Research Department
Nanooptics

Self-assembly of Photo-Switchable Diarylethenes for Optical Microresonator and Arrays

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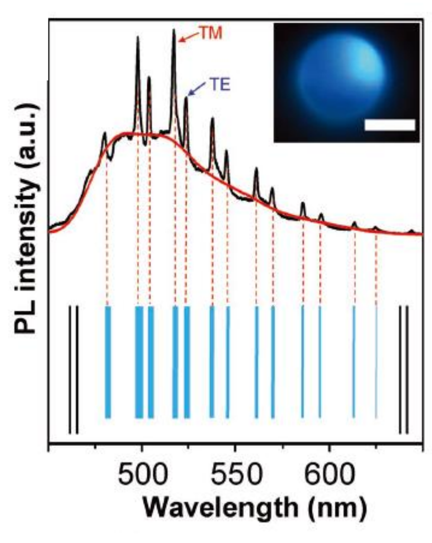
Introduction

1. Using photo-switchable fluorophores to make whispering gallery micro-resonator (WGM), we can control the ON/Off state of fluorescence while the WGM spectral features are kept and observable in the on-state.
2. The solution of diarylethene **1** (DAE **1**) was drop-casted onto the hydrophobic/hydrophilic pre-patterned substrate and the DAE **1** molecules spontaneously aggregate to form the hemispherical micro-disk array on the only hydrophobic pattern.
3. Upon the selective irradiation of focused UV/Vis light to the micro-disk array, it can be utilized as an optical memory display with an intrinsic physical unclonable functions (PUFs) to be use in security systems for identifying individuals.

Optical barcodes



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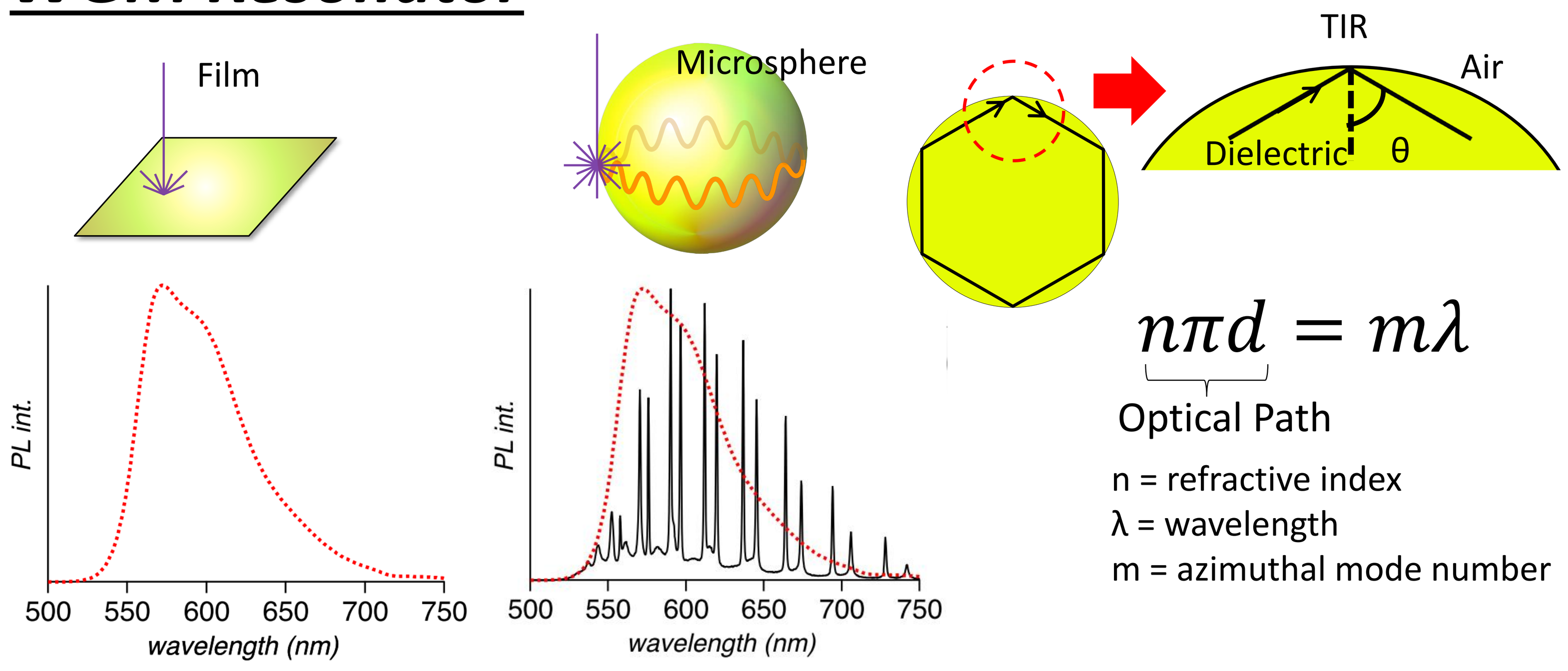
WGM Resonator



