FABRICATION FOR MICRO PATTERNS OF NICKEL MATRIX DIAMOND COMPOSITES USING THE COMPOSITE ELECTROFORMING AND UV-LITHOGRAPHY

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Abstract

A manufacturing process of the micro patterns nickel/diamond composites using the composite of electroforming and UV-lithography is presented. During the lithography, different geometrical photomasks were used to create specific patterns of the resist mold on the metal substrate. Micro holes on the substrate by the etching process can be used to improve the adhesion of the pellets. During the composite electroforming, the desired hardness of the nickel matrix in the micro patterns of nickel/diamond composites can be obtained by the addition of leveling and stress reducing agents. Under moderate blade agitation and ultrasonic oscillation, more uniform dispersion of diamond powders deposited in the nickel matrix can be achieved.

1 Introduction

The composite electroforming had been usually used to fabricate some thin components or devices with high wear resistance, high strength, etc. Their materials used can contain some ceramic particles such as diamond, CBN, SiC, or Al_2O_3 in Ni, Cu, Fe, or Co matrix [1]. Besides, LIGA-like technology [2] that includes UV-lithography and micro electroforming was employed to produce micro-component parts such as actuators, micro sensors [3], micro molds [4]. However, this work will combine UV-lithography and micro composite electroforming to fabricate the nickel matrix diamond composites. In this paper the manufacturing processes of the diamond composites will be studied and the matrix hardness and the diamond concentration will be investigated. In addition, the micro patterns array of nickel matrix diamond composites on the metal disc will be fabricated.

2 Fabrication of the nickel matrix diamond composites

Design of the micro patterns of nickel/diamond composites on the metal substrate was illustrated shown in Fig 1. The fabrication processes contained the LIGA-like technology is described in two main steps: (1) the micro UV lithography that includes the design of the mask, resist coating, and UV light exposure, and (2) the micro composite electroforming that deposited diamond particles into the nickel matrix on the substrate. The experimental procedures for the micro pellets nickel/diamond composites were shown in Fig 2. The detailed production steps were described below.

(1) Pre-treatment: Dip the metal base plate into a degreasing solution in an ultrasonic cleaner to remove the oil film and impurities from the substrate surface, which is then followed by an acid washing of the substrate surface and sequential steps of dipping in sodium hydroxide, sulfuric acid, nitric acid to remove an oxide layer from the surface of the metal substrate for a better interface to allow better coating of resist to the base plate.
(2) UV lithography process: Contain resist coating and baking UV exposure and development, Place the well-cleaned metal base disc on a spin coater for negative type of JSR THB-151N resist coating. The resist-coated substrate then goes through a soft baking step. Using a UV light with a wavelength of 365 nm irradiates the resist through the mask under the exposure power of 330 W. After UV exposure,

the resist on the substrate covered by the photo mark is removed with the resist developer (JSR), and the remaining resist will form an electroformed mold.

(3) Etching process: In order to increase thae adhesive strength of nickel electroformed on the metal substrate, the etching process was employed to make the micro hole on the metal substrate.

(4) Composite electroforming: Place the substrate from the micro lithography in the nickel sulfamate bath so that micro composite electroforming can be conducted. In this step, the micro pellet array on the metal substrate will be derived from composite electroforming with diamond powders and nickel matrix.

The nickel matrix diamond composites were fabricated in the nickel sulfamate bath with diamond powders of 4-6 μm under the blade and ultrasonic agitation. The experimental conditions for composite electroforming procedure were listed in Table 1.

3. Experimental results

The parameters and the optimization of the lithography process, the micro etching, and the micro composite electroforming for the fabrication of the micro pellets of nickel/diamond composites on the disc were investigated and discussed.

3.1 The lithography process

The micro pellet array of nickel matrix diamond composites was fabricated using UV-lithography and composite electroforming. The UV-lithography processes contained the design of the mask, resist coating, UV light exposure, and development to produce a resist mold with a specific micro pattern on metal base as shown in Fig 3. This resist molds with a better geometrical patterns was fabricated under the following operating parameters: soft baking at a temperature of 100 ºC for 23 minutes, the exposure time of 30 seconds, and developing time of 6 minutes for the JSR THB-151N resist.

3.2 The etching process

The chemical etching using phosphoric acid （96g/ml）and nitric acid（4g/ml） for the aluminum alloy substrate was employed to make the holes, which improve the adhesive of micro patterns of composites. Fig 4 showed the variation of the etching depth of the metal with the etching time. The etching depth of the holes increases with the increase of time. But poor wetting causes the etching depth to be limited due to micro hole with a poor mass transfer and wetting. Metal base of the micro nickel abrasive pellet arrays with a moderate hole for improving its adhesive was shown in Fig 5.

