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Fabrication of Al_2O_3 - Al composites by infiltration method

K. Konopka[a], M. Wodzyński[a], M. Szafran[b]

[a]Warsaw University of Technology, Faculty of Materials Science and Engineering, 02-507 Warsaw, Wołoska 141, Poland

[b] Warsaw University of Technology, Faculty of Chemistry, 00-664 Warsaw, Noakowskiego 3, Poland

The present paper is focused on Al_2O_3-Al composites obtained via infiltration of porous ceramics by liquid Al. Presureless inflitration of porous ceramics by liquid metal is driven by capillary forces which make it possible to produce microstructure with percolation of metal phase in ceramic matrix.

In order to improve wettability between Al_2O_3 and Al the ceramic preforms were coated by the Ni-P. Ni-P deposited in form of a thin, tight film encalsulated ceramic grains and as a consequence, the liquid Al contacts first with Ni and then penetrates inside porous perform.

The size of metal phase in this case depends on the size of pores. The size of pores influences also the kinetics and extent of infiltration. This method is useful for composites with metal phase size in the range of micrometers.

1. INTRODUCTION

Ceramic – metal composites find a range of applications, e.g. as materials for energy technology or auto mobile industry because their improved fracture toughness. However, there are problems with production of these composites which require high temperature methods like infiltration, hot-extrusion, hot pressing or HTP are necessary [1-3]. One the most important issues during joining ceramics with metal is the problem of wettability. Different technologies of obtaining composites needs different solution of this problem and lead to different microstructures of composites and as a result to different properties.

The technique of infiltration of porous ceramic preforms by molten metal leads to a large contact area between these two components. The process can be carried out under pressure or without it. Due to filling up of pores in ceramic preform by metal, the microstructure with percolation of metal in the ceramic matrix is obtained. The three dimensional – penetration of metal phase is determined by the porous skeleton of the ceramic matrix. Because of that, the important factor is size and shape of pores, which can be controlled during the production of the preforms [4]. Ceramic preforms with small size of pore are not fully infiltrated [5]. Higher pressure can not help in infiltration of ceramics with small size of porous because it is limited by the strength of porous ceramic material. Therefore, this method is useful for fabricating composites with size of metal phase in the range of micrometers [5,6]. High reactivity between molten aluminium and ceramics is also necessary.

In this paper, the experimental principles of fabricating composites Al_2O_3 – Al by infiltration method are reported.The method of improving wettability Al with Al_2O_3 is analysed.

2. EXPERIMENTAL AND RESULTS

Al_2O_3 – Al composites were obtained by infiltration of porous ceramics by liquid Al. Cylindrical (10 mm diameter and 10 mm height) porous ceramic preforms were prepared by one-side pressing process. Alumina A16SG9 from Alcoa was used. The preforms were dried and sintered at 1550^{O}C for 1 h, followed by cooling in the furnace. Their parameters are presented in Table 1. The earlier works of these authors showed that fully infiltration is possible for preforms with size of pores above 200µm [5,6].

Table 1. Bulk density (d_v), open porosity (p_o), average pore size (d_p) and average size of ceramic grains (d_g) in performs used for infiltration.

d_v (g/cm^3)	p_o (%)	d_p(µm)	d_g(µm)
2.67	20.3	200	500

Observations of porous Al_2O_3 were made using scanning electron microscopy (SEM, Hitachi S-3500N). A representative image of its is presented in Figure 1.

Poor wetting between ceramics and metal is the key issue in production of the metal - ceramic composites. One possibility to overcome this problem is to produce inter - layer of metal with better wettability as a contact to the ceramic support [7,8]. To improved wettability between Al_2O_3 and Al ceramic performs were coated with Ni - P in the chemical reduction process in solution consisted of NaH_2PO_2 H_2O, $NiCl_2{\cdot}6H_2O$ and $C_6H_5O_7Na_3{\cdot}2H_2O$ [9]. The SEM observations revealed that Ni-P were deposited in a form of a thin, tight film encapsulating all ceramic grains (Fig.2).

