Asian Journal of Chemistry; Vol. 26, No. 17 (2014), 5821-5823

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2014.18213

Structure and Magnetic Behaviours of Melt-Spun $Ti_{1.4}V_{0.6}Ni$ Alloy Containing Icosahedral Quasicrystalline Phase†

W. Hu[1], C. Yin[1], Z.Y. Ma[1], W.Q. Liu[1,*] and L.M. Wang[2,*]

[1]School of Materials Science and Engineering, Changchun University of Science and Technology, Changchun 130022, P.R. China
[2]State Key Laboratory of Rare Earth Resource Utilization, Changchun Institute of Applied Chemistry, CAS, Changchun 130022, P.R. China

*Corresponding authors: Fax: +86 431 85583015; Tel: +86 431 85583016; E-mail: wqliu1979@126.com; wanglm@ciac.ac.cn

AJC-15801

The ribbons of $Ti_{1.4}V_{0.6}Ni$ and TiVNi alloys were synthesized by arc-melting and subsequent melt-spinning techniques. The structures and magnetic properties were investigated. The results showed that the icosahedral quasicrystal (I-phase), Ti_2Ni-type face centered cubic (FCC) phase and body centered cubic (BCC) structural solid solution phase existed in $Ti_{1.4}V_{0.6}Ni$ alloy and the Ti_2Ni-type FCC phase and BCC solid solution phase presented in TiVNi alloy. The relationships of M-H (magnetization - magnetic field) and M-T (magnetization-temperature) of the alloy ribbons were investigated by using SQUID (superconductivity quantum interference device). The results demonstrated that the magnetic behaviour was different, which is the $Ti_{1.4}V_{0.6}Ni$ alloy ribbons exhibited higher ferromagnetic properties than those of TiVNi alloy ribbons both at 15 and 300 K.

Keywords: Alloys, Magnetic properties, Magnetic behaviour, Icosahedral quasicrystal, Ferromagnetic properties.

INTRODUCTION

Since the quasicrystalline alloy was first observed in 1984, a number of icosahedral quasicrystalline phases (I-phase) have been successfully obtained. One of the most interesting challenges in quasicrystal research is the discovery of the relationship between the unusual structural and the physical properties of these materials. In particular, it may be expected that the non-periodicity of the atomic arrangement influences the electronic and magnetic properties of quasicrystals. The structural and physical characteristics of Ti-based quasicrystals are still interesting in terms of the structural stability[1,2] and potential applications in hydrogen storage materials[3,4]. The magnetic ordering of localized spins in quasiperiodic structures is also a fundamental issue for study.

Among Ti-based quasicrystals, Ti-Zr-Ni alloys are known to be the best ordered of forming quasicrystal without silicon, comparing with two exceptions, Ti-Zr-Co and Ti-Zr-Fe[5,6]. Although the structure, electrochemical characteristics and mechanical properties of quasicrystals have been lively researched[7,8], but few studies on the magnetic properties have yet been reported. Two kinds of magnetic quasicrystals have been investigated so far. The first belongs to the icosahedral i-AlPdMn and i-AlCuFe families, where the *d* electrons of the transition metal elements represent the reoriented magnetic dipoles[9,10]. The second is a rare earth (RE) containing icosahedral families RE-Mg-Zn and RE-Mg-Cd, where the magnetic moments of *f* electrons of the rare earth atoms are sizable and well localized[9,11,12]. For Ti-based quasicrystals, a few results were reported about the magnetic properties, including the magnetic susceptibilities of Ti-Cr-Si-O alloys[13], the magnetic behaviours of $Ti_{50}Zr_{33}Ni_{17}$[14], the superconductivity property of quasicrystals dominant Ti-Zr-Ni alloy[15] and combined with the role of hydrogen in magnetism[16].

In this work, author investigated the magnetic properties of melt-spinning $Ti_{1.4}V_{0.6}Ni$ and TiVNi alloys by using SQUID, in order to further understand the magnetic properties of $Ti_{1.4}V_{0.6}Ni$ quasicrystals.

