Surface & Coatings Technology 315 (2017) 377–384

Contents lists available at ScienceDirect

Surface & Coatings Technology

journal homepage: www.elsevier.com/locate/surfcoat

Circuit patterning using laser on transparent material

Han-Guel Kim [a], Min Soo Park [b,*]

[a] Graduate School of NID Fusion Technology, Seoul National University of Science and Technology, 232 Gongneung-ro, Nowon-gu, Seoul 01811, South Korea
[b] Department of Mechanical System and Design Engineering, Seoul National University of Science and Technology, 232 Gongneung-ro, Nowon-gu, Seoul, South Korea

ARTICLE INFO

Article history:
Received 7 November 2016
Revised 17 January 2017
Accepted in revised form 16 February 2017
Available online 20 February 2017

Keyword:
Laser-induced backside wet etching (LIBWE)
Glass
Electroless deposition
Conductive patterning
Metal seed layer

ABSTRACT

Glass is chemically very stable at room temperature, and has good resistance to gas, bacteria and organisms. It is also used in many industrial fields owing to its property of transmitting light. In particular, because of the recent developments in electronics, the industrial demand for a process for generating conductive circuit patterns on glass surfaces is increasing rapidly. Circuit patterns on glass are mainly by a special non-contact processing method using a laser beam or a chemical methods. However this method has disadvantages such as low conductivity, high cost and limitation on the size of the material. To solve this problem, processes such as LCLD have been widely studied. However they have disadvantages such as slow speed and limitation on the materials. Therefore, in this study, generation of circuit pattern was tried using the LIBWE process, which is capable of machining the glass regardless of the characteristics of the glass with a relatively simple equipment configuration. In particular, processing of glass was done to create a rough surface and form a seed layer for electroless deposition using a general-purpose laser beam having a wavelength of 1064 nm. Through this method, it is possible to achieve good productivity, and produce conductive and adhesive circuit patterns by a simple process than by traditional processes.

1. Introduction

Glass is chemically very stable at room temperature, and has good resistance to gas, bacteria and organisms. In addition, it is not affected by the reactions of biological samples or chemicals. It is also used in many industrial fields owing to its property of transmitting light. In particular, because of the recent development in electronic, the industrial demand for a process for generating conductive circuit patterns on glass surfaces is increasing rapidly in the field of optical devices, displays, bio-chips and mobile communication devices. Circuit patterns of glass materials can be used in the edge circuits for the touch screens of smart phones and various IoT (internet of things) devices. They are used in the automotive field in areas such as technology front glass heating and transparent antenna. However, direct fabrication of circuit pattern on glass is difficult owing to its characteristics such as brittleness, high hardness, vulnerability to heat, and absence of chemical reaction [1–3].

Hence, for processing of circuit patterns on glass, special non-contact processing methods are applied using a laser beam or a chemical methods. The most widely used process is the one using ITO (indium tin oxide). In this process, after the sputtering of ITO on the glass surface, it is removed by wet etching or by a laser beam [4]. However, it has disadvantages such as low conductivity, high cost and limitation on the size of the material [5].

As an alternative to this process, electronic printing is widely used for generating patterns on glass. Any pattern can be formed using electronic printing by using a material such as silver paste [6]. This method has no limitation to the size of material. Moreover, the pre/post-treatments are very simple. However the conductivity is low, and the adhesive strength is limited because of the paste. In addition, because of the fluidity of the silver paste, it is difficult to make a precise circuit pattern on a surface having a three-dimensional shape.

To solve this problem, LCLD (laser-induced chemical liquid phase deposition) process has been widely studied [7–9]. Scanning of the glass surface in a special metal solution with a locally focused laser beam activates copper reduction, resulting in the deposition of the metal along the path of the laser. By this method small-sized metallic structures can be created without a photo mask on the glass surface. However, the laser feed rate for the reaction is very low (0.01 mm/s). Thus, it is difficult to expect the desired productivity with this process. In addition, it has a drawback that the pattern cannot be narrower than a metal circuit pattern with a width of 0.1 mm.

Alternatively, there is a process for making the circuit through electroless deposition after machining the glass using femtosecond laser beam [10–11]. This process can be used as a μ-TAS (micro-total analysis system) or a lab-on-a chip (LOC) in bio-nano-engineering, because it can create very thin lines. Moreover, the electroless deposition is a highly advantageous mass production process, since it permits parallel

* Corresponding author.
E-mail address: pminsoo@seoultech.ac.kr (M.S. Park).