Experimental Results

Photoswitchability of WGM

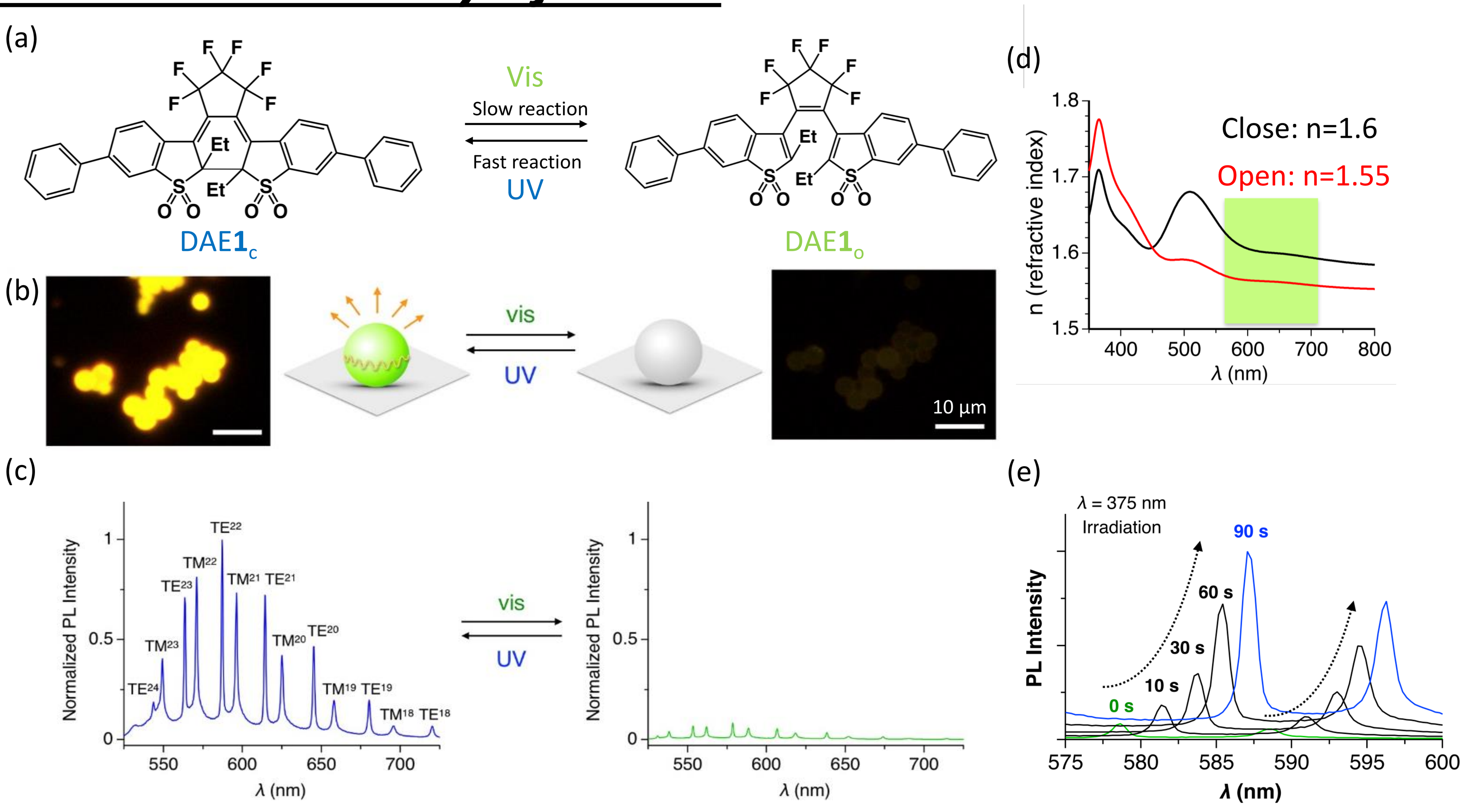


Figure. 1 (a) Molecular structures of oxidized DAE **1** in closed ($\mathbf{1}_C$, left) and open form ($\mathbf{1}_O$, right). (b) Fluorescence micrographs and schematic representations of microspheres from fluorescent $\mathbf{1}_C$ (left) and nonfluorescent $\mathbf{1}_O$ (right). (c) PL spectra of a single microsphere of $\mathbf{1}_C$ (blue) and $\mathbf{1}_O$ (green) (λ_{ex} = 470 nm). (d) Real parts of the refractive indices of 1_C (black) and 1_O (red). (e) PL