EXPERIMENTAL

Pieces of Ti, V, Ni with purities higher than 99.9 % were arc-melted in an argon atmosphere on a Cu hearth which is cooled by water. To minimize the oxygen contamination, the sample chamber was evacuated to 10^{-5} torr and was back and forth filled with high purity argon gas for three times. For the homogeneity of the samples, the ingots were melted at least three times and were flipped at each melting-cooling cycle.

†Presented at 2014 Global Conference on Polymer and Composite Materials (PCM2014) held on 27-29 May 2014, Ningbo, P.R. China

The $Ti_{1.4}V_{0.6}Ni$ and TiVNi alloy ribbons of 2.5 mm in width and 35 µm in thickness were prepared by a single roller melt-spinning method under an argon atmosphere. The circumferential velocity of the copper wheel was 34 m/s. This method could achieve a cooling rate from 10^5 to 10^6 ºC/s, which is fast enough to solidify the liquids and form a non-equilibrium phase. The phase of the as-obtained ribbons was determined by X-ray diffraction (XRD). The magnetization measurements were carried out at the range of 15-300 K using an MPMS-XL-7 SQUID magnetometer, Quantum Design Co. Ltd., USA.

RESULTS AND DISCUSSION

Phase structure: Fig. 1 shows the XRD patterns of the $Ti_{1.4}V_{0.6}Ni$ and the TiVNi alloys. From Fig. 1(a), all diffraction peaks of the $Ti_{1.4}V_{0.6}Ni$ alloy could be indexed to the I-phase, Ti_2Ni-type face centered cubic (FCC) phase and body centered cubic (BCC) solid solution phase. Fig. 1(b) shows that the XRD pattern of the TiVNi indexes Ti_2Ni-type face centered cubic (FCC) phase and body centered cubic (BCC) solid solution phase.

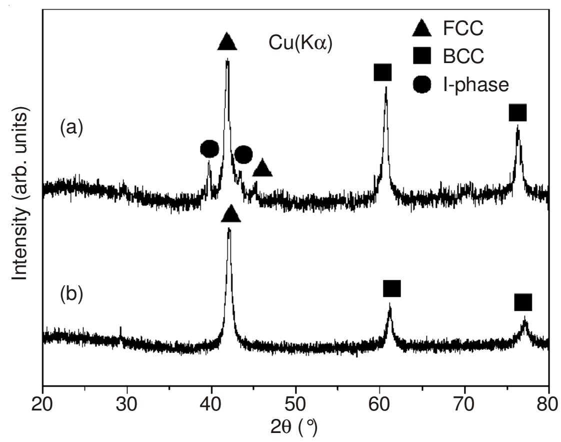

Fig. 1. XRD patterns of (a) $Ti_{1.4}V_{0.6}Ni$ and (b) TiVNi alloys

Magnetic behaviours: The magnetic behaviour was investigated by zero field cooled (ZFC) and field cooled (FC) magnetization measurements. Fig. 2 shows the magnetization curves of the quasicrystal alloys $Ti_{1.4}V_{0.6}Ni$ as a function of temperature under these two measurement configurations. For zero field cooled measurement, the sample was cooled to 5 K in zero fields and then measured up to 300 K in the range of 100 Oe while the field cooled measurement was made by cooling the sample from 300 to 5 K in the same range. It clearly shows that there is a furcation between zero field cooled and field cooled curves at a particular temperature (T = 290 K), which is one of the characteristic features of a superparamagnetic system.

We have also measured the magnetization of $Ti_{1.4}V_{0.6}Ni$ and TiVNi alloys as a function of an applied magnetic field (H) to understand the magnetic state of the quasicrystal at 15 and 300 K, respectively. Visible hysteresis loop could be observed for both of the samples [Fig. 3(a,b)], which demonstrates that both alloys show ferromagnetic properties. However the coercive force (H_c) and the remanent magnetization (M_r) are very tiny and the values of H_c and the M_r are listed in Table-1, which demonstrates that they showed soft magnetism.

