Archives of Materials Science and Engineering

Volume 28
Issue 8
August 2007
Pages 475-478

International Scientific Journal
published monthly as the organ of
the Committee of Materials Science
of the Polish Academy of Sciences

Silver matrix composites reinforced with galvanically silvered particles

J. Wieczorek *, J. Śleziona
Silesian University of Technology, Faculty of Materials Science and Metallurgy,
ul. Krasińskiego 8, 40-019 Katowice, Poland
* Corresponding author: E-mail address: jakub.wieczorek@polsl.pl

Received 25.04.2007; published in revised form 01.08.2007

ABSTRACT

Purpose: The paper presents the possibility of the application of metalic layers drifted with the use of the galvanic methods on the ceramic particles surface. The application of the layers was aimed at obtaining the rewetting of the reinforcing particles with the liquid silver in the course of the producing of silver matrix composites with the use of mechanical stirring method. To enable introducing of the iron powder and glass carbon powder to liquid silver the solution of covering the powder layer with the silver or copper coats was proposed.

Design/methodology/approach: For silver coating the method of non-current deposition from the solution was used.

Findings: Conducted investigations allowed such a selection of non-current coating parameters that durable and qualitatively satisfactory coats on the iron particles surface could be obtained.

Research limitations/implications: In the course of the researches it was stated that the temperature of the bath, the time of the spread and the intensity of the stirring were the most important parameters of the deposition method itself that guaranteed the obtaining of the coat. The conducted investigations allow to state that the most favourably from the quality of the obtained composite point of view were the applications of the silver coat on the surface of the iron particles and copper coat for glass carbon covering.

Originality/value: Selection of the deposited galvanic coats allows to obtain the good quality of the connection on the reinforcing particle sliver matrix interface.

Keywords: Metal matrix composites; Silver matrix; Ceramic particles; Galvanically silvered

MATERIALS

1. Introduction

The application of silver in technology results from its unique properties such as: a colour, good mechanical strength, very good plastic properties, oxidation resistance, high light reflection coefficient and many unique chemical and electrochemical properties. World demand for processed silver in the form of a solder, contact elements or silver matrix composites constantly increases [1-3].

In many listed applications together with a rise in voltage or intensity of the flowing current the application of pure silver is limited on the grounds of appearing electric arc phenomenon or adhesive coupling triggered by long-term using and increased temperature. In the case of difficult working conditions silver matrix composites and its alloys are successfully applied. The reinforcement employed in their case in the form of ceramic particles (Al_2O_3, SiC, ZnO, SnO_2) or metallic particles (Fe, Ni, W), effectively increases electric arc resistance, tribological resistance, electro-corrosive or electro-erosive resistance [4-6].

Universally applied technologies that produce this sort of composites are based on powder metallurgy technology. There are, therefore, grounds for conducting investigations on using casting technologies for producing silver matrix composites. These methods allow to obtain products and semi-finished products in considerably cheaper way and on the significantly larger scale.

Cast technologies used for metal matrix composites production, among them mechanical mixing technology, use the effect of the reinforcing particles wetting by the liquid metal matrix. It is difficult to obtain wetting in the silver-reinforcing particles (ceramic or metallic) system, and it requires a number of the technological efforts that the metal matrix and especially reinforcement are subjected to. In the case of matrix the efficient method of physicochemical properties change in the liquid state is the application of alloy additions. In the instance of the silver the main are: Al, Mg, Sr, Cu, Ni [7].

The essential element for the triggering of the reinforcing particles wetting by liquid metal matrix liquid is correctly selected technique of their surface preparation. Before their introducing into liquid metal the particles are subjected to cleaning, annealing, chemical active coating or agglomerating processes. In the presented paper the authors focused their attention on the possibility of the utilizing of the non-current metallic coating for the reasons of the selected particles surface modification. A contribution to such a selection was a fact that iron particles and glass carbon particles as well generate considerable difficulties during their introduction into liquid silver or its alloys. The preliminary investigations carried out by the authors proved that both agglomerating and chemical preparation are insufficient for providing their wetting by alloy matrix [8-10]. Metallic coating with the use of non-current methods is well known and applied in the industrial practice technique of preparing ceramic powders used for silver matrix composites reinforcement. This technique is applied to the production of composites reinforced with SnO_2 particles as preparation before the further pressing and sintering. Still in the case of the application of liquid phase composites production technologies, non-current silver plating of reinforcing particles has not been widely applied so far.

