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Shape changes of azobenzene particles induced by linearly polarized laser light

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Abstract

Microparticles of azobenzene molecules generated using the colloidal method were deformed by linearly polarized laser light. The shape of the particles was changed based on the selection of the polarization direction of incident light. The fabrication characteristics of the azo particles were investigated under various optical setups of the laser to obtain the desired shapes.

1. Introduction

Azobenzene molecules change their shape through photoisomerization at resonant optical excitation and thermal relaxation [1]. This material movement can be utilized to inscribe the nanostructure of soft materials [2-5]. In particular, a particle consisting of azo molecules is extremely valuable to obtain optical materials that can control the shape and distribution of nanostructures. This is applicable to optical resonators using micro particles to confine optical fields, such as whispering gallery mode.

In this study, we investigated the characteristics of the deformation process of the micro-sized particles of the azobenzene copolymer. The azo particles were generated by the colloidal method using azo solvent and pure water. The effects of optical alignment were examined based on their potential to excite effectively the azo molecules to obtain the desired shapes of azo materials.

2. Experimental setup

Figure 1 shows the experimental setup. Azobenzene particles were dispersed on a glass substrate. The PMMA-co-DR1 (Disperse Red 1, Fig. 2) molecules purchased from Sigma-Aldrich were dissolved into chloroform solution. The solvent was mixed with deionized water, so that colloids of the azo molecule were generated in the water. The droplet of azo colloid was put on a cover glass for optical microscopy. After air-drying the samples at room temperature, azo particles were generated on the glass substrate. The particles were irradiated with linearly polarized light provided from DPSS laser of wavelength 532 nm and intensity 100 mW. The beam diameter of the incident light was adjusted using an optical beam expander element. The shape of the azo particles was evaluated using a transmission optical microscope. In this study, we employed two types of laser irradiation directions (normal and oblique incidence) to selectively excite azo molecules aligned on the sample substrate through photoisomerization.

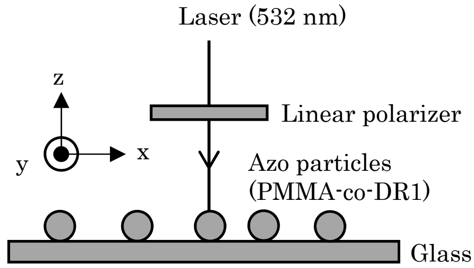

Fig. 1 Experimental setup.

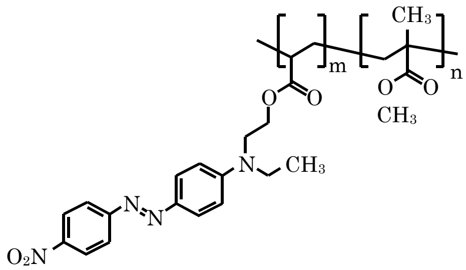

Fig. 2 Molecular structure of PMMA-co-DR1.

3. Results and discussions

Figure 3 shows the transmission optical microscopy image of the azo particles. The 2 μL droplet of azo colloidal solution was put on the glass substrate using a micropipette and the sample was air-dried. As a result, the azo particles were randomly dispersed. The spherical shapes of the particles were obtained with different diameters at the μm scale. The density of particles was sufficiently low to prevent combination of the particles.

Figure 4 shows the shape changes of the azo particles after irradiation with linearly polarized laser light. The propagation direction of the laser was set normal to the sample substrate as shown in Fig. 1. After 5 min of laser irradiation, the azo particles changed shape as shown in Fig. 4(a). The polarization of incident light was set to the y-direction. The azo particle deformed elliptically from the initial shape before laser irradiation (Fig. 3). The direction of shape changes clearly coincided with the polarization direction of the laser. These shape changes were in good agreement with the results of Ref. 6. Furthermore, we changed the polarization direction of the laser irradiation and reirradiated the prefabricated particles. The polarization was set to the x-direction by rotating 90° from the y-direction. The shape in the x-direction was changed corresponding to the polarization (Fig. 4(b)). However, the shape of the y-direction by prefabrication was approximately maintained. It was thought that the azo molecules after prefabrication were mainly aligned in the direction normal to the sample surface through the photoisomerization process. Therefore the molecules were unable to absorb the refabricated light with the polarization of the x-direction parallel to the sample surface.