spectra of a single microsphere of $\mathbf{1}_O$ upon 90s irradiation with UV-LED at λ = 375 nm.

Switchable Optical Resonator Array

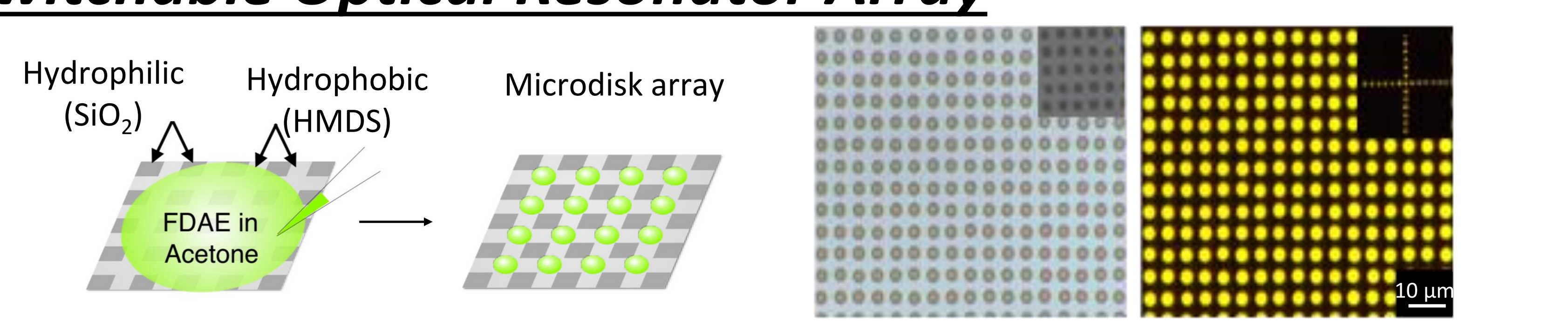


Figure. 2 Two-dimensional array of DAE **1** micro-hemispheres on a pre-patterned substrate (left) and their fluorescent microscopy image (right). Optical and fluorescence micrographs of the micro-hemispheres array. Inset of the left image shows an SEM micrograph of the micro hemispheres array. Inset of the right image demonstrates a “cross” fluorescence pattern written by UV and Vis lasers.