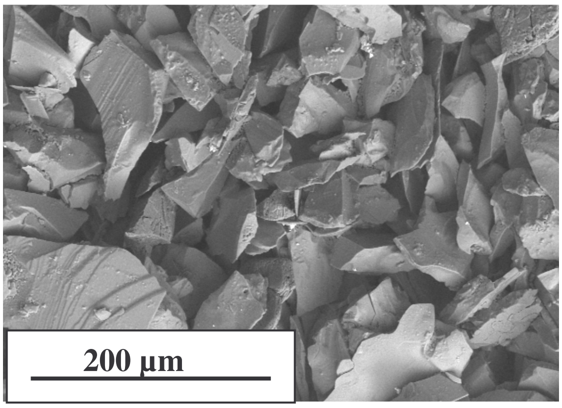

Figure 1. SEM image of the fracture surface of the porous Al_2O_3 preform.

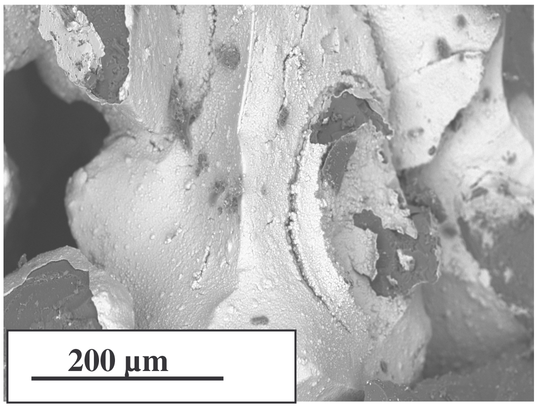

Figure 2.SEM image of the fracture surface of the porous Al_2O_3 preform coated by Ni - P.

Wettability evaluation has been made together with increase of temperature in furnace on pieces of Al_2O_3 with and without Ni-P. The results are presented in Figure 3. These wettability tests have shown no intereaction between Al and Al_2O_3 (Figure 3a) and significant interaction above 800°C between Al and Al_2O_3 coated by Ni-P layer (Figure 3b). This interaction leads to bonding in a contact area.

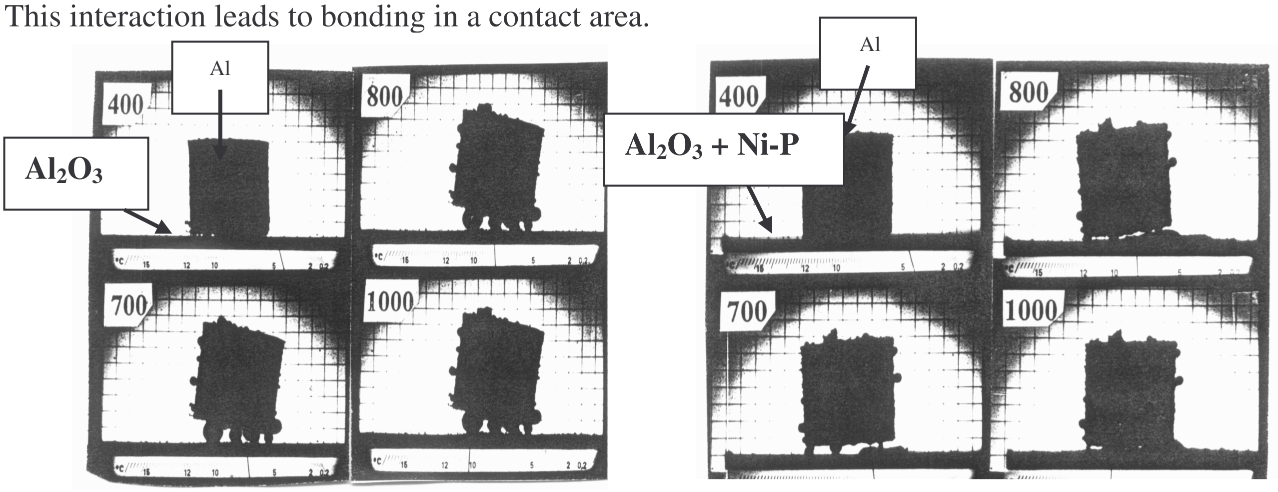

Figure 3. Experiments of wetting between: Al_2O_3 and Al (a); Al_2O_3 coated by Ni - P and Al (b); images of samples in different temperatures in nitrogen atmosphere.