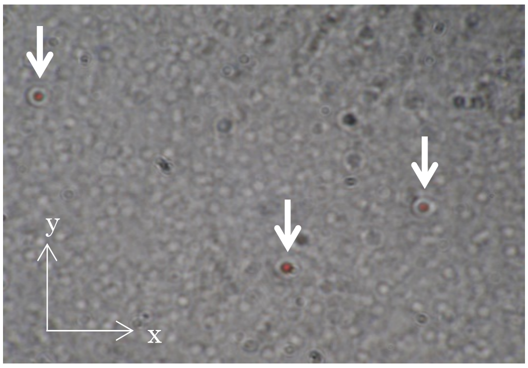

Fig. 3 Transmission optical microscopy image of azo particles generated by the colloidal method.

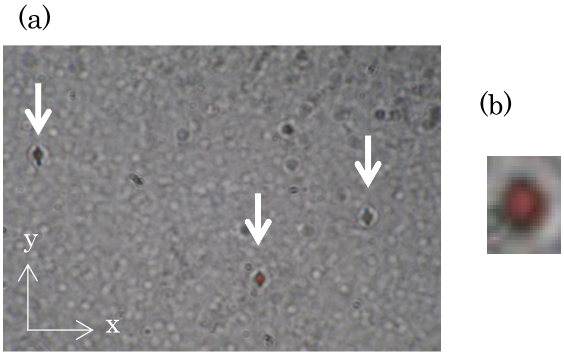

Fig. 4 Shape changes of azo particles after irradiation with the laser light at normal incidence. The particles were excited by the light with polarization in the y-direction (a), and re-excited using polarization in the x-direction (b).

For comparison, we also employed an oblique incidence of laser light as shown in Fig. 5(a). By choosing p-polarization of incident light, we used the electric field components of the optical field in the direction normal to the sample surface. Under these conditions, the azo molecules directed normal to the surface can be excited. Figure 5(b) shows the shape changes of the particles irradiated by p-polarized light at oblique incidence. The incident angle was set at 60°. The particle shape extended to the x-direction along the propagation direction of the incident light. The shape change was thought to be caused by molecular excitation and material movement of the x- and/or z-direction using the electric field components of p-polarization. We also investigated the refabrication of the particle shown in Fig. 5(b). The polarization of obliquely incident light was set to s-polarization. The azo particle was stretched in the y-direction, clearly corresponding to the polarization direction of incident light. The shape was correspondingly shortened in the x-direction. The deformation characteristics at oblique incidence were completely different to the case of normal incidence.

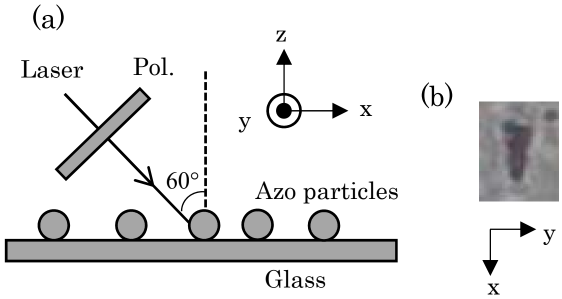

Fig. 5 Optical excitation of azo particles using oblique incidence of light illumination. The optical setup (a), and shape changes of azo particles with p-polarization (b).

4. Conclusions

We investigated the characteristics of shape changes of azo particles by optical excitation using linearly polarized light. The azo copolymer particles generated using the colloidal method were deformed by irradiation of laser light incident from a different direction to the sample surface. The optical alignment was important for exciting azo molecules after photoisomerization. The oblique incidence was effective to excite the azo molecules to obtain the refabrication of azo particles. The results are important for optical device applications of the azo particles.

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