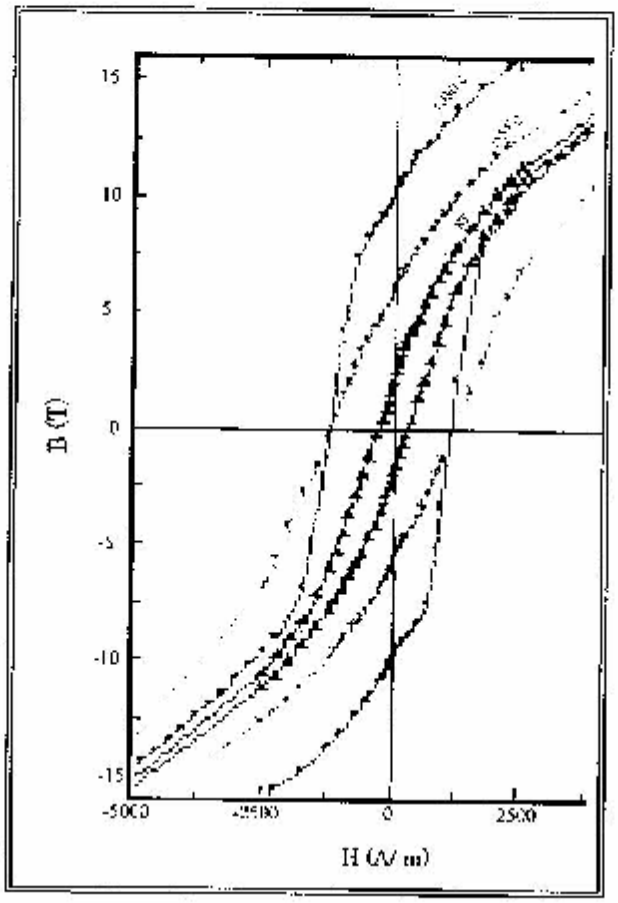


Figure (3): B-H Hysteresis loops of Alnico-5 Alloy at different anneal temperature

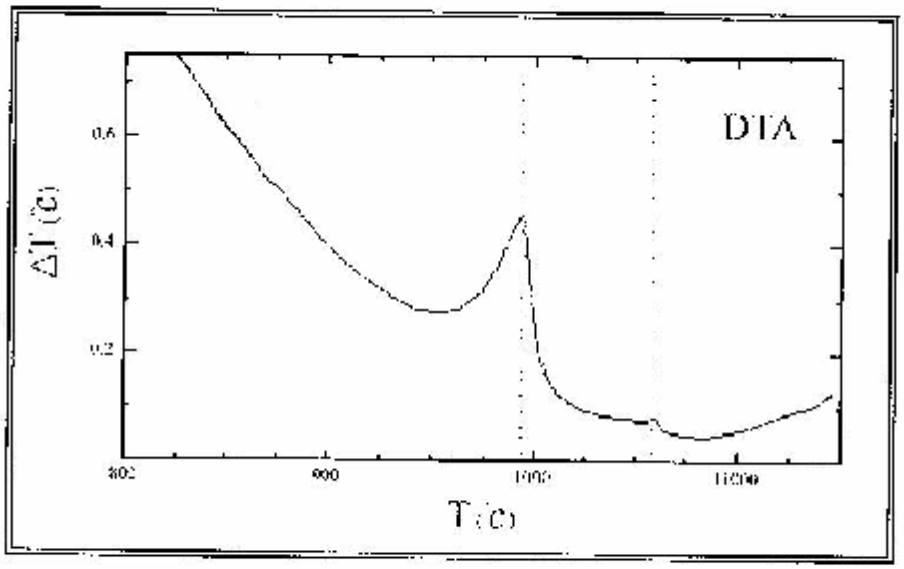


Figure (4): DTA measurement of Alnico-5 Alloy