Infiltration was done in a press with furnace produced by LEYBOLD – HERAEUS. Preforms were mounted in the crucible and soaked with Al at temperature 650°C and pressure 7 MPa as shown in Figure 4.

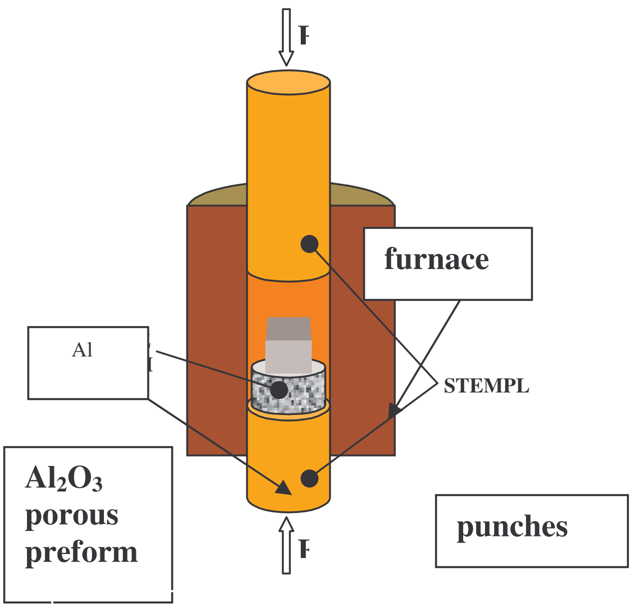

Figure 4. Schematic explenation of infiltration used in the present study.

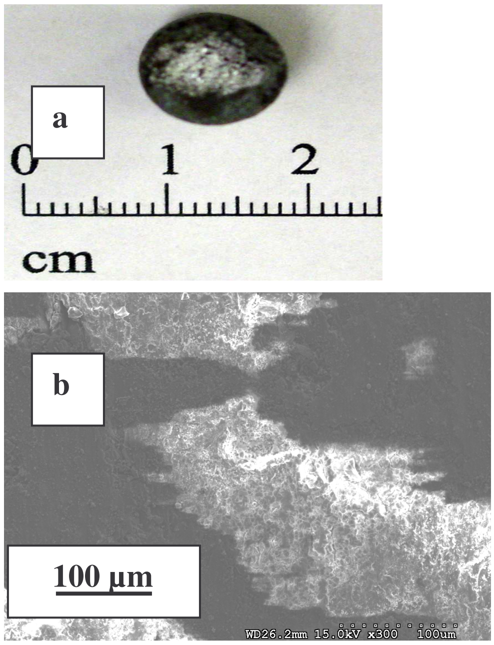

Figure 5. Composites Al_2O_3 – Al:
(a) samples, (b) microstructure of composite; dark area – Al, white – ceramics.

The value of applied pressure was calculated from the strength of Al_2O_3 preforms estimated from the compression tests. The microstructure of composite is presented in Figure 5. Liquid Al release was observed and as a consequence, not all ceramic preform have been filled out by Al (Fig. 5a).

3. SUMMARY

Using Ni-P coating on ceramic preforms improved wetting Al_2O_3 by Al. Ni-P were deposited in form of a thin, tight film which encapsulated ceramic grains. As a consequence, the liquid Al contacts first with Ni and then penetrates inside porous perform.

Infiltration of porous ceramic matrix by the liquid metal allows to obtain homogeneous distribution of metallic phase in the ceramic preform. However, the process of Al relased caused by pressing is observed. This effect should be taken into account in designing of composites (in calculation of the amount of Al which is needed for full infiltration).

This technique used here is suitable for producing composites with size of metal phase in the range of micrometers. Filling up pores by the metal provide a microstructure with percolation of metal phase. Such a microstructure can be an important in applications in which electrical properties of material are relevant.

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