OAM-induced chiral surface relief in azo-polymer via two-photon absorption

Keigo Masuda[1], Yoshinori Kinezuka[1], Mitsuki Ichijo[1], Ryo Sinozaki[1],
Katsuhiko Miyamoto[12], Takashige Omatsu*[12]

[1]Graduate School of Science and Engineering, Chiba University, Japan
[2]Molecular Chirality Research Center, Chiba University, Japan
*Corresponding author: Takashige Omatsu: omatsu@faculty.chiba-u.jp

1. Introduction

Azo-polymer exhibits mass-transport through *cis-trans* photo-isomerization by irradiation of visible light, so as to establish a surface relief [1]. To date, we have discovered that azo-polymer film is deformed to shape a spiral surface relief ('OAM-induced chiral surface relief') on micro-scale by illumination of a cw green optical vortex beam, in which orbital angular momentum (OAM) of the vortex beam twists the azo-polymer [2-3]. In recent years, surface relief formation in the azo-polymer film via two-photon absorption process by illumination of tightly focused femto-/pico- second pulses has been reported to create structures on a nanoscale beyond the diffraction limit [4].

In this presentation, we report on, for the first time, OAM-induced chiral surface relief formation in azo-polymer film via two-photon absorption (TPA) by illumination of picosecond 1μm optical vortex pulses.

2. Experiments and Discussions

An azo-polymer used has no significant absorption in a near-infrared region as shown in Fig. 1(a). A picosecond 1.06-μm laser with a pulse width of 7-ps, a pulse repetition frequency of 100-MHz, and an average power of 300mW was used, and its output was converted to be a right-handed or left-handed circularly polarized optical vortex with a topological charge $\ell = 1$ (right-handed optical vortex) by employing a spiral phase plate (SPP) and a quarter wave plate (QWP). The optical vortex was tightly focused to be an annular spot with a diameter of ~4-μm on the azo-polymer film surface by using an objective lens with a high numerical aperture of 0.9. The corresponding intensity of the focused spot was estimated to be ~4-GW/cm^2. The exposure time of picosecond laser pulses was also measured to be 3 minutes.

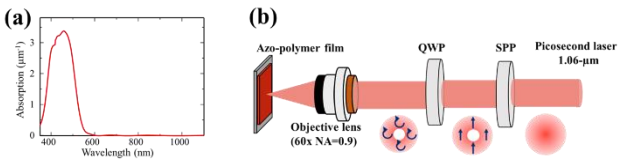

Figure 1. (a) Absorption band of the azo-polymer used.
(b) Experimental set-up

Optical vortex pulses with a total angular momentum $J = 2$ (defined as the sum of SAM and OAM) induced chiral mass-transport of the azo-polymers toward the clockwise direction along an azimuthal direction, so as to shape chiral surface relief with a diameter of 3-um, corresponding to the 0.7 times of diffraction limit. When the spin angular momentum was inversed (i.e. $J = 0$), a non-chiral surface relief was established on the azo-polymer film. These surface reliefs reflected the longitudinal electric field of the incident optical vortex. Theoretical longitudinal electric field of optical vortex with $J = 2$ exhibits azimuthally 4π phase-shift arising from constructive spin-orbital coupling, thereby resulting in the chiral surface relief formation as shown in Fig. 2. In the case of the optical vortex with $J = 0$, deconstructive spin-orbital coupling occurs, thereby preventing chiral mass-transport of azo-polymers.

Further investigation should be necessary to understand fully chiral surface relief formation in the azo-polymer thin film via two-photon absorption process.

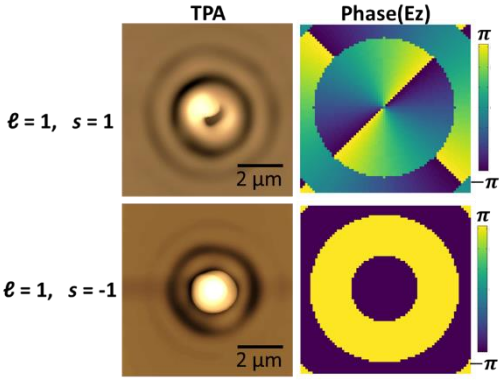

Figure 2. Experimental results and longitudinal electric field of optical vortex

3. Conclusions

We have successfully demonstrated, for the first time, OAM-induced chiral surface relief in azo-polymer film by illumination of picosecond 1μm optical vortex pulses via two-photon absorption. Longitudinal electric field created by a tightly focused incident optical vortex induces chiral mass transport of azo-polymers.

References

[1] N. K. Viswanathan, et al., J. Mat. Chem. **9** (1999) 1941–1955.
[2] M. Watabe, et al., Sci. Rep. **4** (2014) 1-5.
[3] D. Barada, et al., Appl. Phys. Lett. **108** (2016) 051108/1-4.
[4] H. Ishitobi, et al., Opt. Express. **16** (2008) 14106-14114.

Appendix

Secretariat of the JSAP-OSA Joint Symposia
E-mail: joint_osa@jsap.or.jp