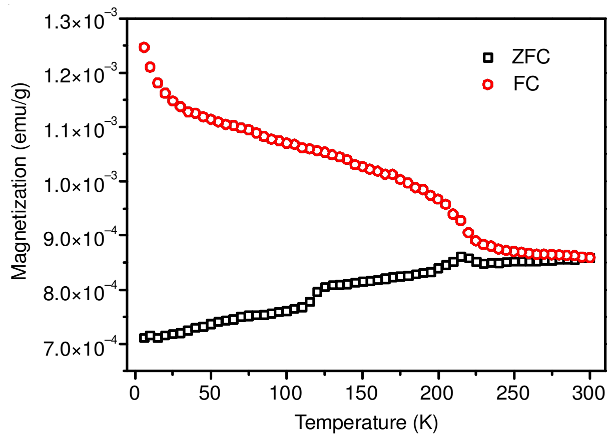

Fig. 2. Plot of magnetization of $Ti_{1.4}V_{0.6}Ni$ quasicrystal for FC and ZFC processes at 100 Oe

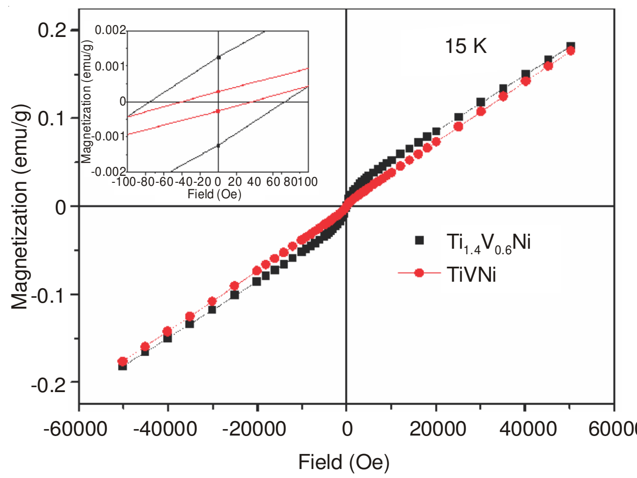

Fig. 3. Plots of magnetization of $Ti_{1.4}V_{0.6}$ Ni alloy and TiVNi alloy as a function of applied magnetic field at 15 K

TABLE-1
STRUCTURE, H_c AND M_r OF $Ti_{1.4}V_{0.6}Ni$ AND TiVNi ALLOYS

Sample	Structure	H_c (Oe)		M_r (emu/g)	
		15 K	300 K	15 K	300 K
$Ti_{1.4}V_{0.6}Ni$	I, FCC, BCC	75.5	32.5	0.001	0.0004
TiVNi	FCC, BCC	40.7	29.8	0.0003	0.0002

It is noticed that the magnetic properties of $Ti_{1.4}V_{0.6}Ni$ and TiVNi alloys (Fig. 4) show some dependency on their structure, the I-phase will result in more contribution to the magnetization of the sample[14]. As mentioned above, the $Ti_{1.4}V_{0.6}Ni$ alloy contains I-phase, Ti_2Ni-type face centered cubic (FCC) phase and body centered cubic (BCC) solid solution phase while TiVNi alloy only contains Ti_2Ni-type face centered cubic (FCC) phase and body centered cubic (BCC) solid solution phase. In the results, as listed in Table-1, the H_c and the M_r of the $Ti_{1.4}V_{0.6}Ni$ alloy, in which I-phase is involved, are higher than that of the TiVNi alloy. In both samples, Ni plays an important role in a stabilization of the quasicrystal phase and is the origination of the magnetic properties in the samples.Both in $Ti_{1.4}V_{0.6}Ni$ and TiVNi alloys, the concentration of Ni is invariable and the difference of their magnetic properties is resulted from their difference in structure when the ratio of Ti to V is varied, for both Ti and V show nonsignificant magnetic properties themselves. Therefore, it is reasonable to explain that

