Analyzing of Phase Change on Binary Alloy System Pt$_{1-x}$ Mn$_x$ (X= 17.5 At. %) By Diffraction Method

Timbangen Sembiring$^{1,2}$, Kerista Tarigan$^3$

$^1$Department of Physics, Universitas Sumatera Utara, Medan, Indonesia
$^2$Nanomedicine Centre of Innovation-PUI, Universitas Sumatera Utara, Medan, Indonesia
$^3$Department of Physics, Universitas Sumatera Utara, Medan, Indonesia

Email: timbangen@usu.ac.id

Abstract. The research on analyzing of phase change on binary alloy Pt$_{1-x}$ Mn$_x$ (x= 17.5 at. %) system had been performed by diffraction and resistivity measurements. The purpose of this experiment is to investigate the change of order-disorder phase transition and its critical temperatures. The polycrystal samples of nominal concentrations of 17.5 were prepared from 99.999 % of pure platinium and 99.99 % of pure manganese. This sample was heat-treated separately at 1150°C for 2 days to remove strains. Then, the sample was quenched by dropping quickly into iced water to get a disordered state. X-ray diffractometer experimental results shows that samples contained 17.5 at. % Mn and heat-treated at the temperature of 1150°C for 2 days were in the disorder state. Meanwhile, ordered state was seen on the sample of 17.5 at. % Mn, heat-treated at 800°C for 10 days.

1. Introduction

The properties of binary alloy systems such as physical, mechanical, electronic, magnetic, thermal and optical properties are determined by the compositions of each elements and various heat treatments. Basically, variations on compositions and heat treatments causes atomic structural changes. Platinium rich and manganese are one of the examples of binary alloy systems showing several structural phases. Based on the phase diagram of Pt-Mn binary alloy system by Massalski, et al and Nagasaki, et al., (Handbook of Binary Alloy Phase Diagram), the faced centered cube-fcc was seen at the area of 17.5 up to 35 at. %. Pt$_3$Mn phase exists in the composition range of 20 to 35 at. % Mn under temperature of 950 °C.

Takahashi, et al. had reported the magnetic properties on the Pt-Mn binary alloy with composition of 12.5 at. % Mn by neutron diffraction experiment. On this composition, anomaly peak was seen on the susceptibility curve and remanent magnetization at the freezing temperature. Sembiring, T. et al investigated the structural fluctuation on Pt-Mn alloy system containing 12.5 at. % Mn single crystal using X-ray diffraction. Based on their results, there is an additional peak found on the sample of 12.5 at. % Mn besides the peak corresponding to the Pt$_3$Mn phase. Actually, this additional peak is rare to find in common binary alloy systems containing Pt-rich and 3d transition elements, indicating that double step-ordering occurs in the small area of Mn compositions.
Based on the phase diagram, it is still unclear information regarding the phase change on Pt-Mn alloy system especially in the area of Pt-rich. In this experiment, samples containing 17.5 at. % Mn are focused to investigate the phase change using XRD.

2. Methods and Experiment

The polycrystal specimens were prepared from 99.999 % pure platinum ingot and 99.99 % pure manganese flake. Those specimens were cut into small pieces, cleaned by chemical solution and weighted as indicated above compositions. Single crystal was grown by the Bridgmen technique. Each sample was put in to arc melting furnace, very low pressure and filled with an argon gas to avoid contamination by oxygen. After inverting and sparkling several times with high voltage, a homogenous sample was obtained. Those samples were heat treated in an evacuated quartz tube at 1150°C for 2 days for sample of 17.5 at. %. Then, the sample was quenched by dropping quickly into iced water to get a disordered state. In order to obtain an order state, this sample was annealed in vacuum quartz tube at 750°C for 5 days then the temperature was decreased gradually into room temperature. Four-circled goniometer X-ray diffraction with source of CuKα was used to perform the experiment to measure the intensity.

3. Results and Discussions

The intensity measurements were conducted on the single crystal sample containing Pt-17.5 at. % Mn by scanning along fundamental reflection of h00-axes, and along superlattice reflections of hhh-axes. The following figures are the peak profiles taken on the sample heat-treated at various temperatures. The values of half maximum (FWHM) were determined by Gaussian fits to each profile. Figure 1a shows intensity measurement on the sample which quickly quenched into ice water from 1150°C. The measured intensity on this sample is quite low although recorded in 10 seconds of counts and broadening along h00 axes. From this profile it is clearly seen that atomic disordering occurs on the alloy system during the heat treatment denoted by the value of FWHM. Disordering state is also confirmed by measured intensity scanning along hhh-axes in which a diffused peak occurred at (½½½) reflection with value of FWHM as 0.16a*.

