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THE COMPARISON OF YIELD OF DEPOSITION OF FUNCTIONALLY GRADED CERMET LAYERS Ni-ZrO_2-8Y, Ni -TiB_2 AND Ni-Al_2O_3 DEPOSITED BY ELECTROPHORETIC DEPOSITION

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Abstract: This paper deals with comparison of yield deposition for functionally graded cermet layers Ni-ZrO_2, Ni-TiB_2 and Ni-Al_2O_3 which were obtained by electrophoretic deposition (EPD) in benzene alcohol-based suspension. The cermet has very interesting properties which can be achieved by a combination of different materials. The yield of deposition for FG cermet layers Ni-ZrO_2-8Y, Ni-TiB_2 and Ni-Al_2O_3 has a significant influence for final powder deposition. On the base of evaluation of results, the yield of deposition was the highest in case of FG cermet Ni-Al_2O_3 followed by Ni-ZrO_2-8Y and Ni-TiB_2. The highest possible yield of deposition leads to the resulting materials with the desired properties.
Keywords: cermet layers, Ni-ZrO_2, Ni-TiB_2, Ni-Al_2O_3, electrophoretic deposition (EPD)

INTRODUCTION

Currently there is a huge challenge when combining the mutually incompatible properties into one material such as hardness at high temperature and stiffness at low temperature. One of the ways to obtain these properties in one material is to create a functionally graded material (FGM). FGM offers a solution of how to prepare for instance FGM with tough core and hard surface in one material.

The FGM is a two component composite characterized by a compositional gradient from one component to the other. The properties are extremely important, especially in materials such as cermet with gradually changing structure. Functionally graded cermet is a structural material composed of a ceramic hard phase and a metal binding phase, in which approximately equiaxed fine grains of the ceramics, which constitute approximately 15-85% by volume, are embedded in a matrix of metal or alloy binder.

For FG cermets Ni-ZrO_2-8Y, Ni-TiB_2 and Ni-Al_2O_3 the combination of metal and ceramic can lead to desired and exceptional properties as opposed to conventional hard metals. All three ceramic powders have very high hardness, low toughness and excellent wear resistance. TiB_2 has very good thermal, electrical conductivity and hardness and can be used as a refractory protective layer on heat-resistance alloys.

With an excellent combination of properties (high strength and stiffness) of Al_2O_3 and an attractive price, it is no surprise that fine grain technical grade alumina has a very wide range of applications. The usage of ZrO_2-8Y instead of ZrO_2 was chosen because adding small percentages of yttria eliminates phase changes and the resulting material can be used as a heat-insulating coating. The mating of these mutually incompatible properties in one material system (cermet) can lead to improving the life span of cutting tools.

The yields of depositions for preparation of FG cermet layers were obtained by method of EPD, which is very suitable for preparing such as materials. The method of EPD was chosen for its versatility when using different kinds of powders (metals, ceramics) and for its cost effectiveness. In order to prepare the green body by means of EPD it is necessary to have stable suspension, which was obtained in our case by electrostatic repulsion only affected the pH values.

EXPERIMENT

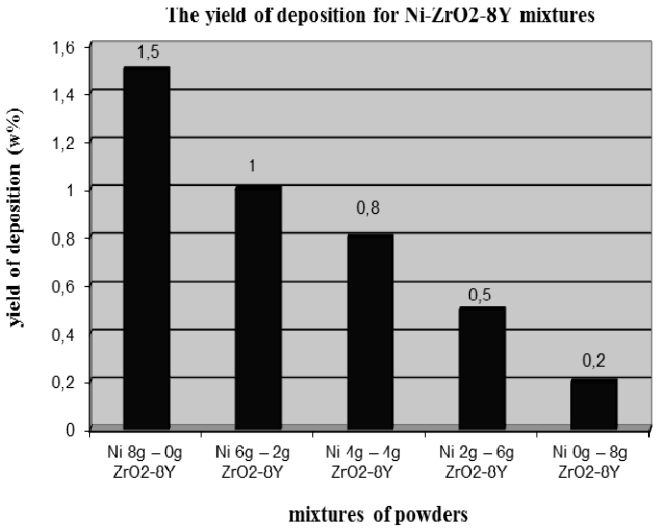
The commercially available powders used in this experiment were Ni with an average particle size of 30 μm, and SSA 15 m^2/g, TiB_2 with an average particle size of 14 μm and SSA 45 m^2/g, ZrO_2-8Y with an average particle size of 20 – 30 nm and SSA 50 m^2/g and Al_2O_3 with average particle size of 150 nm and SSA 10 m^2/g. All types of suspensions consisted of 60 ml of benzene alcohol C_2H_6O 96% (ethanol min.96%, benzine 1%). All powders had constant value of 8g (starting value). In all experiments the 0.3 ml of 65% HNO_3 were used. For the EPD experiment, the Ni electrodes (deposition and counter) were used. Ni electrodes were cleaned in an ultrasonically pured acetone, isopropyl alcohol and distilled water bath and the distance between the electrodes was set to 8 cm. The setting parameters for EPD were constant in all experiments, I=150mA, U=120V, P=10kW (maximum limiting performance), t=5min. All suspensions were treated by ultrasound for 5 minutes in order to disperse. According to the measured values of pH (1 – 1.4) suspension was stable and positively charged.

