Fall 10-4-2015

The measurement of the adhesion force between ceramic particles and metal matrix in ceramic reinforced-metal matrix composites

Dariusz Jarzabek
Polish Academy of Sciences, djarz@ippt.pan.pl

Marcin Chmielewski
Institute of Electronic Materials Technology, Warsaw, Poland

Tomasz Wojciechowski
Polish Academy of Sciences

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Dariusz Jarząbek[1], Marcin Chemielewski[2]
[1] Institute of Fundamental Technological Research, Polish Academy of Sciences
[2] Institute of Electronic Materials Technology
e-mail: djarz@ippt.pan.pl

Abstract

This paper presents the method for measurement of the adhesion force and fracture strength of the interface between ceramic particles and metal matrix in ceramic reinforced-metal matrix composites. Three samples with the following Cu to Al_2O_3 ratio (in vol.%) were prepared: 98.0Cu/2.0Al_2O_3, 95.0Cu/5.0Al_2O_3 and 90Cu/10Al_2O_3. Furthermore, microwires which contain a few ceramic particles were produced by means of electro etching. The microwires with clearly exposed interface were tested with use of the microtensile tester. The microwires usually break exactly at the interface between the metal matrix and ceramic particle. The force and the interface area were carefully measured and then the fracture strength of the interface was determined. The strength of the interface between ceramic particle and metal matrix was equal to 59±8 MPa and 59±11 MPa in the case of 2% and 5% Al_2O_3 to Cu ratio, respectively. On the other hand, it was significantly lower (38±5 MPa) for the wires made of composite with 10% Al_2O_3 .

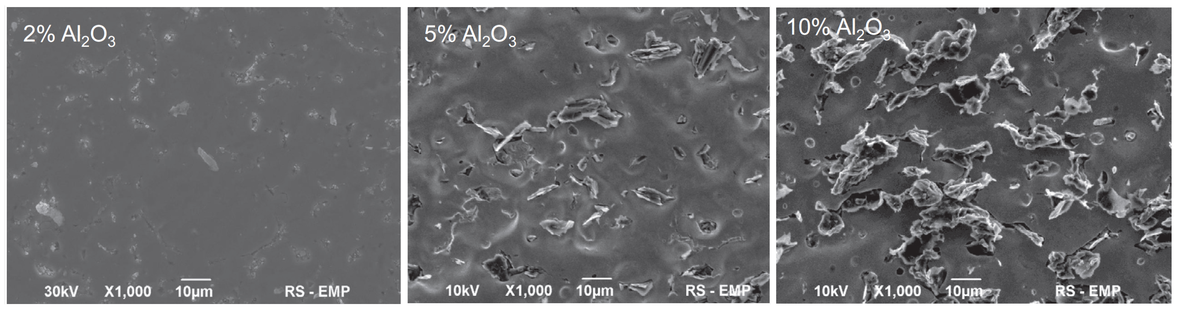


Fig. 1 The SEM image of a surface composites surface. The ceramic particles have usually very complicated and irregular shape.

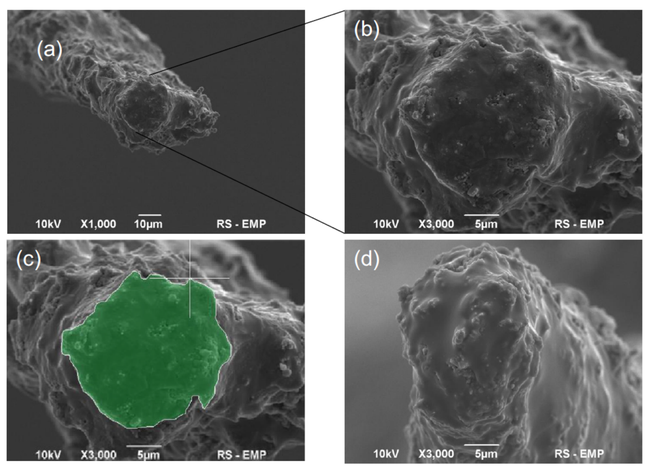
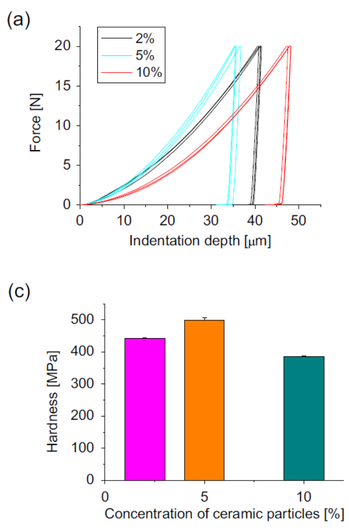


Fig. 3 Images of microwire before the experiment**.** a) SEM image; b) optical microscope image. The ceramic particle is clearly visible. The microwire does not conduct the electric current, hence, it is assumed that the interface is fully exposed.

