EFFECT OF RARE EARTH ON CONDUCTANCE OF ALUMINUM WIRE①

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ABSTRACT

Effects of Rare Earth (Hereafter RE) on the conductance of high-purity and industrial-purity aluminum wires have been studied. RE increases the resistivity of the high-purity aluminum. No evidence has been found that RE will decrease the resistivity of industrial-pure aluminum under various RE content including 0.3% Ce. The individual role of RE and its combined effects with Fe and Si have been discussed too.

Key words: aluminum wire, conductance, resistivity, rare earth (RE), Ce

1 INTRODUCTION

The effects of RE on electric aluminum have been studied for a long time. The results obtained are as follows: [1-5]

(1) RE can increase the strength and wear-resisting properties of some electric aluminum alloys and pure aluminum, increase the heat and oxidation resisting properties under temperatures higher than 150 ℃ and improve the cold wórkability of aluminum.

(2) No beneficial effect has been obtained by RE addition in the high-purity aluminum. Contrarily, the resistivity would be increased by adding RE even in very small amount.

(3) Different results have been obtained for the effect of RE on the electric conductance of industrial-purity aluminum (Aoo, Ao and A1) wires.

This paper describes the effect of RE on the conductance of industrial-purity aluminum wire. Since it is difficulty to obtain results of high accuracy and the accuracy of resistivity requires a figure up to $10^{-3}-10^{-4}$ $\Omega mm^2/m$, the results obtained would be reexamined in the later studies.

2 EXPERIMENT

The aluminum ingots of 500 g were refined in the graphite clay crucible resistance furnace. After refining the melts were held for 5 min, plunged REM and held for another 5 min, then poured into a cast iron mould. The impurities in the raw materials are 0.007,0% Fe, 0.002,4% Si and 0.002,3% Cu. Both metallic Ce and Mn were used. Compositions of the alloys are shown in Table 1. Aluminum ingots were heated to 450 ℃, then forging into 15 mm rods and further rolled into 6 × 6 mm bars at room temperature, then annealed at 410 ℃ and drawn to 3 mm wires by 6 passes. The resistivity measuring set is a newly built one. In

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order to reduce the measuring error, the testing conditions are as follows: The sample length is 2,000 mm, and its nominal diameter is 3 mm. The working current is about 330 mA, a standard resistance of 0. 01 was choosen.

In order to check the reliability of the results, resistivity of samples from the same batch have been measured both in the Institute of Metal Research and the Shenyang Electric Cable Works with a QJ–19 type DC resistance-measuring instrument. The process was made according to the national standard GB 3048 · 2.

3 RESULTS AND DISCUSSION

The results of resistivities of various samples measured in the Metal Research Institute and in Shenyang Electric Cable Works are listed in Table 2, from which we have found that their resistivities, change tendency, relative quantity and the general characteristics are almost the same.

3.1 *Effects of* Fe *and* Ce *on resistivity*

Fig.1 shows the resistivities of industrial-purity aluminum increase with the increase of Ce or Fe, and the effect of Fe is greater than that of Ce. Fig.2 shows the effect of Fe and that of Fe+Ce on resistivity. The resistivity values of the samples with Ce addition are greater than that without Ce addition in the

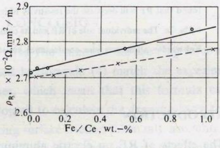

Fig1 Effect of Fe or Ce on Resistivity ρ_R

O—Fe added; X—Ce added

Table 1 Chemical Compositions wt.–%)

Samp. No.	Fe	Si	Fe+Si	RE	Samp. No.	Fe	Si	Fe+Si	RE
Ce1	–	–	–	Ce 0.034	FS8	0.05	0.42	0.47	0
Ce2	–	–	–	Ce 0.14	FS9	0.57	1.03	1.60	0
Ce3	–	–	–	Ce 0.29	FSC1	0.0067	0.0079	0.015	Ce 0.30
Ce4	–	–	–	Ce 0.50	FSC2	0.081	0.052	0.133	Ce 0.25
Ce5	–	–	–	Ce 1.04	FSC3	0.30	0.18	0.48	Ce 0.29
Fe1	0.04	–	–	0	FSC4	0.32	0.20	0.52	Ce 0.27
Fe2	0.1	–	–	0	FSC5	0.52	0.49	1.01	Ce 0.27
Fe3	0.53	–	–	0	FSC6	1.09	1.00	2.09	Ce 0.31
Fe4	0.92	–	–	0	FSC7	0.13	0.22	0.35	Ce 0.35
Fe5	0.02	–	–	Ce 0.33	FSC8	0.16	0.42	0.58	Ce 0.31
Fe6	0.1	–	–	Ce 0.28	FSC9	0.61	1.10	1.71	Ce 0.25
Fe7	0.43	–	–	Ce 0.29	FSR1	0.0075	0.0067	0.0142	RE 0.21
Fe8	0.97	–	–	Ce 0.28	FSR2	0.17	0.10	0.27	RE 0.30
Fe50	0.11	–	–	Ce 0.22	FSR3	0.23	0.14	0.37	RE 0.25
FS1	0.0062	0.0042	0.0104	0	FSR4	0.33	0.21	0.54	RE 0.43
FS2	0.056	0.07	0.126	0	FSR5	0.53	0.43	0.96	RE 0.23
FS3	0.1	0.11	0.21	0	FSR6	1.05	1.08	2.13	RE 0.30
FS4	0.25	0.22	0.47	0	FSR7	0.12	0.24	0.56	RE 0.51
FS5	0.51	0.50	1.01	0	RSR8	0.19	0.41	0.60	RE 0.30
FS6	1.08	1.25	2.33	0	RSR9	0.58	1.07	1.65	RE 0.30
FS7	0.08	0.23	0.31	0					

