Fabrication of flexible and durable heating devices on polyimides by solution-based metal embedding in continuously inscribed micro- and nano-trenches

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ABSTRACT

We develop solution-processable electrode-material embedding in dynamically inscribed nanopatterns. Consisting of dynamic nanoinscribing and silver particle solution deposition, our process can fabricate tailored micro- or nanopatterns on the highly durable polyimide film and sequentially deposit silver nanoparticles by using solution process and doctor blading. The electronic device is also easily applied to the high-performance flexible heater. Due to the unique embedded architecture on the substrate, the heater is invulnerable to both internal delamination and external harsh stimuli.

Keywords: continuous fabrication, dynamic nanoinscribing, metal solution deposition, high-performance heater, flexible durable device

NOMENCLATURE

MNPs	metal micro- or nanopatterns
SPEEDIN	solution-processable electrode-material embedding in dynamically inscribed nanopatterns
DNI	dynamic nanoinscribing
T_g	glass transition temperature
PI	polyimide
Ag NP	silver nanoparticle

1. INTRODUCTION

Metal micro- or nanopatterns (MNPs) have both unique optical properties and reasonable thermal and electrical conductivity and thus are actively applied to various functional devices in electronics, plasmonics, and photonics. However, conventional and established nanopatterning processes typically involving optical lithography, metal deposition, and etch process are not suitable to fabricate these MNPs on flexible and soft substrates because they largely focus on flat and hard substrates. In this research, we introduce an alternative way to continuously produce MNPs on a flexible and highly durable polymer, solution-processable electrode-material embedding in dynamically inscribed nanopatterns (SPEEDIN). As a tangible application, the heating device with MNPs is fabricated by SPEEDIN and verified to heat up to 300 °C without break down even under harsh environments.

2. RESULTS AND DISCUSSION

SPEEDIN process is composed of the dynamic nanoinscribing (DNI) process and silver particle solution deposition, as shown in Figure 1a. First, DNI can directly fabricate clear micro- or nanopatterns on the surface of polymers without any residue since DNI induces sequential deformation of polymers at the near glass transition temperature (T_g). One step further, the depths and shapes of nanopatterns are precisely controlled by modulating processing temperature, speed, and force of DNI. As a result, DNI can easily fabricate micro- or nanopatterns even on the polyimide (PI) substrate with high mechanical and chemical durability (Figure 1c). And then, an aqueous silver nanoparticle (Ag NP) solution is dropped on the DNI-ed PI surface and sequentially doctor-bladed, causing an alignment of Ag NPs to micro- or nanotrenches. Finally, a heating process of the Ag NP solution-coated PI substrate evaporates the water in the solution, embedding only Ag NPs into the trenches (Figure 1d).

The SPEEDIN-ed MNPs are also demonstrated to be flexible and highly durable heating devices up to 300 °C at 5 V (Figure 2). The heating performance of this device is also repeated by 5 times to verify sustainability. Moreover, while MNPs by conventional nanofabrication are typically embossed on the substrate, the SPEEDIN-ed MNPs have embedded architectures which can effectively sustain against external stimuli and internal delamination.

3. FIGURES

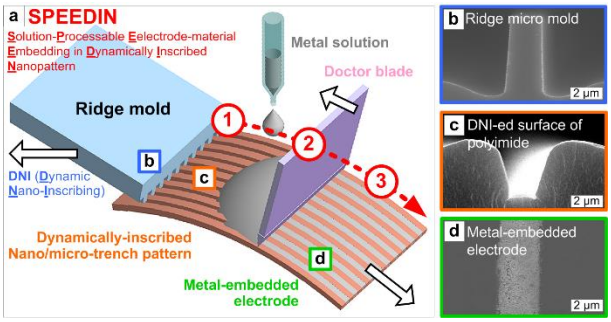

Fig. 1 Schematic of solution-processable electrode-material embedding in dynamically inscribed nanopatterns (SPEEDIN).

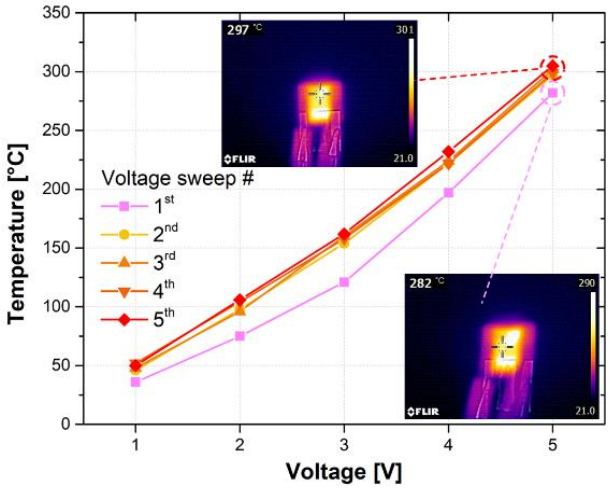

Fig. 2 Heating performance of the SPEEDIN-ed MNPs device.

4. CONCLUSION

We have demonstrated the facile SPEEDIN process which realizes continuous fabrication of flexible and highly durable electronic architectures without conventional nanofabrication. Further, SPEEDIN-ed structures have been also applied to the flexible and high-performance heater, briefly. Going one step forward, we expect the SPEEDIN process may facilitate various metal solutions over the Ag NP solution in this work.

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