Development and property modification of composite metal for Material extrusion printed circuit

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ABSTRACT

Recently, the proportion of 3D printing technology in the electronics industry is expected to average 50% in 2030. It is expected that the 3D printing manufacturing method will be introduced in earnest depending on the development of metal materials for printing. Most of conductive materials for ME based 3D printing are mixture of conductive particles with plastic materials as the base material. Therefore, it is difficult to satisfy the inherent electric conductivity characteristic of the conductive material. Also, the very low electric conduction efficiency per unit volume of the printed pattern is a problem.

In this paper, we will discuss a system that can print simple electronics by printing liquid metals based on composite metals, and conductive materials that can form circuit wiring immediately after printing. The melting point of the metal material is remarkably improved so that the metal material can be printed even on the plastic of general ME printing. Also, the electrical properties and rheological behavior of the composite metal may be varied by mixing the additives. Immediately after printing unlike the conductive paste material, the composite metal is electrically connected to the electronic parts and the electrical characteristics are satisfied without post-treatment. Thus, it is possible to propose a manufacturing method of an electronic device capable of immediately printing by utilizing the 3D printing technology. We may expect the bright future of the 3D printing electronics industry by the circuit design that manufactures electronic devices on the spot and breaks the boundaries of the dimension.

Keywords: Eutectic Alloy, Liquid Metal, Material Extrusion, 3D Printed Electronics,

1 INTRODUCTION

Recently, development of electronic devices and parts using 3D printing is getting popular, and various researches are being conducted to stably print metal wiring of electronic circuits on a printed polymer substrate. Particularly, various researches are going on in the field of Molded interconnect device (MID), embedded electronics, and metal 3D printing. In the case of the Material Extrusion (ME) method represented by Fused Deposition Modeling (FDM), the surface roughness of the molding and the electrical characteristics of the material limit the performance of the raw material produced in the conventional manufacturing system[1]. If such a problem is solved, it will be widely utilized in the field of conventional electronic devices and parts manufacturing.

In this paper, we propose a method for embedding electronic circuits in 3D objects using ME printing method. By placing the SMD module, it is possible to assemble between component mounting, circuit wiring and polymer substrate. The output printed in this series of processes can be created as a three-dimensional electronic device with both mechanical and electrical functions. To evaluate the performance, an electronic circuit capable of operating the LED was printed, and power was applied to check whether the circuit was operating.

Utilizing the advantages of this approach, a function equivalent to that of an electronic device implemented in a conventional manufacturing system can be implemented. In addition, it is possible to provide high value-added expandable electronic product manufacturing and manufacturing services through application of various conventional electronic components and 3D printing technology.

2 EXPERIMENTAL DETAIL

The LED circuit was fabricated using three types of material extrusion nozzle systems. Figure 1 shows each ME printing nozzle heads. Figure 1 (a) shows the FDM nozzle head. In this experiment, the polymer (F-PLA-N001) and the conductive polymer (GRPHN-175) were simultaneously printed. (b) is a pneumatic dispensing type nozzle head having an ultraviolet lamp, and prints an ultraviolet curable polymer (se-8272) and silver nanoparticle ink (PS-004). Finally, (C) is a pneumatic dispensing type nozzle head, which prints an eutectic alloy. And Figure 2 (a) and (b) is shows the LED circuit and LED flashlight manufacture. We fabricated the LED flashlight by printing the LED circuit with the conductive material on the polymer printed substrate and then placing the SMD including the battery. Table 1 shows the resistivity and wire thickness for each of the three types of conductive materials. The silver nanoparticle ink shows the resistivity characteristics for the sintering conditions after the post-treatment of the printing.

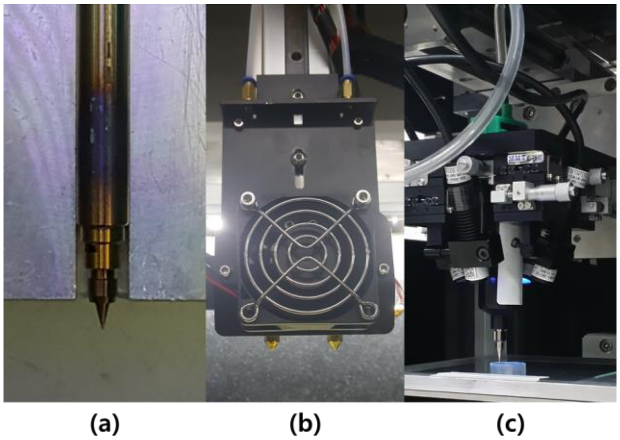

Figure 1: Material Extrusion 3D Pringting Nozzles

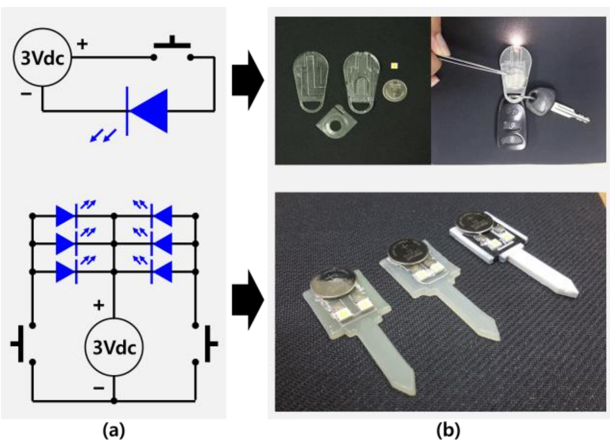

Figure 2: Electronic circuit configuration and 3D printed LED devices.

Table 1 Measuring Resistivity of LED Circuit Wiring

Materials	**Conductive Polymer**	**Composite Metal**	**Silver Nanoparticle Ink**
Resistivity	616.480 mΩ·㎝	15.438 μΩ·㎝	2.248 μΩ·㎝
Thickness	3300 ㎛	530 ㎛	3 ㎛
Post tretment	-	-	150℃ in 30min.

3 RESULTS AND DISCUSSION

Circuit wirings printed with conductive polymer have the largest pattern width and thickness. However, when the LED is turned on, the brightness is the lowest. On the other hand, the resistivity of the eutectic alloy and silver nanoparticle inks is measured to a small degree and shows sufficient electrical characteristics to illuminate the LED. In case of silver nanoparticle ink, it was measured higher than that of normal silver. Due to incomplete annealing conditions, the porous form is created in the pattern, and a relatively low-thickness print pattern appears to be affected[2]. The LED circuit showed a difference in the brightness of the LED depending on the resistivity of the conductive material. This is a common result, and the lower the resistivity of the circuit wiring, the brighter the LED. Unlike traditional electronic devices or PCB manufacturing methods, parts and wiring can be completed by printing substrates based on user requirements, placing components, and printing wiring. That is, when a printer is output, an electronic product is produced. If the circuit board is printed using composite metal, no additional post-treatment is required. Immediately upon printing, it exhibits conductivity suitable for the circuit. Therefore, it is suitable for the continuous process, and it is advantageous that the wiring can be changed variously and easily according to the design of the substrate. In the future, we expect to become a next-generation manufacturing technology that can increase the degree of freedom of product design and increase the value added of the manufacturing process. For more information about the manufacturing process and the analysis of the material characteristics will be announced through poster presentation at the conference site.

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