Opto-Thermomechanical Nanoprinting and Nanorepairing

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Abstract: A new printing method based on opto-thermomechanical (OTM) transfer of nanoparticles with a continuous-wave laser is introduced. The OTM method allows for not only additive nanoprinting but also nanorepairing.
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Introduction

Additive manufacturing, known as the industrial version of 3-D printing, has already been used at the macroscales by engineers and designers for the rapid prototyping and low-volume production. Unfortunately, such rapid prototyping techniques are yet to be developed for the manufacturing at the nanoscales[1–5]. In this paper, I introduced a new opto-thermomechanical (OTM) method for not only additive nano-printing but also nano-repairing[1].

Results

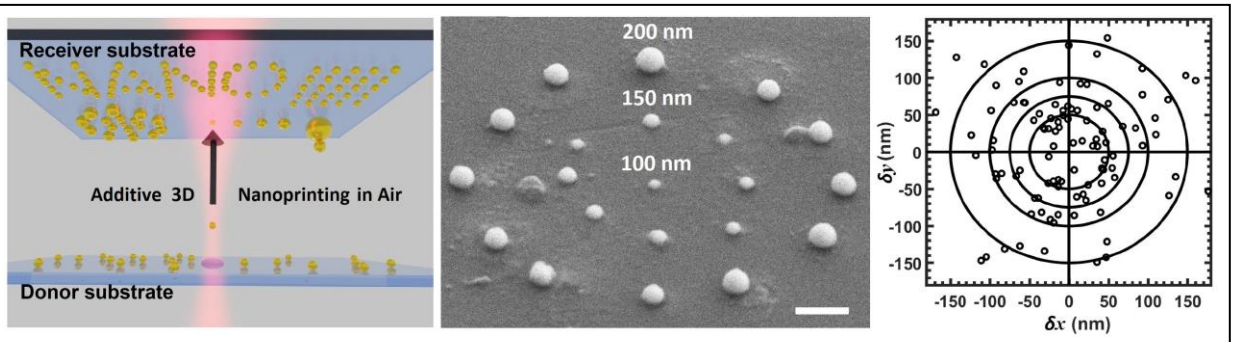

Fig. 1. Left image: Schematic of the OTM nanoprinting method. Middle image: SEM image of a circular pattern that is formed by selectively printing of three different sizes of AuNPs (100nm, 150nm, and 200nm) on a glass substrate. Right image: Printing Accuracy of the OTM method. Reprinted with permission from ref. [1] Copyright (2020) American Chemical Society.

Fig. 1 schematically shows the working principle of the OTM nanoprinting method. Gold nanoparticle (AuNPs) are drop casted on a flexible substrate named as donor substrate. A AuNP on the donor substrate is heated with a continuous-wave (CW) laser with a wavelength of 1064 nm. The heat transfers from the AuNP to the donor substrate and cause a rapid thermal expansion of a donor substrate. This rapid thermal expansion release the AuNP from the donor substrate and transfers it to a receiver substrate placed on top of it. The middle image in Fig. 1 shows a circular pattern that is formed by selectively printing of three different sizes of AuNPs (100nm, 150nm, and 200nm) with the OTM nanoprinting method. A printing accuracy of sub 100nm can be achieved by this method as shown in the right image of Fig. 1.

The OTM nanoprinting can be also used for repairing any printing errors or nanorepairing. Fig. 2 shows such a process. A letter “N” is first printed by additively transfering of fourteen 200 nm AuNPs on an ITO-coated glass substrate as shown in Fig. 2a. To repair the pattern “N”, three AuNPs (marked in the red circles) are selectively removed from the letter as shown in Fig.2b. Then two new AuNPs (marked in the blue circles) are added to the letter “N” to repair the structure as shown in the optical image in Fig. 2c. Both the nanoprinting and the nanorepairing can be conducted on the same platform under ambient conditions.

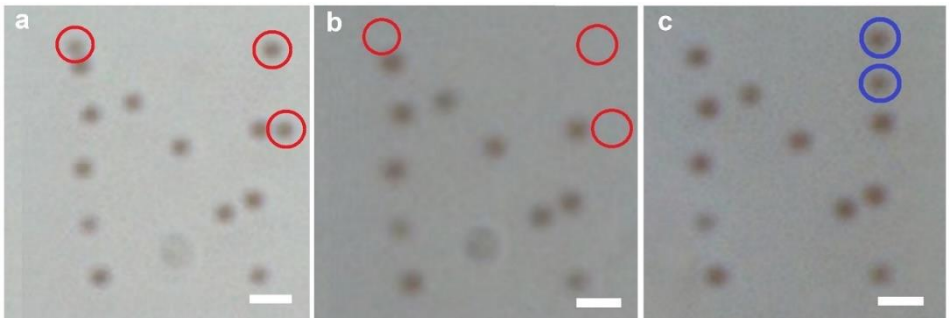

Fig. 2. Demonstration of Nanorepairing. (a) A letter 'N' consisting of 200-nm AuNPs is printed on an ITO-coated glass substrate using pre-heating. The gap between the donor and receiver substrate was ~1.5 µm. The AuNPs inside the three red circles are selected to be removed. (b) Three AuNPs are removed from the substrate. (c) Two AuNPs (in the blue circles) are added to the letter 'N'. Reprinted with permission from ref. [1] Copyright (2020) American Chemical Society.

In conclusion, an affordable OTM-NP method that allows for both additive nano-printing and nano-repairing with sub-100 nm accuracy has been successfully demonstrated.

References

1. M. S. Alam, Q. Zhan, and C. Zhao, "Additive Opto-Thermomechanical Nanoprinting and Nanorepairing under Ambient Conditions," Nano Lett., acs.nanolett.0c01261 (2020).

2. F. Karim, E. S. Vasquez, Y. Sun, and C. Zhao, "Optothermal microbubble assisted manufacturing of nanogap-rich structures for active chemical sensing," Nanoscale **11**, 20589–20597 (2019).

3. C. Zhao, P. J. Shah, and L. J. Bissell, "Laser additive nano-manufacturing under ambient conditions," Nanoscale **11**(35), 16187–16199 (2019).

4. A. Sánchez-Solís, F. Karim, M. S. Alam, Q. Zhan, T. López-Luke, and C. Zhao, "Print metallic nanoparticles on a fiber probe for 1064-nm surface-enhanced Raman scattering," Opt. Lett. **44**(20), 4997 (2019).

5. M. S. Alam and C. Zhao, "Nondestructive Approach for Additive Nanomanufacturing of Metallic Nanostructures in the Air," ACS Omega **3**(1), 1213–1219 (2018).