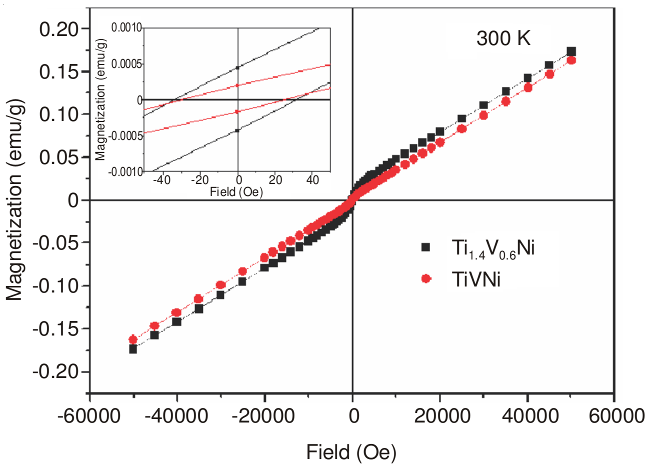

Fig. 4. Plots of magnetization of $Ti_{1.4}V_{0.6}$ Ni alloy and TiVNi alloy as a function of applied magnetic field at 300 K (b)

the I-phase will make more contribution to their ferromagnetic properties.

Conclusion

In present studies, we have prepared $Ti_{1.4}V_{0.6}Ni$ and TiVNi alloys by melt-spinning method. The phase was identified by XRD. The $Ti_{1.4}V_{0.6}Ni$ phase structures are composed by the icosahedral quasicrystal, Ti_2Ni and BCC structural solid solution phase and the TiVNi phase structures are composed by Ti_2Ni and BCC structure solid solution phase. The magnetic behaviours of the samples were examined and their difference that resulted from mixed structure was noticed and discussed. It is supposed that I-phase will make more contribution to the ferromagnetic properties of the $Ti_{1.4}V_{0.6}Ni$ and the TiVNi samples.

ACKNOWLEDGEMENTS

This work is financially supported by the Specialized Research Fund (Youth Teacher Category) for the Doctoral Program of Tertiary Education of the Ministry of Education of China (20112216120001), the Jilin Province Development Program of Science and Technology (20140204055GX), the Jilin Province Natural Science Foundation (201215141).

REFERENCES

1. R.M. Stroud, A.M. Viano, P.C. Gibbons, K.F. Kelton and S.T. Misture, *Appl. Phys. Lett.*, **69**, 2998 (1996).
2. K.F. Kelton, W.J. Kim and R.M. Stroud, *Appl. Phys. Lett.*, **70**, 3230 (1997).
3. A.M. Viano, R.M. Stroud, P.C. Gibbons, A.F. McDowell, M.S. Conradi and K.F. Kelton, *Phys. Rev. B*, **51**, 12026 (1995).
4. J.Y. Kim, R. Hennig, V.T. Huett, P.C. Gibbons and K.F. Kelton, *J. Alloys Comp.*, **404-406**, 388 (2005).
5. W.J. Kim and K.F. Kelton, *Philos. Mag. A*, **72**, 1397 (1995).
6. W.J. Kim and K.F. Kelton, *Philos. Mag. Lett.*, **74**, 439 (1996).
7. W.J. Kim, P.C. Gibbons and K.F. Kelton, *Philos. Mag. A*, **78**, 1111 (1998).
8. A. Sadoc, J.Y. Kim and K.F. Kelton, *Philos. Mag. A*, **79**, 2763 (1999).
9. S. Nimori, A.P. Tsai and G. Kido, *Physica B*, **237-238**, 565 (1997).
10. M. Roy, *J. Magn. Magn. Mater.*, **302**, 52 (2006).
11. D. Rau, J.L. Gavilano, Sh. Mushkolaj, C. Beeli and H.R. Ott, *J. Magn. Magn. Mater.*, **272-276**, 1330 (2004).
12. I.R. Fisher, Z. Islam, J. Zarestky, C. Stassis, M.J. Kramer, A.I. Goldman and P.C. Canfield, *J. Alloys Comp.*, **303-304**, 223 (2000).
13. J.Y. Kim, J.S. Schilling and K.F. Kelton, *Solid State Commun.*, **105**, 551 (1998).
14. Y.M. Lee, J.K. Jeon, H.M. Shin and J.Y. Kim, *Z. Kristallogr.*, **224**, 67 (2009).
15. V. Azhazha, A. Grib, G. Khadzhay, S. Malikhin, B. Merisov and A. Pugachov, *Phys. Lett. A*, **303**, 87 (2002).
16. P. Termsuksawad, S. Niyomsoan, R.B. Goldfarb, V.I. Kaydanov, D.L. Olson, B. Mishra and Z. Gavra, *J. Alloys Comp.*, **373**, 86 (2004).