3.3 Properties of the diamond composites

A typical fracture surface of the nickel matrix diamond composite was shown in Fig 6. The uniform distribution of diamond particles and the grit concentration can be adequately controlled by speed and time of the blade and ultrasonic agitation. In addition, the hardness of the pure nickel matrix electroplated under different doses of leveling agent and stress reducing agent at the current density of 2ASD was shown in Fig 7. From this figure, when no leveling agent and stress reducing agent were added under the current density of 2 ASD, the resulted hardness of the plated nickel layer was HV220. When 10 cc of leveling agent and 5 cc of stress reducing agent were added under the current density of 2 ASD, the hardness obtained from the plated nickel layer could reach HV420. In addition, generally, the hardness of nickel layer electroplated increase with the decrease of the current density. This is because when the current density is lower, the nickel ions that are undergoing dissolution at the anode are smaller size of granules that will form fine granule packing. Therefore, the hardness of nickel matrix ranges from HV220 to HV420. Hence, the matrix hardness and the diamond concentration of the composites can be adjusted to the desired condition for the specific application.

3.4 Micro pellet array of nickel matrix diamond composites

When only a blade agitation during the composite electroplating was applied, the diamond powders in the nickel matrix showed a relatively poor dispersion with some aggregations (Fig. 8 (a)). Fig. 8(b) demonstrated the improved diamond powder dispersion with combination of blade agitation and ultrasonic oscillation. Therefore, a combination of blade agitation and ultrasonic oscillation during the composite electroplating can be recommended to improve the diamond dispersion in the nickel matrix.

When Figs.9(a) and (b) showed a typical micro electroformed pellet array of nickel/diamond composite on the disc produced at blade rotational speed and ultrasonic oscillation with a time ratio of 3:7. Hence, employing micro UV lithography and composite electroforming can adequately produce some micro geometrical patterns of metal matrix composites for some specific applications.

4. Conclusions

1. The micro pellets of nickel/diamond composites on the metal base can be sucessfully fabricated by the composite electroforming and UV-lithography.
2. For micro composite electroforming, the hardness of nickel layer electroplated on the substrate can be increased with the increased amount of leveling agent and stress reducing agent.
3. Using a moderate blade agitation and ultrasonic oscillation during the composite electroforming can improve the dispersion and concentration of diamond powders in the nickel matrix of micro pellets on the disc.

Acknowledgments

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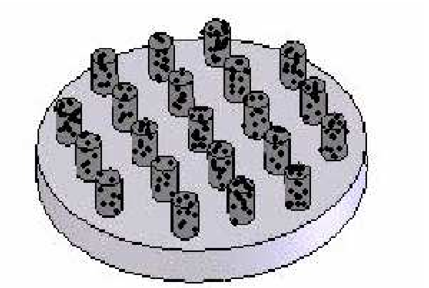


Fig.1 A schematic micro pellets of nickel/diamond composites on the disc.

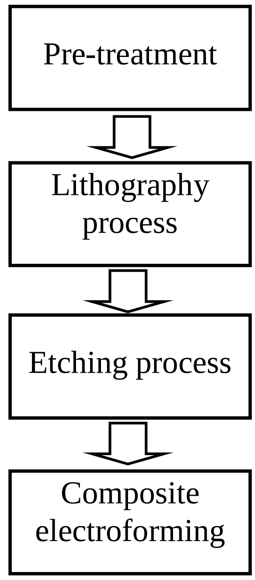


Fig.2 Fabrication processes for the nickel matrix diamond composites

Table 1 Experimental condition for composite electroforming

Bath composition	Concentration
Nickel sulfamate	400 g/l
Boric acid	45 g/l
Nickel chloride	1 g/l
Wetting agent	10 cc/l
Leveling agent	0～10 cc/l
Stress reducing agent	0～5 cc/l
Diamond	35 g/l
Operating conditions	
Temperature	50 ºC
Current density	1～10 ASD
Agitator	Blade and ultrasonic

Table 2. The four type for the etching process

	Etch	Composition	Time (min)	Temperature (℃)
A	Yes	Phosphoric acid nitric acid	30	90
B	Yes	Phosphoric acid nitric acid	60	90
C	Yes	Phosphoric acid nitric acid	90	90

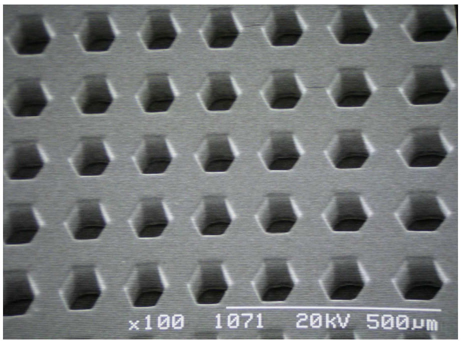


Fig.3 A JSR resist mold

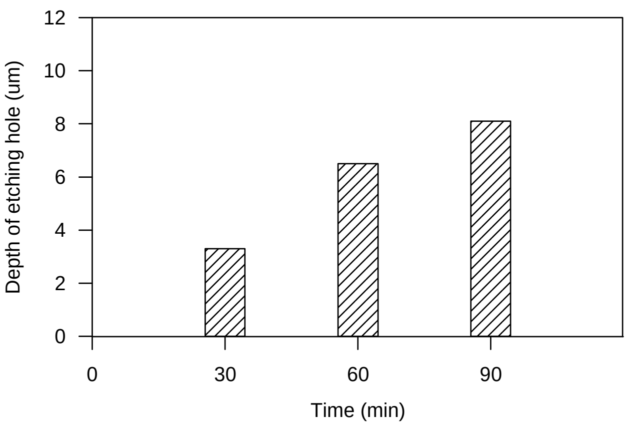


Fig.4 Variation for the depth of etching holes with different of etching time during the etching process.

