Laser additive manufacturing at the nanoscales under ambient conditions

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Abstract: Additive manufacturing at the macroscale has been used by engineers for rapid prototyping. In this paper, I introduced a new nanoparticle-desorption process that can be used for additive manufacturing at the nanoscales.

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 [1–4]. In this paper, I introduced a new method for laser additive manufacturing at the nanoscales. A laser induced nanoparticle desorption process that is used for the manufacturing is studied [3].

Results

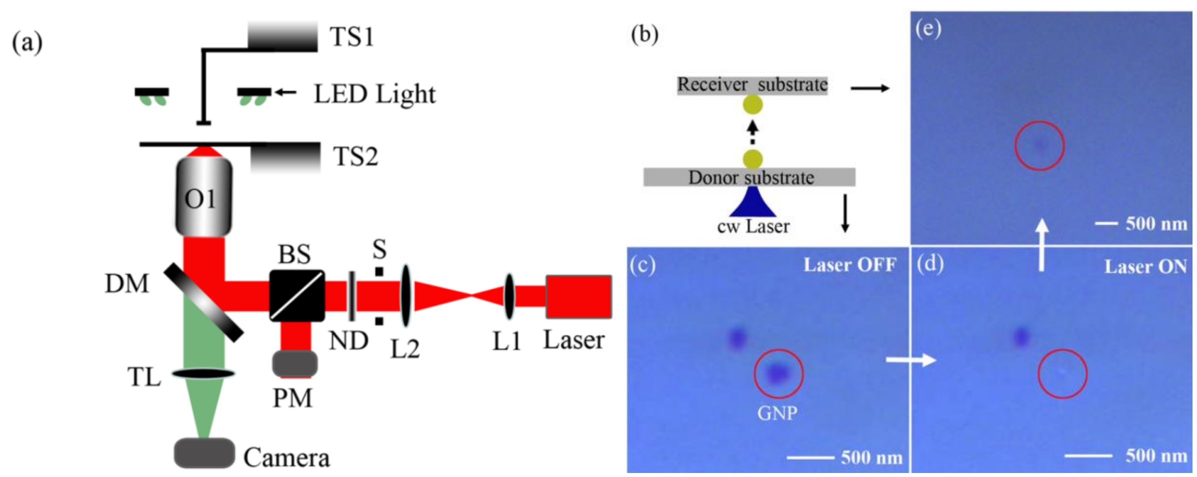

Fig. 1. (a) Layout of the experimental setup. L: lens; TL: tube lens; DM: dichroic mirror; BS: beam splitter; O1: objective lens; PM: power meter; TS: translation stage; ND: variable neutral density filter; S: shutter. (b) Schematic of the release-and-place process. (c) Optical image of GNPs on a donor substrate when the laser is off. (d) Targeted GNP released from the donor substrate when the laser is on. (e) Released GNP on the receiver substrate. Reprinted with permission from ref. [3] Copyright (2018) American Chemical Society.

Fig. 1a schematically shows the experimental setup of the laser-induced nanoparticle desorption approach, which is based on the heating of gold nanoparticles (GNPs) and rapid thermal expansion of a soft substrate. A continuous-wave (CW) laser with a wavelength of 1064 nm serves as the heating laser. The laser beam is first expanded with two lenses and then reflected by a dichroic mirror. Finally, it is focused on the sample with an oil immersion objective lens. A shutter is used to switch the laser on and off. A plastic coverslip is placed on a translation stage for precise position control. Colloidal GNPs with a diameter of 200 nm from BBI solutions are diluted and then dropcast on the plastic substrate. The GNP solution is then left naturally dried on the substrate.

A second substrate is mounted on another translation stage and suspended on top of the plastic substrate. A light-emitting diode light source is used for illumination, and the GNPs on the plastic substrate are imaged on a camera. Because GNPs will be released from this substrate, we call them donor substrate. Fig. 1c shows the optical image of a GNP on the donor substrate when the laser is off. The red circle indicates the area to be illuminated with the heating laser. Once the heating laser is switched on, the GNP is immediately released from the donor substrate. Fig. 1d shows the same optical image after the laser is turned on. The GNP in the red circle desorbs from the donor substrate and transferred to another substrate placed on top of it. Because GNPs are transferred to the top substrate, we call them receiver substrate. Fig. 1e shows the optical image of the receiver substrate with a GNP that is transferred onto. The black dot in the red circle shows the GNP that is placed on the receiver substrate.

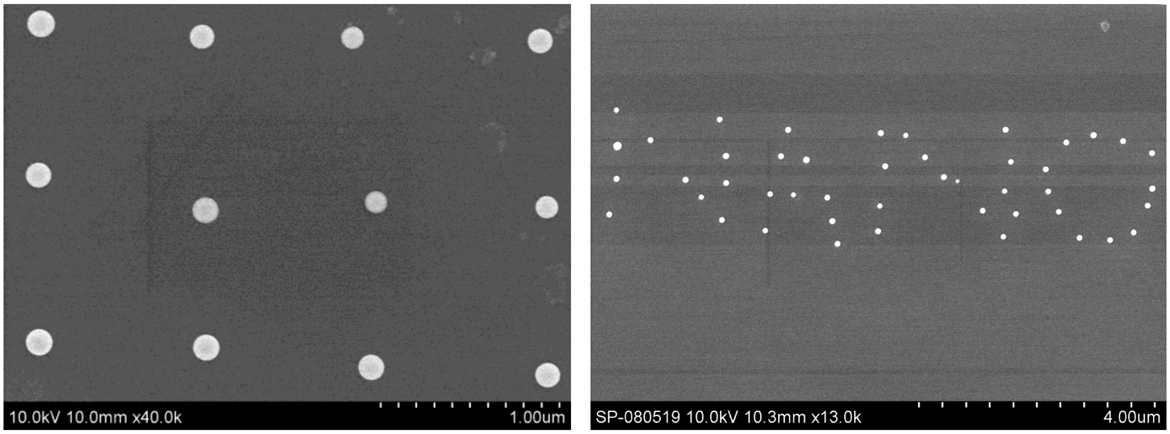

Fig. 2. Left image: A 4×3 array of 150nm gold nanoparticles that is printed on a glass substrate. Right image: A letter “NANO” consisting of 100nm gold nanoparticles that are printed on a glass substrate.

GNPs can be additively released from the donor substrate and transferred to the receiver substrate for additive nanomanufacturing. The images in Fig. 2 shows two patterns that are fabricated with this method. The left image in Fig. 2 shows a 4×3 GNP array that is printed on a glass substrate with this method. The GNP array consists of GNPs with diameters of 150 nm. The right image in Fig. 2 shows a letter “NANO” that is printed on a glass substrate with this method. The GNPs that are printed have diameter of 100nm.

References

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