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A method of etching and powder blasting for microholes on brittle materials

Y.S. Liao, L.C. Chen*

Department of Mechanical Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei, 106, Taiwan

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ABSTRACT

Brittle materials such as semiconductors, ceramics, glasses, piezoelectric etc., are difficult to machine by traditional machining methods. This paper provides an approach to create holes or grooves more efficiently via powder blasting process. Instead of one protective layer for mask that is conventionally used, two layers are coated on the surface of the substrate material. The inner layer is water-soluble resin with excellent adhesion to the substrate but having weak resistance to powder erosion, and the second layer is a photosensitive oligomer that is adhered well to the first layer and has very high resistance to powder erosion. Such a protective coating possesses two contrary characteristics: high resistance to powder blasting and easy removal from substrate after powder erosion. Once the openings of the second layer are formed at the desired positions via a photo-etching method, a printing method, or other methods, the holes or grooves can be obtained by etching through the openings of the second layer to the first layer and the substrate by a powder blasting process. Then the whole protective coating is easily and smoothly stripped off without any damage to the substrate by dissolving the first layer with water. Due to easy removal of the mask plus the good resistance to powder blasting and a much higher erosion rate than the one obtainable by wet and dry etching processes, the proposed process can be applied to create holes or grooves on brittle material, instead of chemical etching process, so as to achieve a good quality and superior rate of production.

1. Introduction

Due to their special electronic, optical, physical, and mechanical properties, semiconductors, ceramics, glasses, and piezoelectrics have been widely used in computers, consumer products, communications equipment, manufacturing industries, automobiles and by the military. These materials possess the common characteristic of being hard, brittle and difficult to process. In many applications, drilling of microholes or ditching micro slots are needed. Since the traditional machining processes are ineffective for such brittle materials, the groove on the ceramic substrate was obtained by initially punching on a green ceramic sheet by a press and then followed by baking, or by dry or wet etching process in the past (Sin and Song, 2002). However, the dimensional accuracy of groove by punching and baking process is not sufficient due to the shrinkage of the ceramic substrate during baking, and dry or wet etching process is an extremely slow etching method.

Powder blasting had been used in various applications, and its negative effects on the blasted parts had been studied (Hutchings et al., 1981). But recently, powder blasting has been proposed as a new, simple and very fast mechanical etching method for the fabrication of micro systems on brittle materials (Slikkerveer, 1999). The erosion rate of powder sand blasting process is on the order of 1 mm/min, which is a much higher rate than the one obtainable by wet and dry etching processes, and micropatterning resolution typically is around 50 μm for powder particle size of 30 μm (Belloy et al., 2000). This simple process has been proved as a potential technique for machining brittle materials, but the research on applications of this process is relatively few. This paper proposes a method to create holes or grooves more efficiently via powder blasting process.

In the process of powder blasting, mask was closely stuck on or magnetically attracted to the substrate to protect the area of substrate not to be powder blasted (Belloy et al., 2002). Conventionally, a rubber or metal sheet was the main material of mask and was cut by a cutter to form the mask pattern. This process involves troublesome operations besides unsatisfactory dimensional accuracy and working efficiency (Belloy et al., 2001). Recently, a photoresist has been used as a mask material (Slikkerveer et al., 1998; Slikkerveer and Veld, 1999). With the aid of a mask aligner, the opening on the photosensitive resin mask can be accurately located on the wafer substrate after the exposure and development pro-

* Corresponding author. Tel.: +886 2 23377319; fax: +886 2 23035181.
E-mail address: liichun@ntu.edu.tw (L.C. Chen).

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cess. However, since the resistance to powder blasting and the removability of the mask are two contrary characteristics, the mask is either insufficient to protect the substrate or it is difficult to remove reliably from the substrate without damaging the electroplated metal (Dentinger et al., 2002) after powder blasting process. It has therefore been demanded to find a method that makes mask to possess both of these two important characteristics to improve dimensional accuracy and good quality of powder blasting process.

The present paper proposes a method to create holes or grooves by paving two different layers of protective mask made of two different materials so as to achieve the properties of a very high resistance to powder blasting and good removability. In the following sections, procedures of this method are introduced first. Performance test is conducted to evaluate the proposed method. Finally, numerous conclusions are drawn and given.

2. Etching and powder blasting method

The method includes the steps of preheating the substrate to 80 °C and coating on the substrate a thickness 20 μm or so layer of water-soluble resin, a mixture of polyvinyl alcohol and polyvinyl acetate, by a coating machine as shown in Fig. 1(a). After drying the first layer, the substrate is preheated to 70 °C again, and a photosensitive polymer with desired thickness according to time required to resist powder blasting is coated with a coating machine onto the first layer as shown in Fig. 1(b) This second layer is formed by the mixture of urethane acrylate oligomer, photopolymerization and a cellulose derivative initiator with excellent adhesion to the first layer and high resistance to powder erosion.