2. The characteristic of the non-current silver coating on ceramic particles

Chemical pure metals coating such as: nickel, copper, silver, gold, may be conducted on the metalic and ceramic surfaces and on the polymers (6). Non-current coating consists in reducting metal ions present in the water solution to the metalic form with the use of introduced into the bath reducer. The reduction process should take place on the particles surface. To achieve this, particles should be subjected to preliminary treatment. It provides good adhesion of applied metallic coat to the base and good quality of the layer (monolithic, non-pourus). Preliminary treatment consists of three following stages:

- particles surface cleaning, improving in the significant way particles wetting by the bath,
- particles immersing in the bath containing allergenic solution eg. stannic chloride,
- particles immersing in the bath containing activator, eg. palladium chloride.

As a result of such a procedure small, dispersed palladium germs form on the particles surface, which initiate autocatalytic process of chemical metalic coating (5).

Metalic pallad germs forming proceeds as a result of redox reaction between adsorbed on the particle surface tin ions and palladium ions, according to the reaction:

$$Sn^{2+} + Pd^{2+} \rightarrow Pd^{0} + Sn^{4+} \quad (1)$$

In the case of the Ag coat the process of the chemical coating is carried on in the solutions containing silver nitrate with the ammonia addition. Ammonia complexes form according to the reaction:

$$AgNO_3 + 2\,NH_3 \rightarrow Ag(NH_3)_2NO_3 \quad (2)$$

Metalic silver layer forming on the activated surface of the ceramic particles requires the presence of the reducer in the solution. As reducers applied are: tartaric acid, glucose and formaldehyde. The glucose application provides the fast course of reaction and arising compact silver layers. At the moment of reducer addition into the solution $Ag(NH_3)2NO_3$ complex disintegration occurs together with Ag2O forming. In the case of the glucose application as a reducer (C6H12O6) it reacts with the Ag_2O and creates pure metalic silver. Summary reaction looks as follows:

$$24\,AgNO_3 + 24\,NH_3 + 12\,H_2O + C_6H_{12}O_6 \rightarrow 24\,Ag + 6\,H_2O + 6\,CO_2 + 24\,NH_4NO_3 \quad (3)$$

The stages of particles chemical covering with silver coat are presented in the Fig. 1.

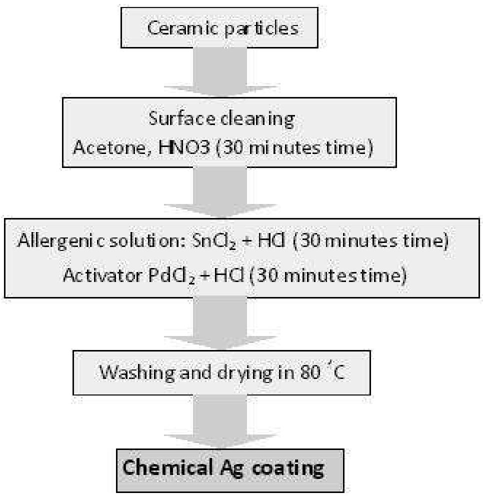

Fig. 1. The stages of the chemical silver coating

3. Target and scope of the researches

The target of conducted investigations was covering glass carbon powder and iron powder with the metalic coats. Prepared so powders served to obtain silver matrix composites reinforced with these particles. To produce Ag-reinforcing particles composites mechanical mixing cast method was used.

The scope of the investigations included:

- powders preparation: Ceramic (glass carbon), metalic (iron)
- through covering them with silver coats by chemical deposition,
- the evaluation of the obtained coats surface quality,
- powders introducing into the pure silver with the use of mechanical mixing method,
- composite casting,
- produced composites structure evaluation.

4. Silver coating

In the process of non-current silver deposition in the adopted experiment programme variable parameter was the particles immersing in the silver plating bath and the bath temperature.

