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Synthesis and Characterization of Silver/Alumina Powders

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Abstract

In this research, synthesis and characterization of silver/alumina composite powders was investigated. This kind of metal/ceramic composite powders is used for fabrication of cutting tools inserts. The role of silver is toughening the final product. The powders were synthesized via co-precipitation method. The composition of the synthesized powders was Ag/80% wt Al_2O_3 $Ag/80\%\ wt\ Al_2O_3$. Silver nitrate, aluminum nitrate and sodium carbonate were used as precursors. The synthesis process had two steps: (1) precipitation of silver/aluminum compounds by adding sodium carbonate solution to the mixture of aluminum and silver nitrate solutions drop by drop and (2) Calcination of the precipitates in air atmosphere. On the basis of the Scanning Electron Microscopy (SEM) investigations, the dimensions of the initial precipitates were below $2\mu m$. Furthermore, the X-ray Diffraction (XRD) analysis confirmed that during calcination the initial precipitates at $800^{\circ}\mathrm{C}$, the volatile constituents such as carbon dioxide evaporated completely and the desired composite compounds were formed.

KEYWORDS: Silver/Alumina Powders, Precipitation, Calcination, Composite.

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1. Introduction

Metal matrix composites (MMCs) are a group of materials which are used in different industrial applications such as electrical contacts, welding electrodes and cutting tools. The matrix of metal matrix composites maybe silver, copper, cobalt or other metals. However, according to the application, the reinforcement can be an oxide, carbide, nitride or another metal. Cu/Al_2O_3,WC/Cu, WC/Co, Al/AlN and W/Cu are examples of metal matrix composites which are widely applied in various industrial fields. Also, the reinforcement can be in different forms like particles, fibers or whiskers [1-7].

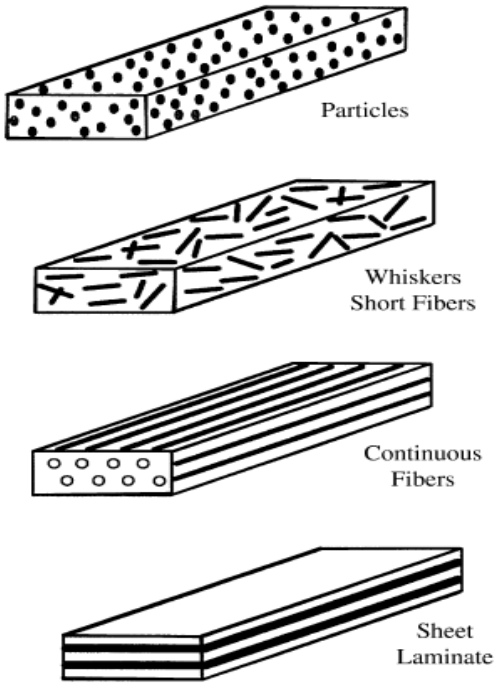


Fig.1 Different types of Metal Matrix Composites [7]

Metal matrix composites can be synthesized via different metallurgical processes like casting and powders metallurgy. In the case of powder metallurgy, the starting powders like tungsten and copper are mixed, cold pressed and sintered at elevated temperatures. The temperature and atmosphere of sintering is determined according to the kind of the matrix phase and reinforcement. For example sintering atmosphere of W/Cu composite powders shall be hydrogen while argon can be used as the sintering atmosphere of Cu/Al_2O_3 [6, 8]. It has been shown that using composite powders instead of the mixed ones enhances the physical and mechanical properties of the sintered powders like electrical conductivity, relative density and hardness. The composite powders can be synthesized by several methods such as mechanical alloying, thermo-mechanical and co-precipitation methods.

Ag/Al_2O_3 composites are a kind of metal matrix composites which are used as cutting tools inserts [9, 10]. In this composite the role of silver is upgrading the fracture toughness of alumina. The silver/alumina composites can be synthesized via powder metallurgy route which is consisted of cold pressing and sintering of silver and alumina powder

mixtures. However, based on the above discussion using Ag/Al_2O_3 composite powders enhances the properties of the sintered bulk. In this research, $Ag/80\%\ wt\ Al_2O_3$ composite powders were synthesized via co-precipitation method using silver nitrate, aluminum nitrate and sodium carbonate as precursors. The synthesized powders were characterized by Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD).

Materials and Methods

Sodium Carbonate, silver nitrate and aluminum nitrate were used as starting materials. In order to synthesis the powders with 20%wt Ag, a predetermined mixture of silver and aluminum nitrate was made in distilled water. Subsequently, the mixture was added to sodium carbonate solution drop by drop. The solution was heated to about 60℃ and stirred by a magnetic stirrer for 4h. The formed precipitates were filtered, washed, dried and calcined in air atmosphere at 800℃. The microstructure of the synthesized powders was evaluated by Scanning Electron Microscopy (SEM). Also, the metallurgical phases of the calcined powders were determined by X-ray Diffraction (XRD) technique. Fig.2 shows the stages of the applied synthesis process.