The yields of depositions were calculated after 5 minutes of drying of powder for all presented nanopowders. The EPD device can operate at the temperature range of 0–40°C. In our case the temperature was adjusted to 25°C and pH values was measured at 25°C on pH meter 730.

The yield of deposition was investigated for powder mixtures with different weights of powders. The five measurements of yield of deposition were performed for each material system. The starting value of Ni powders was 8g which was gradually change to 8g of ZrO_2-8Y, TiB_2 and Al_2O_3. The yield of deposition was obtained as follows: for the first deposition, the 8g of Ni were disperse in 60 ml of benzene alcohol + 0.3 ml of 65% HNO_3. After 5 minutes of EPD the Ni electrodes were pulled out and the deposited powders were dried for 5 minutes. Afterwards the electrode with the deposited powders was immersed into the second suspension with 6g of Ni and 2g ZrO_2-8Y and this procedure continued until the suspension of 8g of ZrO_2-8Y. This procedure was the same for Ni-TiB_2 and Ni- Al_2O_3 cermets. The details of EPD parameters, suspensions, pH and yield of deposition are shown on tab. 1-3.

Table 1. EPD parameters, pH and yield of deposition in benzene alcohol–based suspension for Ni–ZrO_2-8Y

Setting parameters	Suspension	pH	Yield of deposition [w%]
I= 150 mA U= 120 V P= 10 W tdep= 5 min T= 25°C	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ + Ni 8g – 0g ZrO_2-8Y	1.1	1.5
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ Ni 6g – 2g ZrO_2-8Y	1.2	1
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ + Ni 4g – 4g ZrO_2-8Y	1.2	0.8
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ + Ni 2g –6g ZrO_2-8Y	1.3	0.5
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ + Ni 0g – 8g ZrO_2-8Y	1.5	0.2
Overall yield of deposition			4



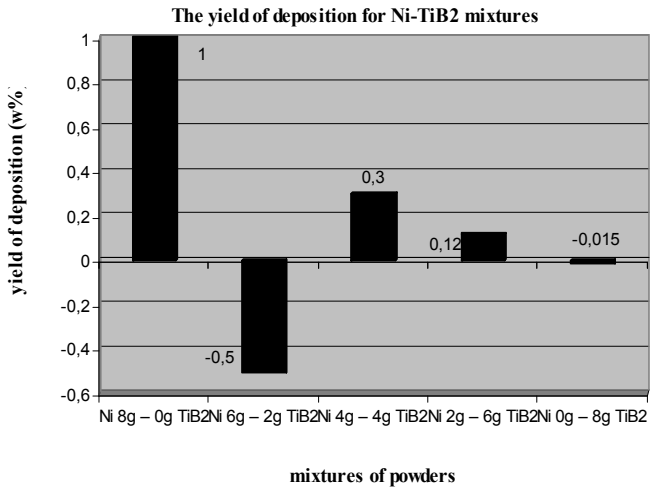
Graph 1. The yield of deposition or Ni-ZrO_2-8Y mixtures

Table 2. EPD parameters, pH and yield of deposition in benzene alcohol–based suspension for Ni–TiB_2

