On the Magnetometric Studies of Transformation in Pure Manganese

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Synopsis

The transformation points in pure distilled manganese were magnetometrically investigated by the modified Weiss's method. It was found that the manganese had four phases, α, β, γ and δ, in solid state and that the three transformation points were 702, 1065 and 1138°C, respectively. The melting point of the pure manganese was 1252°C. The behaviours of these transformations were also clarified.

I. Introduction

When a pure solid manganese is gradually heated, transformations occur three times; passing successively through the β and γ states, α manganese is transformed into the fourth phase δ. This was early discovered at Prof. T. Ishiwara's laboratory in our Institute. The existences of α, β and γ phases were determined by the present writer by means of a thermal dilatation and other methods and the results were utilized in the studies on the diagrams of Al-Mn and Fe-Mn binary alloys and reported at the World Engineering Congress.(1) Moreover, the existence of a new phase δ differing from the above-mentioned had been predicted beforehand in that report and was determined in our laboratory(2) by measuring its specific gravity in a salt bath at high temperatures.

The magnetic properties of manganese at high temperatures were already studied by Dr. K. Honda,(3) Dr. Y. Shimizu,(4) and Grube and Winkler.(5) But their results were not always in agreement with the present result obtained with a pure manganese.

II. Method of experiment and specimen

The pure distilled manganess specimen was sealed in a transparent silica tube to prevent oxidation and the magnetizations were measured during heating and cooling. To prevent the mutual reaction of silica tube and manganese at high

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* The 622nd report of the Research Institute for Iron, Steel and Other Metals.

(1) T. Ishiwara, World Engineering Congress, Tokyo (1929).

(2) H. Yoshisaki, Chemical Society of Japan, 54 Annual Meeting, Kyoto (1932), Kinzoku no Kenkyu 14 (1937), 91; Sci. Rept., 26 (1937) 182.

(3) K. Honda, Ann. der Phys., 32 (1910), 1027; Sci. Rept., 1 (1912), 1; M. Owen, Ann. der Phys., 37 (1912), 657.

(4) Y. Shimizu, Sci. Rept., 19 (1930), 411.

(5) G. Grube u. O. Winker, Zeit. Elektrochemie, 42 (1936), 815.

temperatures, this tube was filled with well burnt and chemically pure alumina powder and the silica tube was sealed after being evacuated to high vacuum for several hours at an optimum temperature.

The specimen was suspended horizontally in a gap between the poles of an electromagnet and the measurement was done by the modified Weiss's method. When the distance between the two magnetic poles was 40 mm and the magnetizing current was 20 amp, the magnetic field excited attained to about 8,000 Oersteds. The heating furnace, 40 mm in outer diameter, 15 mm in inner diameter and 140 mm in length, was wound with platinum wire to make it nonmagnetic. The measurement of temperature was done by using the well calibrated Pt-Pt·Rh thermojunction and potentiometer, the hot junction being placed near by the specimen.

Distilled manganese used in this investigation was of the following composition; carbon 0.01 per cent, aluminium 0.029 per cent, iron 0.045 per cent, silicon trace and manganese 99.9 per cent. It was distilled by the method usually adopted in our laboratory.(6) The shape of specimen used in this observation was almost ellipsoidal, the weight being about 1.2 grams.

III. Results

The results of measurements of magnetization are shown in Fig. 1. The specimen was first heated to about 1200°C and then cooled to room temperature, and re-heated to about 800°C and cooled, and finally heated to 1300°C which is higher than the melting point of manganese and cooled.

The magnetization of distilled manganese was stabilized by the recrystalization caused by heating at about 1070°C. Moreover, the magnetization was further stabilized by the process of repeated heatings and coolings, and thus the remarkable change of magnetization appeared at every transformation. The positions of transformation point however, were not influenced by these repeated heatings and coolings.

When the manganese was gradually heated from room temperature to high temperatures, the magnetization value decreased according to the Curie's law, but in the neighbourhood of 700°C, a sudden increase of magnetization appeared, showing that the transformation $M_1(\alpha \rightleftarrows \beta)$ took place at that temperature. The further heating showed a more increasing tendency toward magnetization and the second sudden increase appeared in the neighbourhood of 1060°C, showing the transformation $M_2(\beta \rightleftarrows \gamma)$. Thereafter, it increased at a smaller rate, and the third pronounced change appeared at about 1140°C, showing the transformation $M_3(\gamma \rightleftarrows \delta)$. Finally, at about 1250°C a very remarkable increase of magnetization suddenly appeared again, corresponding to the melting point of manganese. After that, the elevation of temperature in the small range of measurement in the molten state did not bring about the substantial increase of magnetization. In the

(6) H. Yoshisaki, Kinzoku no Kenkyu, 14 (1937), 91; Sci. Rept., 26 (1937) 182.

cooling stage, the magnetic property changed in the order reverse to the above as shown in Fig.