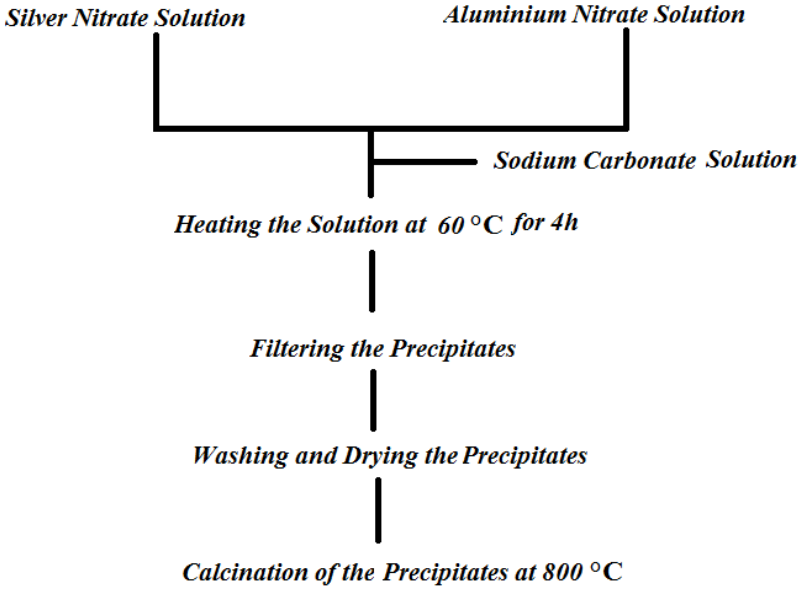
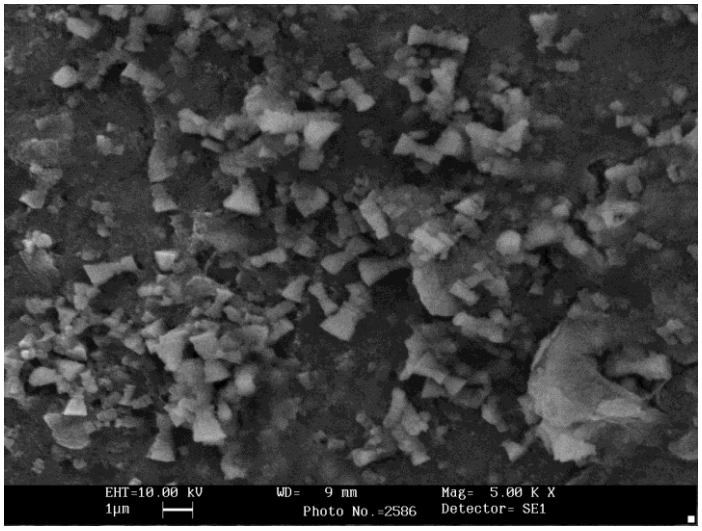