Table 2 Resistivity

Samp. No.	Resistivity, Ω mm²/m Elec. Cable Works	Inst. Met. Res.	Samp. No.	Resistivity, Ω mm²/m Elec. Cable Works	Inst. Met. Res.
Ce1	0.027100	0.026915	FS8	0.027895	0.027726
Ce2	0.027107	0.027094	FS9	0.028570	0.028530
Ce3	0.027174	0.027118	FSC1	0.027330	0.027120
Ce4	0.027474	0.027349	FSC2	0.027862	0.027617
Ce5	0.027819	0.027685	FSC3	0.028085	0.027838
Fe1	0.027271	0.026935	FSC4	0.028176	0.028211
Fe2	0.027247	0.026974	FSC5	0.028555	0.028357
Fe3	0.027764	0.027587	FSC6	0.029068	0.028770
Fe4	0.028332	0.027987	FSC7	0.028060	0.027902
Fe5	0.027383	0.027221	FSC8	0.028186	0.028261
Fe6	0.027429	0.027363	FSC9	0.028752	0.028533
Fe7	0.027966	0.027727	FSR1	0.027234	0.027161
Fe8	0.028510	0.028581	FSR2	0.027822	0.027497
Fe50	0.027389	0.027209	FSR3	0.027927	0.027721
FS1	0.027944	0.027728	FSR4	0.028248	0.028022
FS2	0.027944	0.027728	FSR5	0.028430	0.028392
FS3	0.028165	0.027860	FSR6	0.029052	0.029076
FS4	0.028114	0.028118	FSR7	0.027878	0.027893
FS5	0.028250	0.028066	FSR8	0.028053	0.028094
FS6	0.029072	0.028938	FSR9	0.028697	0.028484
FS7	0.028213	0.028022			

over-all experimental range, and the increment is nearly equal to that of the sample containing 0.3% Ce (Fig.1). This indicates that the combined effect of both Fe and Ce additions approaches to the sum of the individual effect of Fe and Ce, instead of an offset of the effect of Fe by Ce (at.−0.3%).

3.2 *Effects of* RE *on Resistivity of Aluminum Wire*

Fe and Ce are the most ordinary impurities in aluminum electric wire. Their individual and total content are strictly limited in the standards. But in our samples the contents of Fe and Si (Tab.1) vary in a wide range. Fig.2 shows the effects of rare earth on the resistivity of aluminum electric wires containing various contents of Fe and Si. In the figure the stipulated content of Fe+Si for aluminum Aoo, Ao and A1 and the resistivity level of IEC standard are marked. The resistivity of aluminum wire increase with the increase of the content of Fe+Si and will exceed the IEC standard value if Fe+Si > 1%. Fig.3 shows the rare earth have no evident effect on the resistivity of the aluminum wires. The resistivities for all the three kinds of wires fluctuate below the standard value if the content of Fe+Si < 1. There is no apparent difference between the resistivities of the wires containing 0.3% Ce but no rare earth. In other words, no evidence has been found that Ce would decrease the resistivity of aluminum wire.

4 DISCUSSION

Three problems will briefly be discussed:

(1) The recoveries are always fluctuated, so that it is more resonable to use the residual contents rather than the addition of the rare earth in the aluminum to describe the roles of

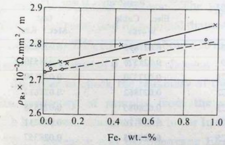

Fig2 Combined Effect of Fe and Ce on Resistivity ρ_R

O−without RE; X−0.3% Ce added

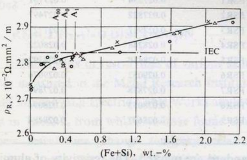

Fig3 Effect of RE on Resistivity of ρ_R Aluminum

Wire Containing Various Content of Impurities

O−without RE;X−0.3% Ce added;

△−0.3% MM added

RE whenever the fluctuation could not be eliminated.

(2) Recently, Harry[6] reported an experiment in which the aluminum 8××× was used to replace the EC or 1350 electric aluminum. The conductance of five products containing 0.25−1. 0% Fe are all beyond 61% IACS. It seems that Fe gives no harmful effect on the conductance of these products.

(3) The harmful effect of RE on conductance of the high-purity aluminum is well known. As RE is added to aluminum containing Fe and Si, their behaviour and interactions are not clear yet, and the explanations that RE would cancel the harmful effect of Fe and Si are unreliable.

5 SUMMARY

After a series of experiments, no evidence has been found that rare earth can increase the conductance of the aluminum electric wire both in high purity aluminum and industrial-purity aluminum contaning certain Fe and Si. RE will decrease the conductance of high-purity aluminum, but their effect is less than that of Fe.

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