Table 1.
The processes of covering powders with silver coats

Powder sort	Particles size, μm	Etching	Immersion in the bath time, min	Allergenic substance
$C_{s(100)}$	100	no	30	$PdCl_2$
$Fe_{(200)}$	200	yes	30	$SnCl_2$

The colour change observation conducted after the process and microscopic observations of the powder layer allowed to select optimum conditions guaranteeing creation of continuous, thick enough layer. These parameters correlation is presented in Table 1.

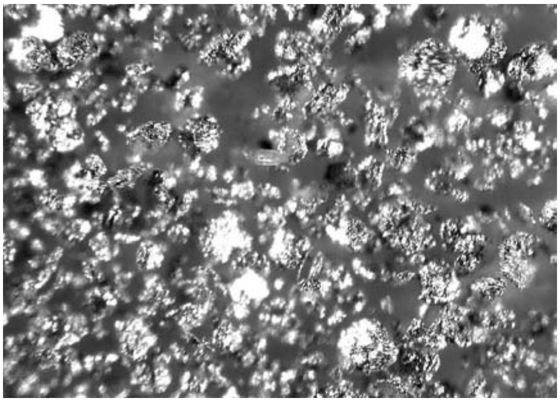

Fig. 2. Iron powder Fe (200) appearance after the chemical silver deposition process; optical microscope, mag. 250x

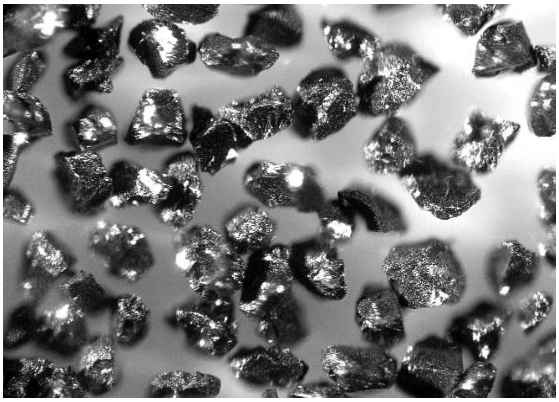

Fig. 3. Glass carbon Cs (100) appearance after the chemical silver deposition processb), optical microscope, mag. 250x

The selected for further investigations powders with put on them silver layer are presented in a Figures 2 and 3.

5. Composites production and evaluation

The next stage of the investigations, finally verifying the efficiency of the selected reinforcement preparation method was the composite material production. The process of prepared powders introduction into liquid silver matrix was conducted in the 1100C temperature. In the case of glass carbon powder induction furnace was used for matrix melting [11]. This furnace allows to carry on fast melting process and guarantees stable temperature in the course of the reinforcement phase particles introduction. In the case of using iron particles as reinforcement the application of induction furnace was not possible because of the ferromagnetic properties of the powder itself [12]. The trials of the introduction ended with the creation of agglomerates impending or even preventing from iron powder wetting by the liquid matrix alloy. In the case of the composites reinforced with iron particles in the intersection of the obtained ingot particles clusters and discontinuities of the matrix are visible (Fig. 4). Their forming should be connected with metal movements caused by rotary currents in the induction furnace and interactions between arising magnetic field and iron particles. To eliminate disadvantageous magnetic influences of the induction furnace for particles introduction this furnace was replaced with a resistance furnace. In the case of silver and its alloys the melting time and particles introduction process lengthening connected with the application of resistance heating does not have the influence on the obtained composite quality.

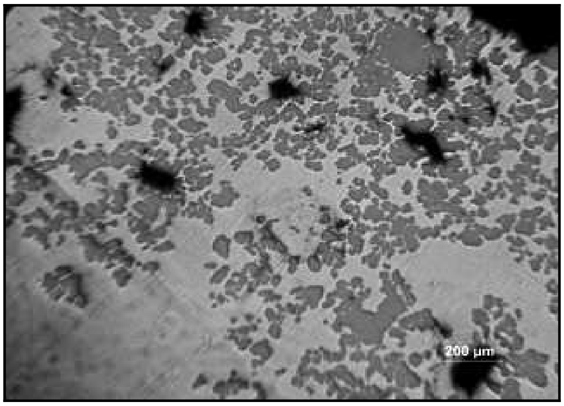

Fig. 4. The structure of silver alloy based composite material reinforced with iron powder Fe (200) after the process of chemical silver deposition (the process conducted in the induction furnace)

Silver, owing to its chemical resistance did not oxidize during the melting and soaking even without the application of the protective atmosphere. In each of the cases graphite pot was used and mixing was done with the use of the graphite mixer, which protected liquid metalic bath against dissolving oxide in it.