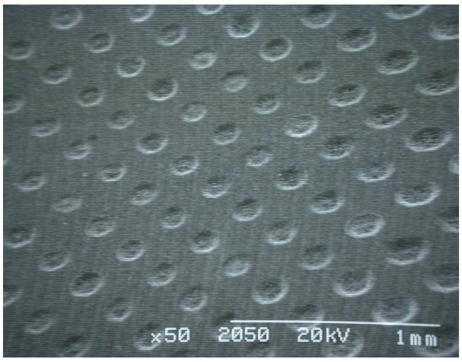


Fig.5 Appearances of circular holes on the metal substrate produced under the etching process.

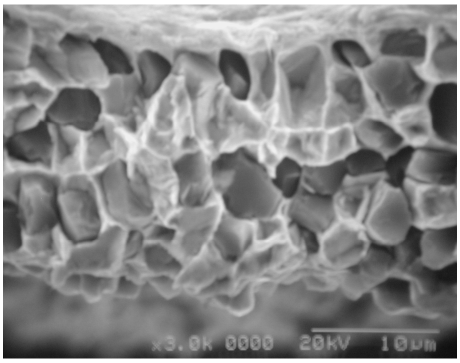


Fig.6 A typical fracture surface of the nickel matrix diamond composite electroformed.

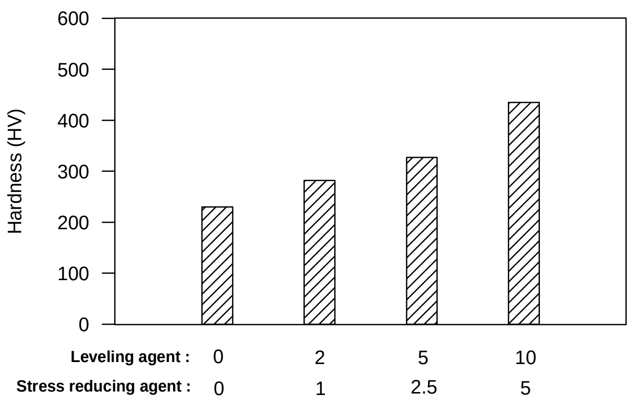
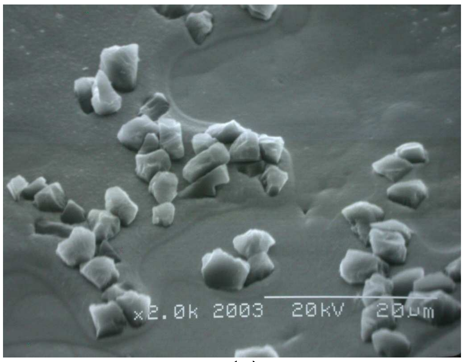
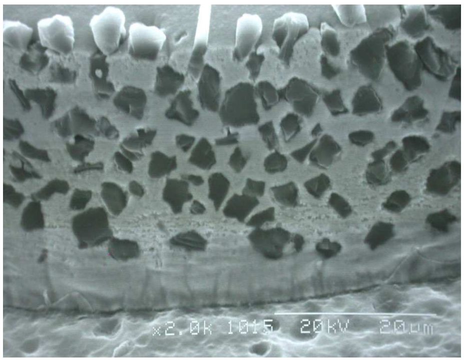


Fig.7 The average hardness of the electroplated pure nickel matrix at 2ASD.

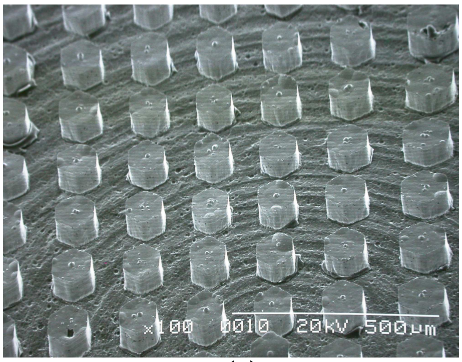


(a)

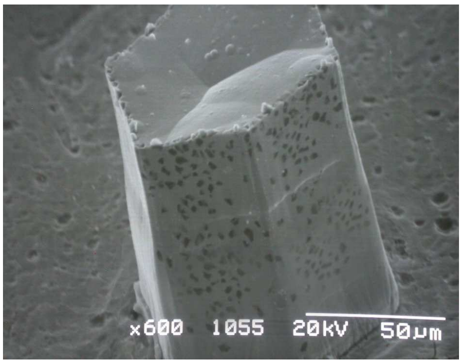


(b)

Fig.8 Appearances of the diamond powder dispersion in the matrix using (a) only a blade agitation during the composite electroplating and (b) the blade agitation and ultrasonic oscillation.



(a)



(b)

Fig.9 (a) A typically micro electroformed pellet array of nickel/diamond composite and (b) magnification of (a).