Fig. 5 The contact area evaluation. The SEM images of the top of the two ends of the broken wire were used in order to precisely determine the contact area between the ceramic particle (a,b,c) and the copper (d). The contact area in images was measured using a dedicated computer programme (c).



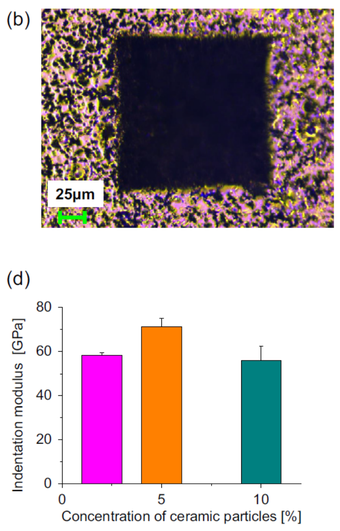


Fig. 6 Results of microindentation experiments. a) the sample with 5% Al2O3 is stiffer than the sample with 2% Al2O3. However, the sample with 10% Al2O3 is less stiff than other two samples. b) an example image of an imprint. The black point are ceramic particles. They are significantly smaller than the imprint's area c), d) the hardness and the indentation modulus of the sample with 10% concentration of ceramic particles are significantly lower then for the other two.

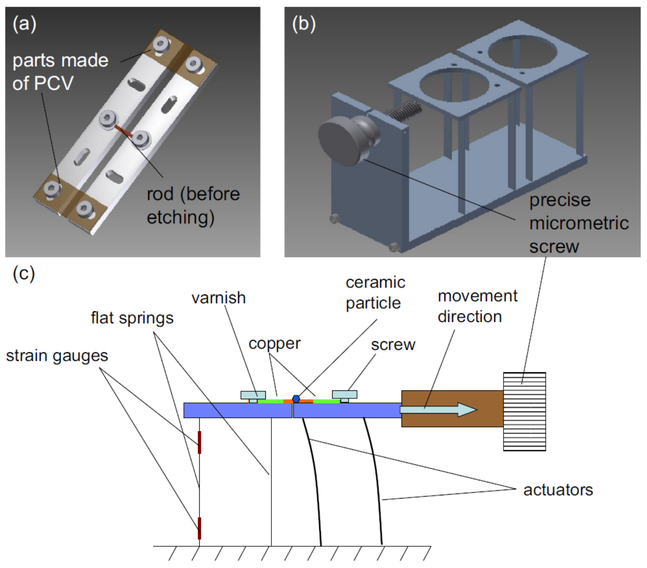


Fig. 2 The microtensile tester setup. a) the sample holder. It consists of two aluminium bars to which the rode made of investigated composite is clamped by two small screws. The bars are connected to each other by parts made of PCV. b) The precise micrometric screw allows the movement of the first stage towards the second one. The tension of the microwire is then applied by releasing the screw. c) The scheme of the microtensile tester. It consists of two stages, to which two endings of the microwire are fixed. Flat springs on which stages are mounted are used to apply and to measure the force. The strain gauges bridge is used for the precise determination of the force which is applied on a microwire.

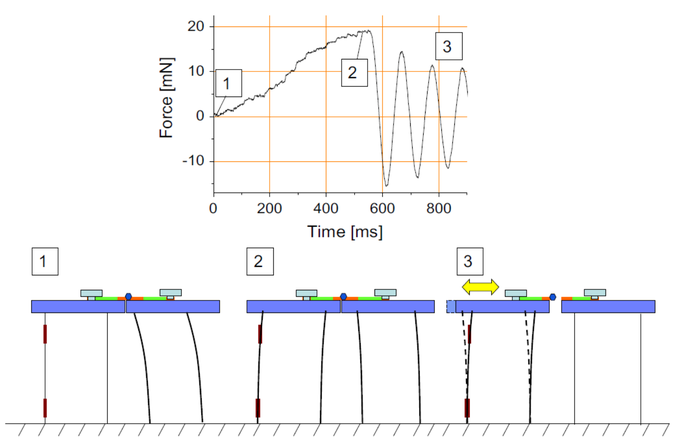


Fig. 4 The force vs time curve. The loading velocity was equal to approximately 40 mN/s. At the beginning of the experiment the signal from the strain gauges was equal to 0 – there was no tension (1). By releasing the micrometric screw the tension was applied (2). After the micowire had been broken, the stage started oscillating (3).

