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Research of Air Oxidation Kinetics of Ag-10Ni Composite

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Abstract

The paper deals with the research of air oxidation kinetics of silver-based composite. Oxidation kinetics of silver-based composite material, containing 10 weight percent of nickel, was studied. Changes of specific weight gain experimental curves in air in the 500-900°C temperature range are well described by the law of complex parabola. On the basis of this equation calculation formulas are obtained allowing constructing theoretical oxidation curves of the studied objects, which practically coincide with the experimental results. The temperature dependence of linear and parabolic constants of oxidation process is defined.

Keywords: Ag-Ni pseudoalloy, oxidation kinetics, heat resistance.

Introduction

Due to the excellent physical properties, such as thermal conductivity, electrical conductivity and heat resistance, silver provides low heating of electrical contacts and rapid removal of heat from the contact points. Oxidation resistance under conventional conditions and low cost make silver indispensable material for manufacturing various electrical contacts.

For improving mechanical properties and increasing heat and abrasion resistance nickel is added into the silver composite. (Gushinskiy, Maltsev, et. al. 2012). Nickel additives increase hardness and strength of the composite in comparison with pure silver and significantly reduce its plasticity. Ag-Ni composite materials have been developed and applied as electrical contacts in the last century. However, so far only two conventional powder metallurgy methods, chemical co-precipitation and mechanical stirring, are most commonly used for these composites (Jian-Bin Xie, Chun-Ming Wen, Guo-yi Qin, Sin-Yong Xu, Jin-Xin Guo, 2014).

It should be noted that the Ag-Ni composite is a heterogeneous system of immiscible components in the solid state and their mutual dissolution in liquid state is extremely low (Singleton & Nash, 1987). The system does not contain chemical compounds; i. e. typical pseudoalloy is formed capable of implementing set of properties that are incompatible in single material. For example, higher hardness values of contacts in Ag-Ni pseudoalloys can be attributed to the uniform distribution of nickel particles in silver matrix (Kim, 2008).

Working Methodology

Calculation of the oxidation parameters of Ag-10Ni composite is conducted according to the experimental data obtained by the continuous weighing in air in 500-900°C temperature range and calculating formulas of oxidation process are obtained. Theoretical oxidation kinetic curves are built according to these formulas, precisely describing specific weight gain process.

Oxidation constant Kr is determined by the slope of the tangent to the experimental kinetic curves at the point $\tau=0$, W =0.

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The parabolic constant Kp is calculated considering the experimental data W=f(τ).

Theoretical oxidation curves and experimental results are compared and temperature dependence of linear and parabolic constants of oxidation process is defined.

Results

Processing of these data showed that the kinetics of the oxidation process is well described by the law of complex parabola:

(1) $$\frac{W}{W_r} + \frac{W^2}{W_p} = \tau$$

or in differential form:

(2) $$\frac{dW}{d_r} + \frac{K_r K_p}{2K_r W + K_p}$$

where: W – is the specific weight gain of the test sample during the time τ, and Kr and Kp - rectilinear and parabolic oxidation constants. Equation (1) can be written as:

(3) $$W \sqrt{\left(\frac{K_p}{2K_p}\right)^2} + K_p \tau - \frac{K_p}{aK_r}$$

From the equation (2) it is evident that the constant Kr is the initial instant rate of the specific weight gain W and is determined by the slope of the tangent to the experimental kinetic curves at the point τ=0, W =0. The parabolic constant Kp is calculated on the basis of the equation (4) considering the experimental data W=f(τ), represented by dark circles in Figure 1, which almost coincide with the theoretical solid curves 1,2,3,4,5.

(4) $$K_p = \frac{w^2}{\tau - w_p / K\tau}$$

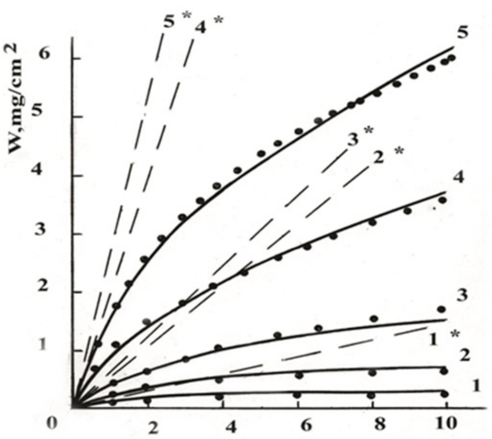

Figure 1. *The kinetics of oxidation of Ag-10Ni composite at temperatures: 500o(1), 600o(2), 700o(3), 800o(4) and 900oC(5) and rectilinear oxidation constants of the test samples.*

Table 1 shows computed values of the rectilinear and parabolic oxidation constants at various temperatures.

Table 1. *Oxidation parameters of Ag-10Ni composite*

Oxidation parameters	Temperature, t°C				
	500	600	700	800	900
K_r, mg/sm^2 h	0,15	0,53	0,60	2,04	2,76
K_p, mg/sm^4 h	0,01	0,06	0,37	1,64	4,85

For predicting the cource of the studied process correct calculation of oxidation parameters and seeking a suitable kinetic model are extremely important. Following calculation formulas on the basis of equation (3) allow obtaining theoretical values of specific weight gain W, depending on the duration of the experiment at the test temperatures:

$$W = \sqrt{0.001 + 0.01\tau}\ \ -0.033 \sim (500°)$$

$$W = \sqrt{0.003 + 0.06\tau}\ \ -0.057 \sim (600°)$$

$$W = \sqrt{0.093 + 0.37\tau}\ \ -0.306 \sim (700°)$$

$$W = \sqrt{0.162 + 1.64\tau}\ \ -0.402 \sim (800°)$$

$$W = \sqrt{0.772 + 4.85\tau}\ \ -0.879 \sim (900°)$$

Conclusion

According to the experimental data of continuous change in the specific gain of Ag-10Ni samples in 500-900oC temperature range calculating formulas of oxidation process are obtained. Kinetic curves, built according to these formulas, precisely describe specific weight gain process and practically coincide with the experimental data.

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