


cu-al/al_2o_3 cermet synthesized by reactive ball milling of cuo-al system

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abstract. a mechanochemical method of a single-stage synthesis of a metal matrix composite consisted of copper aluminides, cu_al_4, reinforced by fine particles of aluminium oxide was investigated. it was demonstrated that cuo and al can react forming directly γ-cu_al_4 intermetallic compound when the initial content of aluminium is higher than stoichiometric one. it is shown that al_2o_3 particles in the synthesized cermet have a size ranging from 500 to 100 nm.

1. introduction

the ordered intermetallics based on aluminides of transition metals have been evaluated for their potential applications after consolidation as high temperature structural materials. in order to improve the strength of intermetallics, especially at elevated temperatures, ceramic particles can be added as reinforcement. composite material formed in this way is called as a cermet.

cermet materials, which contain light metal alloys, have very good mechanical properties and therefore they are applied as construction materials in defence, aircraft and cars technology [1-4].

the mechanical properties of composite materials reinforced with ceramic particles depend on the matrix properties, mutual wettability of interphase and the amount of reinforcing particles. currently copper-based composite materials are produced by using several routes such as mixing of cu and alumina powders, internal oxidation of cu-alloy in powdered form or by mechanical blending of copper with dispersed al_2o_3 powder and subsequently cold pressed. the mechanochemical approach to the mncs synthesis is likely to be the most promising because it allows obtaining materials characterized with nanocrystalline structure. this technique allows incorporating the metallic and ceramic phases into particles. it causes that material is more homogeneous in microstructure and therefore has high strength and better interfacial contacts between reinforcements and the matrices [5-8].

copper-based composites have relatively good mechanical properties and electrical conductivity. however, it is worth to mention, that even small amount of alumina additions into cu matrix, increases its mechanical properties, simultaneously lowering considerably electrical conductivity [9-13].

in this work, the in situ technique to carry the shs reaction between pure al and cuo powders was used. al-cu intermetallic compounds directly formed during this reaction. our objectives are to produce a cu_al_4 intermetallics reinforced by alumina. two different proportions of initial components, stoichiometric into cu_al_4 intermetallics and excess of aluminium, were tested to mechanochemical synthesis of composite.

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2. EXPERIMENTAL

Materials

Copper oxide (Fluka, purity 99.9%) and aluminium (POCh, purity 99.9%), both in microcrystalline form, were used in experiments. The two-component system, i.e. CuO-Al, was prepared as two physical mixtures: with 27.4 wt.% and 31.2 wt.% of aluminium, respectively. The second mixture contained 20% of aluminium excess in relation to stoichiometry of Cu$_9$Al$_4$.

Instrumentation and milling procedure

Mechanochemical treatment was provided in a laboratory planetary mill - Fritsch GmbH Pulverisette 6 with vials and balls made of hardened steel. The rotational speed rpm was equal of 550.

The milling processes were performed under protective atmosphere of argon. The total mass of powders was 5 g and the ball-to-powder mass ratio was 10:1. Small amounts of powder were taken out from the vial after selected milling times for the solid phase analyses.

Equipment and methods of phase identification

X-ray powder diffraction patterns were obtained using a Philips X'Pert diffractometer (CuK$_\alpha$) in the 2\(\theta\) range of 10-90\(^\circ\).

A Hitachi S-4700 instrument (SEM) equipped with an energy dispersive X-ray spectrometer was used for the microstructural examination and elemental microanalysis. The BSE imaging and EDX elemental analyses were carried out at an electron beam voltage of 20 kV.

The gas pressure and temperature in the milling vial were monitored using GTM System with radio transmission of data to receiver remote from the mill.

3. RESULTS AND DISCUSSION

Testing of Al-Cu system relates to industrial importance, because Al-Cu alloys are used as components in the production of commercially important structural materials defined as a duraluminium [14]. The binary Al-Cu phase diagram [15] shows several intermetallics, among them the main are CuAl$_2$, Cu$_4$Al$_2$, Cu(Al) and Al(Cu) solid solutions. It worth to mention that CuAl$_2$-Al(Cu) is the promising metal matrix composite widely used in automobile industry, because its cost is relatively low and Al(Cu)
solid solution matrix is mechanically tougher than a pure Al matrix. It has been pointed out that, from practical point of view, the Al-rich region in Cu-Al phase diagram is more important. However, in the present study we have tried to obtain Cu₉Al₄ phase by mechanochemical route from Cu-rich region, according to the below equation:

\[ 9 \text{CuO} + 10 \text{Al} \rightarrow \text{Cu₉Al₄} + 3 \text{Al₂O₃} \, . \]

The \( \gamma \)-Cu₉Al₄ phase has a cubic primitive cell with relatively high lattice parameter (\( a=0.87023 \) nm) and space belongs to group P-43m. This phase is a typical Hume-Rothery phase, which conventionally is formed peritectoidally at 870 °C [16].

Products of both tested mixtures after 20 hours of milling consisted of a very fine powders in black colour. SEM micrograph in Fig. 1 indicates that synthesized composite powder is highly homogeneous. The EDAX analysis indicates that the dark uniformly distributed phase is Al₂O₃ and the lighter one consists mainly of copper with small amount of aluminium. It can state that this time of milling involved the formation of metal matrix composite consisted of Cu-Al matrix reinforced by embedded Al₂O₃ particles. The particle size of alumina ranges from 100 to 500 nm.

Fig. 3. Temperature and pressure changes during combustion process occurring in tested mixture of CuO-Al.

Fig. 4. X-ray diffraction patterns for mixture with 31.2 wt.% content of aluminium at different stages of composite formation.
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REFERENCES