The structure of obtained composites reinforced with glass carbon or iron particles is presented in the Figures 4-6.

The application of the resistance furnace for silver matrix melting and iron particles introduction allowed to eliminate having been formed earlier particles clusters and matrix porosity. The structure of the obtained in the resistance furnace Ag-Fe composite is presented in the (Fig. 5).

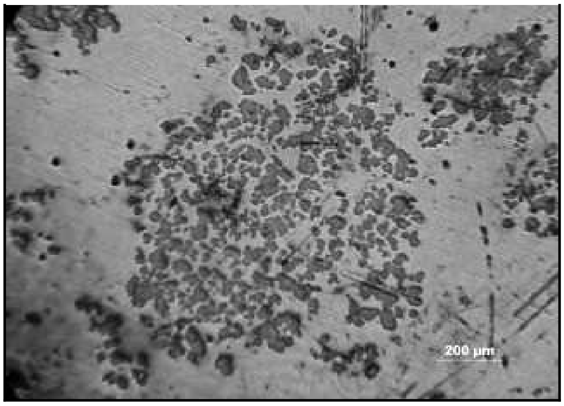

Fig. 5. Silver alloy based composite material reinforced with Fe (200) iron particles structure after the process of chemical silver deposition (the process conducted in the resistance furnace)

In this case particles are much better distributed in the volume and matrix discontinuity is not noticeable as in the case of induction furnace application. During the glass carbon particles introduction into the liquid matrix difficulties in the particles wetting process might be observed despite the formed on the particles coat. Arising wetting difficulties was solved thanks to introduction alloy component into the silver in the form of 3% magnesium.

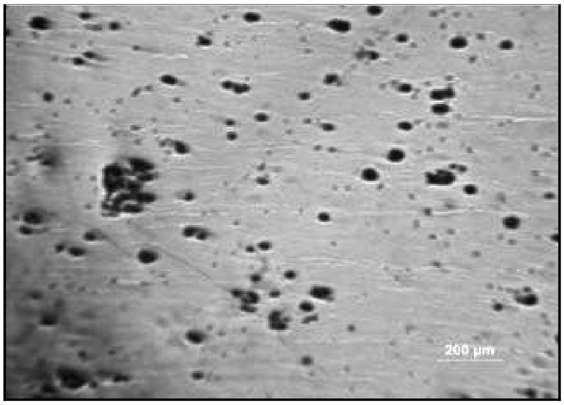

Fig. 6. Silver alloy based composite material reinforced with glass carbon particles Cs (100) after the process of chemical silver deposition

Its addition solved altogether the lack of wetting problem and allowed to keep composite production process repeatability. The Ag-glass carbon particles structure is presented in the Fig. 6.

In this case the induction furnace application was without any visible influence on the composite material structure. The particles are uniformly distributed in the composite ingot intersection. Porosity or the discontinuity of the matrix was not observed. In both cases of analyzed composites reinforced with glass carbon particles and iron particles production tests the efficiency of applied method of the particles preparation by non-current silver drifting on their surface.
Further researches will be concentrated on the metal plating process optimization and on the identification of possibilities of production cheaper coats on the particles through the reinforcement particles copper-platting application instead silvering.

6. Summary

Conducted investigations allowed such a selection of non-current coating parameters that durable and qualitatively satisfactory coats on the iron particles surface could be obtained**.** Such coats perform their technological tasks enabling the wetting of the iron particles introduced into liquid silver. In the case of glass carbon powder the application of the silver layer is not sufficient to obtain wetting. To enable wetting in the Ag-Cs system the modification of the liquid alloy with the magnesium addition is essential. Non-current silver coating on particles marked for introduction as silver or its alloys reinforcement is the method that allows to efficiently solve appearing difficulties of the lack of wetting in matrix-reinforcement system.

Acknowledgements

This work was carried out with financial support of The Polish Committee for Scientific Researches under grant no PBZ-KBN-103/T08/2003

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