Meanwhile, Figure 1b depicts a peak profile on the sample which annealed 750°C for 5 days and decreased gradually into room temperature. The measured intensity at the (100) reflection is higher compared to the intensity of quenched sample. On the other hand, the value of FWHM of this peak is decreased by 0.086a* which is comparable as one on the peak of (200) reflection, called a Bragg reflection.

By analyzing the value of FWHM, position of reflections and peak intensity for sample containing Pt-17.5 at % Mn, this experimental result shows that phase change occurred on the atomic ordering due to change of temperature treatments. Similar results had been reported on Pt-rich-Mn alloy system containing 12-15 at. % Mn by Takahashi, et.al in which phase Cu3Au existed on the small area of compositions. Under the critical temperature, Cu3Au phase show reflections on h00-axes and equivalent positions.
Figure 1. Peak profiles taken along h00- and hhh-axes on the samples containing Pt-17.5 at. % Mn with various heat treatments. (a) Broad peak profile at (100) for quenched sample, (b) peak at (100) for annealed sample, (c) peak profile for (200) reflection (Bragg reflection) and (d) peak profile taken along hhh-axes.

Peculiar results had been reported by Sembiring, et.al, on Pt7Mn in which a unique phenomenon of phase change occurred under in-situ experiment. They explained the existence of a new type of ordering phase called ABC6-type ordering structure below temperature of 650 °C. Then, phase CuPt3 was seen between the temperature of 650 °C up to 1000 °C. Above 1000 °C, the disordered state occurred which indicated by diffused peak at (100) and equivalent positions and relatively lower in intensities.

4. Conclusions

Based on the above experimental results, it can be drawn some conclusions related to the phase change on Pt-17.5 at. % Mn. Atomic disordering phase occurs on the sample quenched at temperature of 1150°C indicated by diffused peaks with a higher value of FWHM both at h00-axes and hhh-axes and equivalent positions. Ordering state is clearly seen on the sample when it was annealed at 750°C for 5 days and decreased gradually into room temperature. Measured intensity at (100) and equivalent positions gave more confirmation that atomic ordering Cu3Au phase occurred in this alloy composition. The values of FWHM on (100) and (200) peaks are comparable. For the future work, it is very important to measure electrical resistance as a function of temperature on this sample, so that the critical temperature of phase change can be recorded.
5. References

[1] Khachaturyan, A. G 1978, Prog. Mater. Sci. 22 (4) 24.

[2] Kittel C, 1997 Introduction to Solid State Physics (John-Wiley, New York,) 7th ed., p. 23.

[3] Massalski, T. B, Okamoto, P. R, Subramanian, H and Kacprzak, 1990, Binary Alloy Phase Diagrams (ASM International, Materials Park, 2nd ed., p. 1579.

[4] Morgownik, A. F. and A. Midosh, J, 1983, Solid State Commun. 47 325.

[5] Ohshima, K and Watanabe, D, 1973, Electron diffraction study of short-range-order diffuse scattering from disordered Cu–Pd and Cu–Pt alloys: Acta Cryst. A 29, 520.

[6] Raub, E and Mahler, W 1955, Die Legierungen des Mangans mit Platin, Iridium, Rhodium und Ruthenium, Z. Metallk. 46 282.

[7] Rudman, P.S, 1960, A zeroth approximation calculation of order with application to the phase diagram, Acta Metall. 8 321.

[8] Schneider, A and Esch, U, 1944, Z. Elektrochem. 50, 290.

[9] Saha, D. K. and Ohshima, K, Wey, M. Y, Miida, R and Kimoto, T, 1993, Structure and magnetism of fcc Pd–Mn alloys: J. Phys.: Condens. Matter 5, 4099.

[10] Saha, D. K., Shishido, T and Ohshima, K, 2002, X-Ray Diffraction Study of Atomic Short-Range Order in Pt–15.0 at.% Cr Alloy, J. Phys. Soc. Jpn. 71, pp. 2456-2458

[11] Sembiring, T, Takahashi, M, Yashima, M, Shishido, T and Ohshima, K, 2002, A partial phase diagram of Pt-rich Pt-Mn Alloys, J. Phys. Soc. Jpn. 71, 2459-2465.

[12] Takahashi, M, S. Yoshimi, K, Ohshima and Y, Watanabe, 2000, Atomic and magnetic short-range order in a Pt–8.8 at.% Mn spin-glass alloy, Phys. Rev. B 61 3528.

[13] Takahashi, M, Sembiring, T, Yashima, M, Shishido, T and Ohshima, K, 2002, ABC6 Type Ordered Structure in Pt-rich Pt-Mn Alloys, J. Phys. Soc. Jpn. 71 681.