http://dx.doi.org/10.1016/j.surfcoat.2017.02.049
0257-8972/

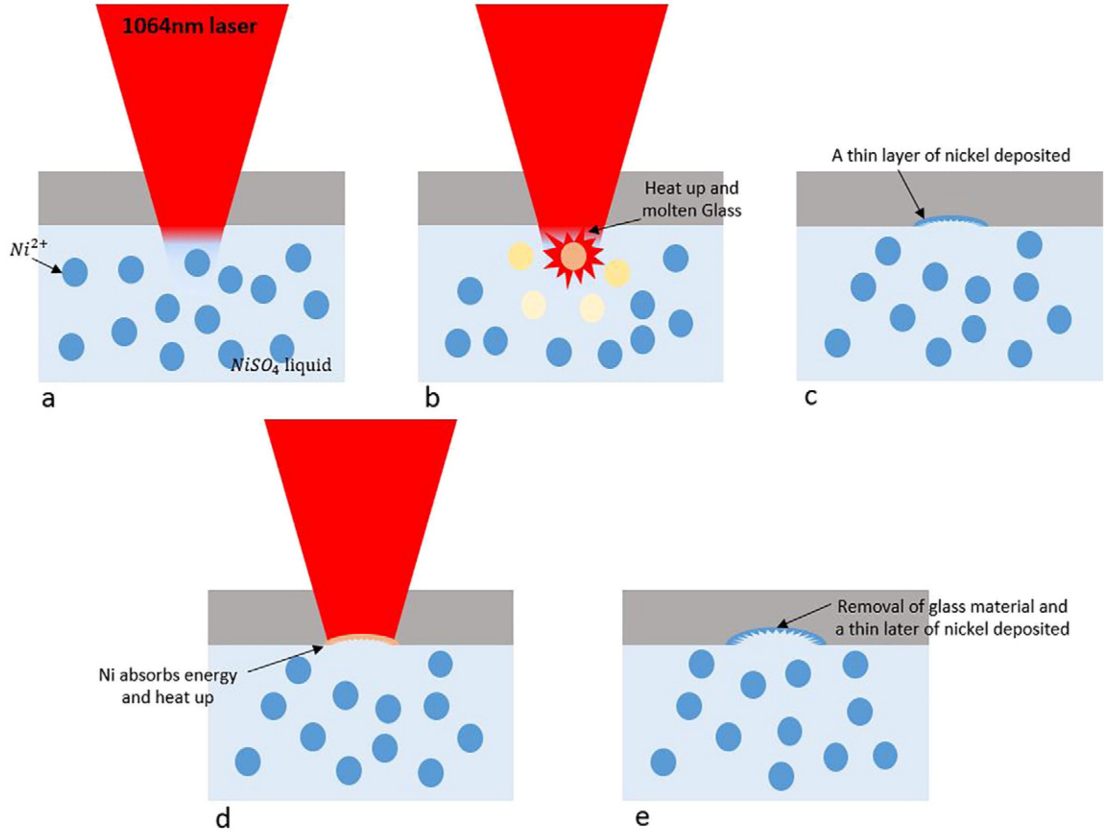

Fig. 1. Principles of the LIBWE process (a) Laser irradiates from the top (b) Small explosions after heat up liquid and molten glass (c) Removal of glass material and Ni deposition on the underneath of the glass (d) The deposited Ni absorbs the laser energy and heats up the immediate glass region. (e) Facilitate removal of the molten glass.

manufacturing. However, it can be used only with a good light-reactive glass because the mechanism of selective electroless deposition is based on the anchor effect by surface roughness. Thus, quartz, which contains a large quantity of SiO_2, is not suitable because sufficient level of roughness is not created by this method. It is also difficult to apply universally, because expensive femtosecond laser is used. In addition, it is difficult to expect adequate productivity owing to the low machining speed required for generating a well-defined shape.

In this study, circuit patterning was tried using the LIBWE (laser-induced backside wet etching) process, which is capable of machining the glass surface regardless of the characteristics of the glass, with a relatively simple equipment configuration. Processing of a glass surface was performed to create a rough surface and form a seed layer for electroless deposition using a general-purpose laser beam having a wavelength of 1064 nm. Through this method, it is possible to achieve good productivity, and produce conductive and adhesive circuit patterns by a simple process than by traditional processes.

2. Experimental details

2.1. Generation principles of selective metal seed layers for electroless plating

Electroless plating, known as chemical or auto-catalytic plating, is a non-galvanic plating method that involves several simultaneous reactions in an aqueous solution, which occur without the use of external electrical power. Unlike electro-plating, it can be applied to various substrates, such as plastics or organisms. For obtaining good electroless plating, it is necessary to have a seed layer to react well with the metal ions and adequate surface roughness [12–13]. Thus, the LIBWE process was chosen to conduct surface treatment on glass.

Fig. 1 illustrates the proposed mechanism of the LIBWE process; this process involves irradiation on a metal sulfate solution using a laser beam having a wavelength of 1064 nm. During the first pulse, the laser beam passes through the glass substrate, irradiates it and heats up the $NiSO_4$ liquid. During the first few nanoseconds of the pulse, the temperature rises by a few hundreds of degrees Celsius (Fig. 1(a)). As a result, the solution, which has absorbed the heat energy at the high temperature, drastically vaporizes instantaneously, and temperature of the molten glass surface drops slightly (Fig. 1(b)). The initial high temperature causes the $NiSO_4$ liquid to decompose and initiate nickel deposition (Fig. 1(c)). Upon the arrival of the second pulse, a part of the laser energy is absorbed by the $NiSO_4$ liquid, causing the liquid to heat up again, while the other part of the energy is absorbed by the deposited nickel. Upon continuous irradiation, the nickel absorbs more energy and gets heated further (Fig. 1(d)). The nickel layer facilitates melting of the glass, and the bubbles and shock waves that are

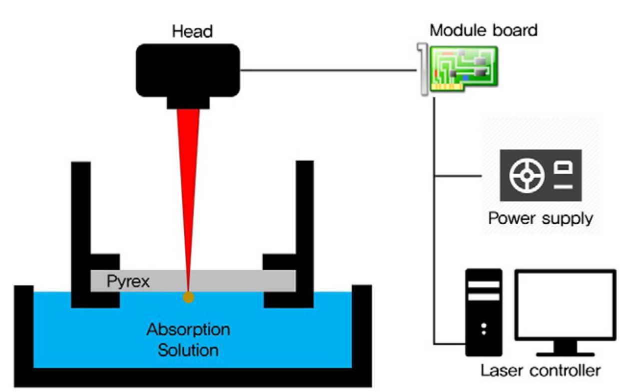

Fig. 2. Schematic diagram of laser machining system.