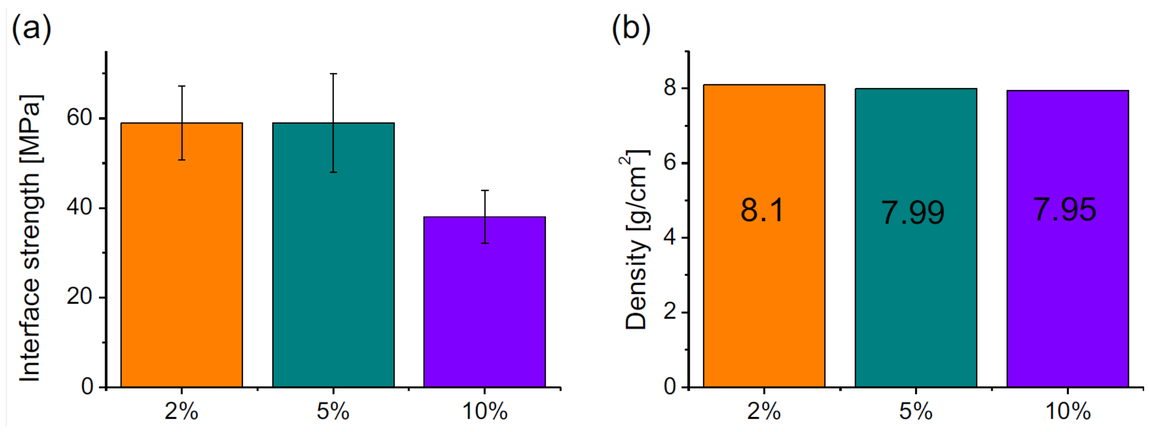


Fig. 7 The strength of the interface between ceramic particle and metal matrix. It is equal to 59±6 MPa and 58±7 MPa in the case of 2% and 5% Al2O3 to Cu ratio, respectively, but it is significantly lower (37±4 MPa) for the wires made of composite with 10% Al2O3.

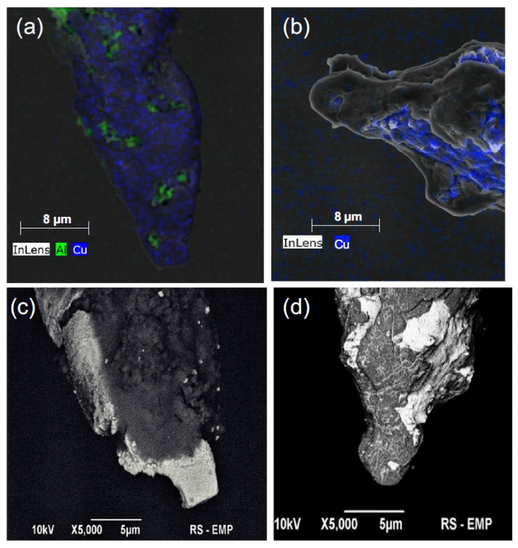


Fig. 8 The nanowires after the experiment. In order to ensure that the microwires break at the interface, the broken microwires were investigated by EDX (a, b) or by BSE (c,d). According to these images, the microwire was broken exactly at the interface. e) the back-scattered electrons image of the group of particles which started to break while a microwire was transported to the SEM.

Conclusion

- Microtensile tester allows the interface strength determination
- The force can be measured down to **0.1mN**
- Due to the SEM investigation of tensiled wires it is possible to determine the contact area with **15% measurement error**
- The technique allows investigation of the influence of different parameters of production process on the interface strength

References

1. Jarząbek D.M., Chmielewski M., Wojciechowski T., *The measurement of the adhesion force between ceramic particles and metal matrix in ceramic reinforced-metal matrix composites*, COMPOSITES PART A-APPLIED SCIENCE AND MANUFACTURING (ISSN: 1359-835X), Vol.76, pp.124-130, **2015**

The present research was supported by the Polish National Science Centre, grant DEC-2012/07/N/ST8/03297.

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