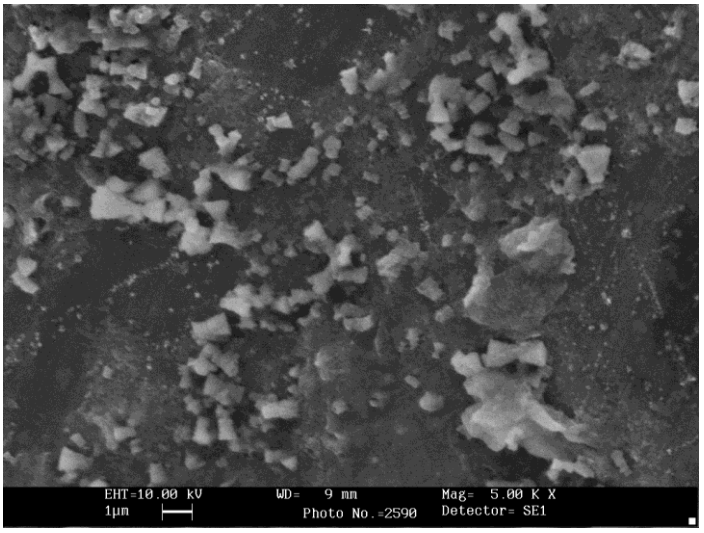
Fig.2 The applied synthesis method

Results and Discussion

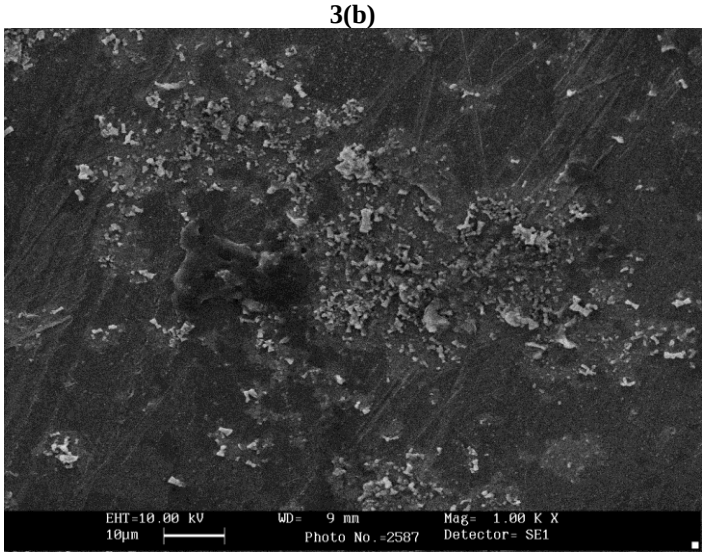
Fig.3 shows the microstructure of the initial precipitates in different magnifications. As it can be seen, the powder particles have a bowtie shape. Also, some cubic precipitates can be observed within the microstructure. The particles have a wide range of size distribution. However, the particle dimensions are mainly below $2\mu m$. Furthermore, it can be declared that the particles have been agglomerated to some extent. The agglomeration of the synthesized may be due to remaining of sodium within the composition of the precipitates. Sodium can be removed by further washing of the precipitates.



3(a)



3(b)



3(c)

Fig.3 (a,b,c) Microstructure of the initial precipitates

Fig.4 shows the XRD pattern of the calcined powders. According to this figure the calcined powders are consisted of silver and alumina phases. The intensity of the corresponding peaks of silver is relatively lower than that of alumina which may due to lower volume fraction of silver within the microstructure of the calcined powders.

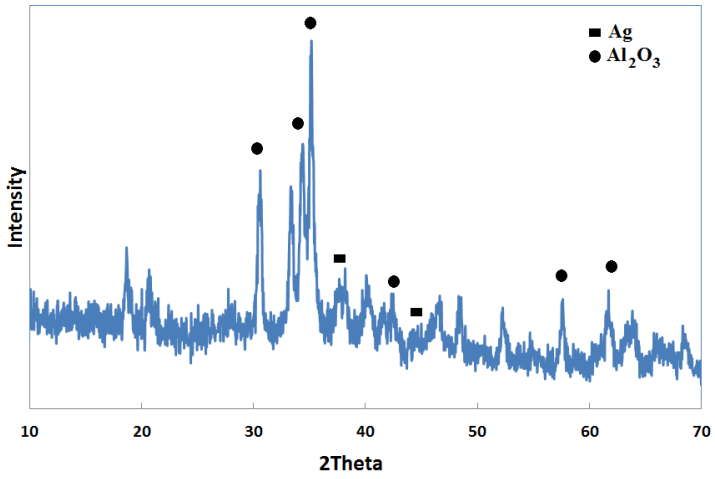


Fig. 4 XRD pattern of calcined precipitates

During the calcination process, the volatile compounds such as carbon dioxide evaporate and the weight of the initial precipitates decreases [4, 11]. The proposed reactions of calcination are as below:

$$Ag_2CO_3 \rightarrow Ag_2O + CO_2 \quad (1)$$

$$Al_2(CO_3)_3 \rightarrow Al_2O_3 + 3CO_2 \quad (2)$$

As it is proposed, during calcination process carbon dioxide evaporates and silver and aluminum oxide is formed. However, calcination of silver carbonate includes two steps. During the second stage of calcination silver oxide decomposes to silver which is the desired phase within the microstructure of the synthesized composite powders [11]:

$$Ag_2O \rightarrow Ag + {}^{1}/_{2}\, O_2 \quad (3)$$

As mentioned above, the size of the synthesized composite powders is mainly lower than $2\mu m$ which results to high sinterability of the powders. The synthesized powders can be sintered in liquid and solid states. In the case of solid state sintering, the sintering temperature is below 960℃ which is the melting point of silver while in the latter one the sintering temperature is higher than melting point of silver. However, it can be declared that by liquid phase sintering of the synthesized powders, the relative density of the powder compacts will be increased significantly. Moreover, due to the fine dispersion of the constituents within the microstructure of the synthesized powders, the properties of the sintered specimens will be desired and homogeneous.

The mechanism of densification during solid and liquid phase sintering is not identical. The dominant mechanism of densification during solid state sintering is diffusion of atoms via different paths like grain boundaries, dislocations and surface of powder particles. On the other hand, the densification mechanism during liquid phase sintering is included three different stages: rearrangement, solution-reprecipitation and final stage sintering. However, due to non-solubility of alumina

in molten silver, the second stage of liquid phase sintering may not have a significant role on consolidation and the rearrangement of alumina particles by the molten silver maybe the effective mechanism for consolidation of the cold pressed powders.

CONCLUSION

$Ag/80\%\,wt\,Al_2O_3$ composite powders were synthesized via chemical procedure using silver nitrate, aluminum nitrate and sodium carbonate as precursors and the following results were obtained:

1- Composite powders which their dimensions were mainly below $2\mu m$ were synthesized via co-precipitation method.

2- The morphology of the initial precipitates was like bowtie. Also, some cubic precipitates could be observed within the microstructure.

3- The initial precipitates were agglomerated during synthesis process.

4- Calcination of the initial precipitates at $800℃$ was due to formation of desired phases within the microstructure of the synthesized powders.

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