A nanotransfer technique for silver ink using ultraviolet roll to roll nanoimprint

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Printed electronics (PE) is expected to be a major breakthrough to meet these demands of lightness, flexibility and transparency. PE devices are fabricated by conventional printing techniques, whose equipment cost is relatively lower than that of conventional optical lithography techniques. In particular, ink-jet printing [1] is typically used for the fabrication of PE devices because of higher resolution, compared to the other printing techniques such as screen printing. However, the throughput of ink-jet printing is lower than the other method that uses moulds or printing plates because the traversal time of an ink-jet nozzle tends to be long. To obtain a higher resolution and a high throughput simultaneously, nanotransfer printing (nTP) is receiving a lot of attention [2]. Previously, we have succeeded in an nTP method using a roll mold with a metal film coated by vacuum evaporation method [3]. However, vacuum evaporation method is a time-consuming process and it is impossible to transfer a metal nano-pattern continuously. On the other hand, we also have succeeded in nTP technique using a silver ink via spin coating [4]. In this study, we demonstrate an nTP technique in air for a silver ink using ultraviolet roll to roll nanoimprint (UV-RTRNIL).

Figure 1 and 2 show the fabrication processes of our nTP technique using UV-RTRNIL. ZEP520A, and ZED-N50 (Zeon Co.) were used for a positive-type EB resist and a dedicated developer, respectively. First, ZEP520A was spin coated at 2000 rpm on a cleaned Si substrate and baked 120 °C for 20 minutes, resulting in the thickness of approximately 500 nm. Then, line and space pattern was delineated by electron beam lithography (EBL) (Fig. 1(1)) using a scanning electron microscope with a drawing system (SEM; ERA-8800FE, Elionix Co.). Next, the exposed ZEP520A was developed (Fig. 1(2)) and a chromium layer was deposited by vacuum evaporation (VPC-260F, Ulvac Kiko Inc.) (Fig. 1(3)). Subsequently, we carried out liftoff via a dedicated remover of ZDMAC (Fig. 1(4)). To obtain a high aspect ratio pattern, the bosch process was performed (Fig. 1(5) and Fig. 3(a)). Next, the sample was coated with a release agent of optool DSX 0.1 % (Daikin Industries Ltd.) and baked at 120 °C for 5 min (Fig. 1(6)). To obtain a flexible replica mold, then, UV-NIL was carried out using PAK-01-CL (Toyo Gosei Co., Ltd.) (Fig. 1(7-9)). Finally, the flexible replica mold was coated with a chromium oxide release layer [3, 4] (Fig. 1(10) and Fig. 3(b)). Using the replica mold, we performed nTP process of nano-patterns made of a silver ink (T10Z-A02, Dowa electronics Co.) via UV-RTRNIL. First, the silver ink was directly dropped onto the replica mold attached on a roll substrate (Fig. 2(1)). To reduce the residual thickness of the silver ink, roll-to-roll liquid transfer imprint lithography (LTIL) was carried out [5]. After LTIL, the silver ink was split into two: that on a polyester film and that on the replica mold (Fig. 2(2)) and silver ink on the mold was cured using a heat gun (Fig. 2(3)). During the next rotation, the UV-curable resin was dropped. An UV lamp was then turned on, and the resin was pressed between the mold with silver ink and the film (Fig. 2(4)). Finally, the cured resin and the silver ink layer was transferred, resulting in the nano-scale metal line (Fig. 2(5)). Figure 4 shows the obtained silver nanopattern and its transmittance. Consequently, we succeeded in the fabrication of nanoscale metal line pattern via UV-RTRNIL process in air using a silver ink.