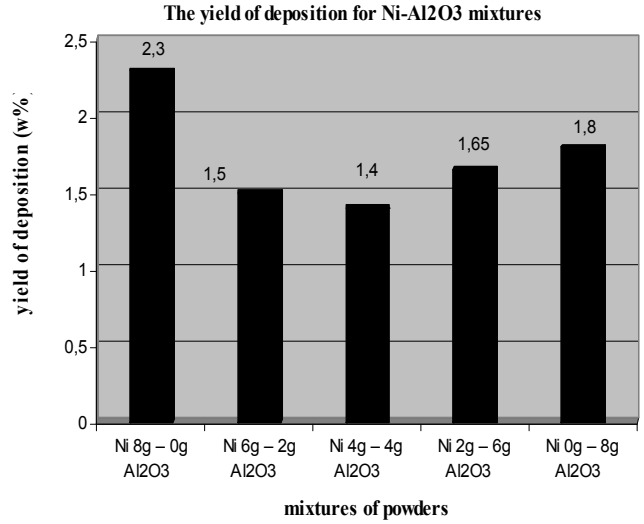
Setting parameters	Suspension	pH	Yield of deposition [w%]
I= 150 mA U= 120 V P= 10 W tdep= 5 min T= 25°C	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ Ni 8g –0g TiB_2	1.1	1
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ Ni 6g –2g TiB_2	1.2	-0.5
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ Ni 4g – 4g TiB_2	1.1	0.3
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ + Ni 2g – 6g TiB_2	1.1	0.12
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ + Ni 0g – 8g TiB_2	1.2	-0.015
Overall yield of deposition			0.9

Table 3. EPD parameters, pH and yield of deposition in benzene alcohol–based suspension for Ni – Al_2O_3

Setting parameters	Suspension	pH	Yield of deposition [w%]
I= 150 mA U= 120 V P= 10 W tdep= 5 min T= 25°C	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ Ni 8g – 0g Al_2O_3	1.1	2.3
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ Ni 6g – 2g Al_2O_3	1.2	1.5
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ Ni 4g – 4g Al_2O_3	1.1	1.4
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ + Ni 2g – 6g Al_2O_3	1.1	1.65
	60 ml of benzine alcohol + 0,3 ml of $HN0_3$ + Ni 0g – 8g Al_2O_3	1.2	1.8
Overall yield of deposition			8.7



Graph 2. The yield of deposition for Ni-TiB_2 mixtures



Graph 3. The yield of deposition for Ni-Al_2O_3 mixtures

DISCUSSION

The challenge of preparing such cermet layers by means of EPD is complicated. The first problem is that stability suspension is hard to achieve by electrostatic repulsion.

In this paper the electrostatic repulsion was done by affected the ph values by adding the HNO_3. The proof of suspension stability could be done by the zeta potential measurement. As shown on graph 1, the yield of deposition decreased almost linearly with adding of ZrO_2-8Y nanopowders.

The highest yield of deposition occurred in FG cermet Ni-Al_2O_3. The overall yield of deposition was 8.7 compare to 4 w% for Ni-ZrO_2-8Y and 0.9 w% for Ni – TiB_2 which is too low for obtaining the material of desired properties. As can be seen on graph 3, the yield of deposition was almost the same for pure Ni and Al_2O_3 and the gradient profile is the most convenient when compared to Ni–TiB_2 and Ni-ZrO_2-8Y. For this reason the FG cermet Ni-Al_2O_3 seems to be the best solution in the case of yield of deposition.

The second problem was to adhere the coating on the deposition electrode. As seen on graph 2, with the second immersion of the electrode and after 5 minutes of running the EPD process, the decrease in yield of deposition occurred, the value was -0.5 w%. The same decrease occurred even for the last deposition – 0.015 w%. There is an assumption

that this can happen because of weak forces among individual particles deposited on the electrode and the applying of electric field disturbed the deposit. This is a very rare situation which has a negative impact on the resulting yield of deposition and final powder compact.

CONCLUSION

Based on the demonstrated results, it is possible to confirm the possibility to prepare the functionally graded cermet´s layers of Ni-ZrO_2-Y8 Ni-TiB_2 and Ni-Al_2O_3. It was shown that the higher yield of deposition was for Ni-ZrO_2-Y8 followed by Ni-Al_2O_3 and Ni- TiB_2.

All these experiments are good indicators not only for preparing the FGMs but also for preparation suspension and determination of parameters of EPD. In the future for preparation of cermet layers by means of EPD, there is a need to optimize the EPD parameters for given characteristics of deposited powders and the type of used suspension.

All these experiments were carried out in laboratories of the Institute of Technologies and Materials, Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava.

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