Next, the pattern formation on the second layer is performed. A photo mask having a prescribed mask pattern is brought into contact therewith, and light for exposure is irradiated through the mask to expose this photosensitive layer for polymerization to occur as depicted in Fig. 1(c) and (d). The light for exposure can be X-ray, electron beam, laser beam and ultraviolet light. After exposure, the exposed film is developed with an alkali developer to remove the unexposed area. The openings on the second layer are formed after the exposure and development process as shown in Fig. 1(e). Next, powder materials such as Al_2O_3 are sprayed from nozzle above the substrate, and thus, by this process, the area without protection by the second layer where the holes or grooves are to be created are eroded as shown in Fig. 1(f). After the blast process, the second layer can be easily peeled off by dissolving the first layer with water as shown in Fig. 1(g). The holes created on silicon or ceramic substrate are shown in Fig. 1(h).

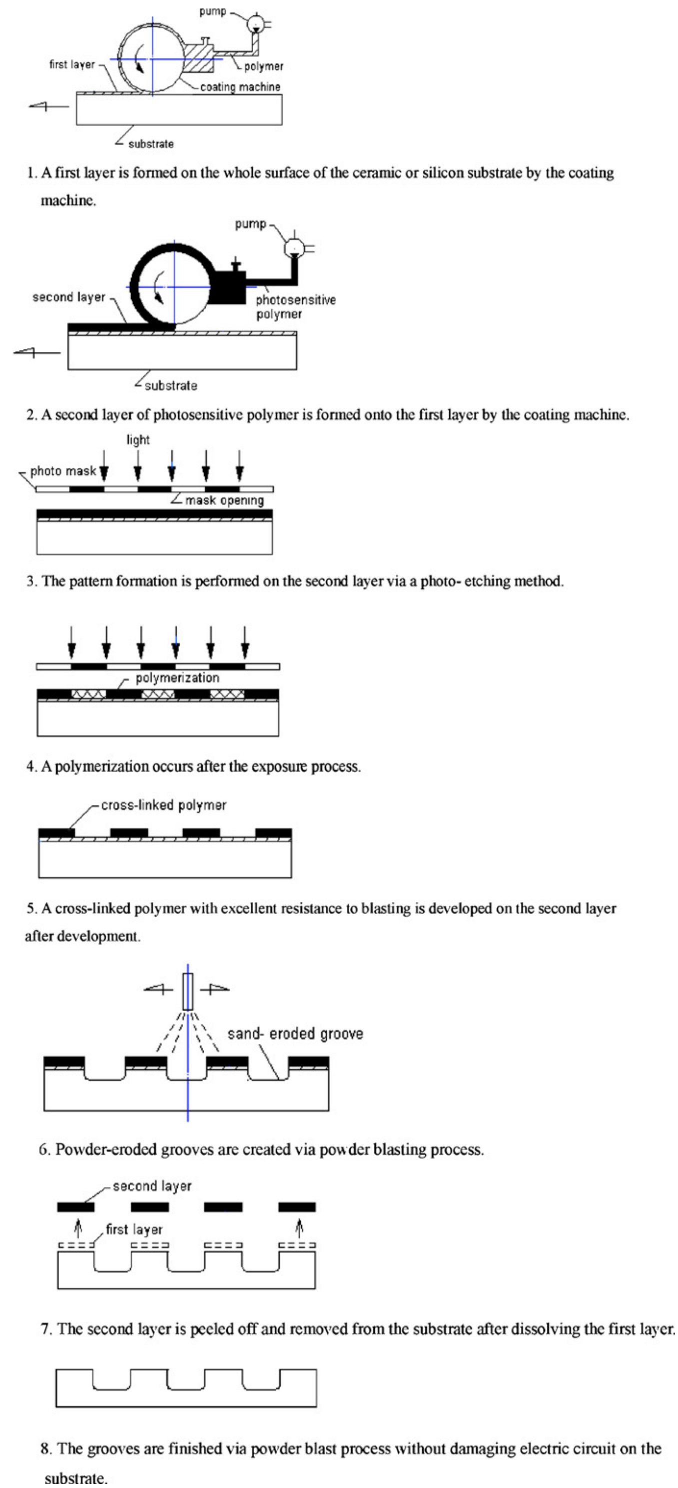

Fig. 1. (a) A first layer is formed on the whole surface of the ceramic or silicon substrate by the coating machine. (b) A second layer of photosensitive polymer is formed onto the first layer by the coating machine. (c) The pattern formation is performed on the second layer via a photo-etching method. (d) A polymerization occurs after the exposure process. (e) A cross-linked polymer with excellent resistance to blasting is developed on the second layer after development. (f) Powder-eroded grooves are created via powder blasting process. (g) The second layer is peeled off and removed from the substrate after dissolving the first layer. (h) The grooves are finished via powder blast process without damaging electric circuit on the substrate.

3. Experimental conditions and process

A good mask is essential to success of powder blasting process, and the accuracy of holes or grooves on work substrate is attributed to high resistance of mask to powder blasting, and good removablity of the mask after powder blasting process. To evaluate the performance of the proposed method of this paper, mask properties were first tested out, then the achievements of this method, like the accuracy of holes, appearance of substrate after powder blasting were determined.

3.1. Experimental conditions

3.1.1. Mask test

For seeking out mask properties for general use in mask application, the Na-glass substrate was used as substrate for this test. At first, the Na-glass substrates were coated with a layer of water-soluble resin and next with a second layer of photosensitive