Direct print of magnetic particles by optical vortex - laser induced forward transfer

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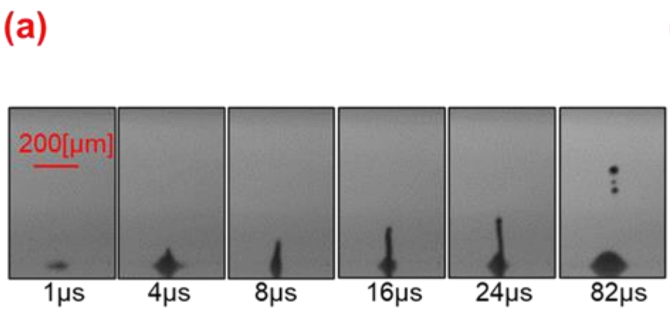
Optical vortex with a spiral wavefront carries an annular spatial form with a central dark core and an orbital angular momentum (OAM) associated with its helical wavefront. We and our co-workers have currently proposed an optical vortex laser induced forward transfer (OV-LIFT) technique, in which OAM of the optical vortex twists a donor liquid film with high viscosity to form a spinning jet with a long flight distance and eject a pL-scale microdroplet through Rayleigh-Plateau instability [1]. Going beyond the conventional inkjet printing, this OV-LIFT technology allows the direct print of extremely high viscosity material (~Pa·s) with high spatial resolution, and it will open the door towards next-generation printed photonics / spintronics / electronics.

In this study, we here repot on the direct print of 100 micron-scale dots including magnetic ferrite nanoparticles (particle size: 100-300 nm) without any coffee-ring effects by employing the OV-LIFT technology. We also address the core formation of magnetic ferrite nanoparticles in the printed dots.

A nanosecond green laser with a wavelength of 532 nm and a pulse duration of 10 ns was used as a light source, and its output beam was converted into the first-order optical vortex by employing a spatial light moderator (SLM). The generated optical vortex was loosely focused to be a ϕ90 μm annular spot. Temporal dynamics of donor flight was observed from the side with a ultrahigh speed camera (~500 ns/frame).

A magnetic ferrite nanoparticle suspension of a mixed solvent of water and glycerol was used as a donor, and its viscosity was ranged within from 0.006 to 0.75 Pa· s. Figure 1(b) shows a radius of circle, in which 90% of the nanoparticles exist, as a function of the donor viscosity. These indicate that the direct print of uniform dots including magnetic ferrite nanoparticles without any coffee-ring effects was possible at the viscosity of >0.1 Pa· s.



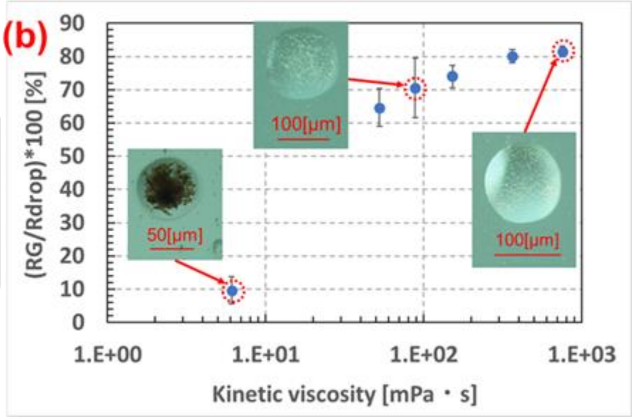


Fig. 1 (a) Time-laps of the formation of an ejected microdroplet by OV-LIFT. (Pulse energy:19.2μJ,Kinetic viscosity 6 mPa· s)
(b) Radius of circle, in which 90% of the nanoparticles exist, as a function of the donor viscosity.

[1] R. Nakamura et al., "Optical vortex-induced forward mass transfer: manifestation of helical trajectory of optical vortex," Opt. Express, vol. 27, no. 26, p. 38019 (2019)..