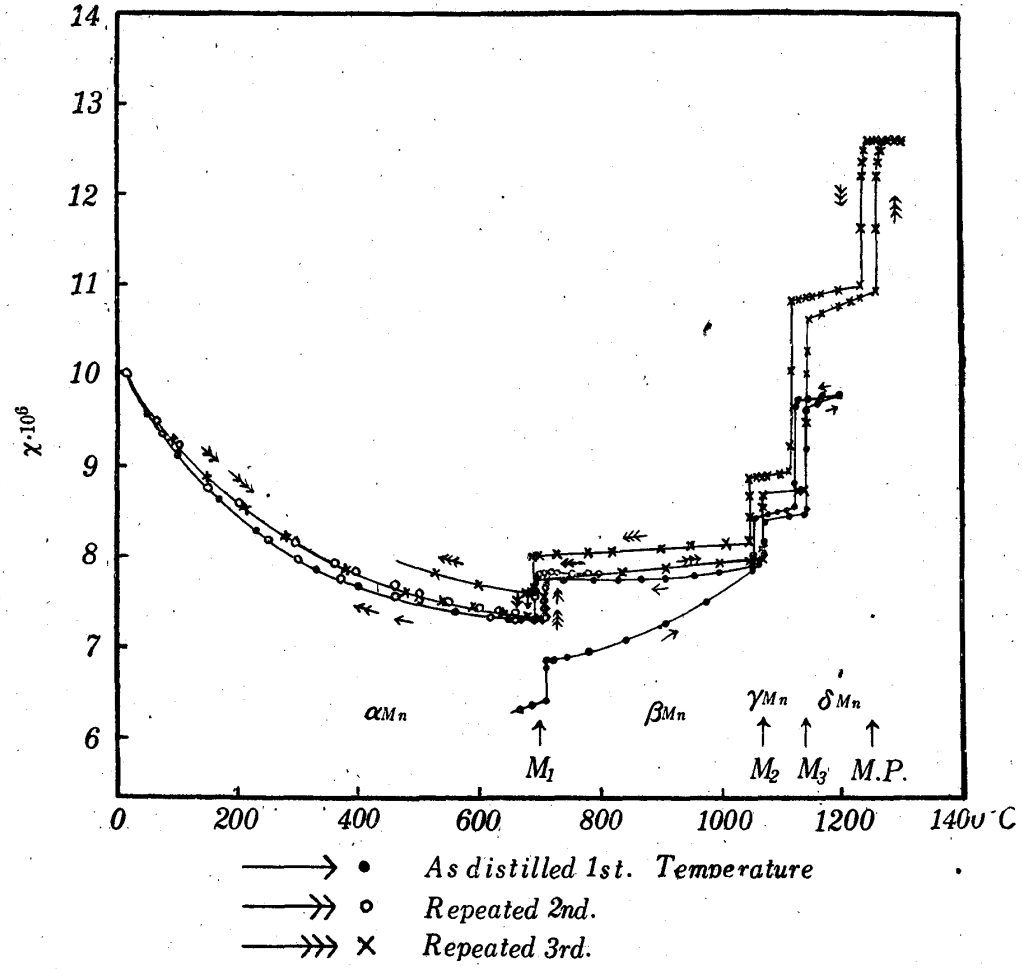

Fig. 1

The results mentioned above show the remarkable properties of manganese; the magnetization increases as the transformation proceeds and the value of magnetization in β, γ or δ state continuously increases at a small rate with the rise of temperature.

The accompanying table shows the transformation points of manganese at heating and cooling, respectively.

Table 1.

Transformation	Transformation temperature °C		
	Heating	Cooling	Mean
M_1	709	695	702
M_2	1072	1058	1065
M_3	1146	1130	1138
M. P.	1260	1244	1252

Summary

1. Transformation of pure distilled manganese was studied by means of magnetic analysis.

2. In solid state, manganese has three transformations at 702, 1065 and 1138°C, and melts at 1252°C.

3. The magnetization of manganese decreases gradually with the rise in temperature in α state and increases at a small rate in β, γ and δ states.

4. The magnetization of manganese increases remarkably at each transformation. The respective amount of increase is in the regular sequence of $M_1(\alpha \rightleftarrows \beta) < M_2(\beta \rightleftarrows \gamma) < M_3(\gamma \rightleftarrows \delta)$, and the amount of magnetic change at M_3 transformation point is about twice as large as those at others. At the melting point, the magnetization also increases, the amount being next to that at the M_3 transformation.

In conclusion, the present writer wishes to express his hearty thanks to Professor Dr. T. Ishiwara, the ex-director of the Research Institute for Iron, Steel and Other Metals, under whose kind direction the present investigation was carried out.