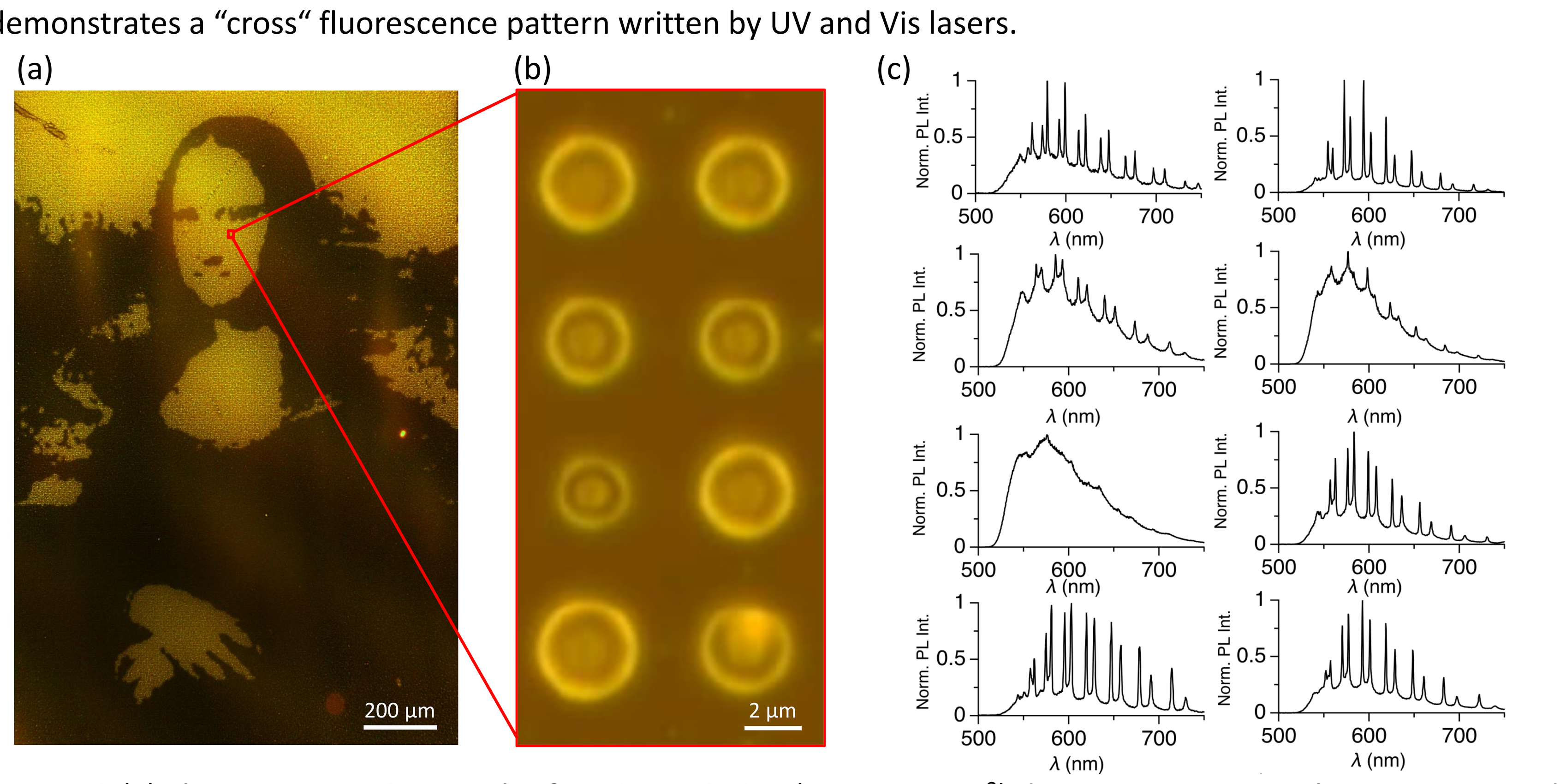


Figure. 3 (a) Fluorescence micrograph of a micropainting (1.6 x 2.7 mm²) drawn on a quartz substrate, prepared by irradiation at λ_{ex} = 350 – 390 nm to the microarray of $\mathbf{1}_O$ through a patterned photomask. (b) Optical micrograph of the resultant micro-hemisphere array with a 2 x 4 matrix. (c) PL spectra of the arrayed micro-hemispheres.

Direct Precipitation on the Substrate

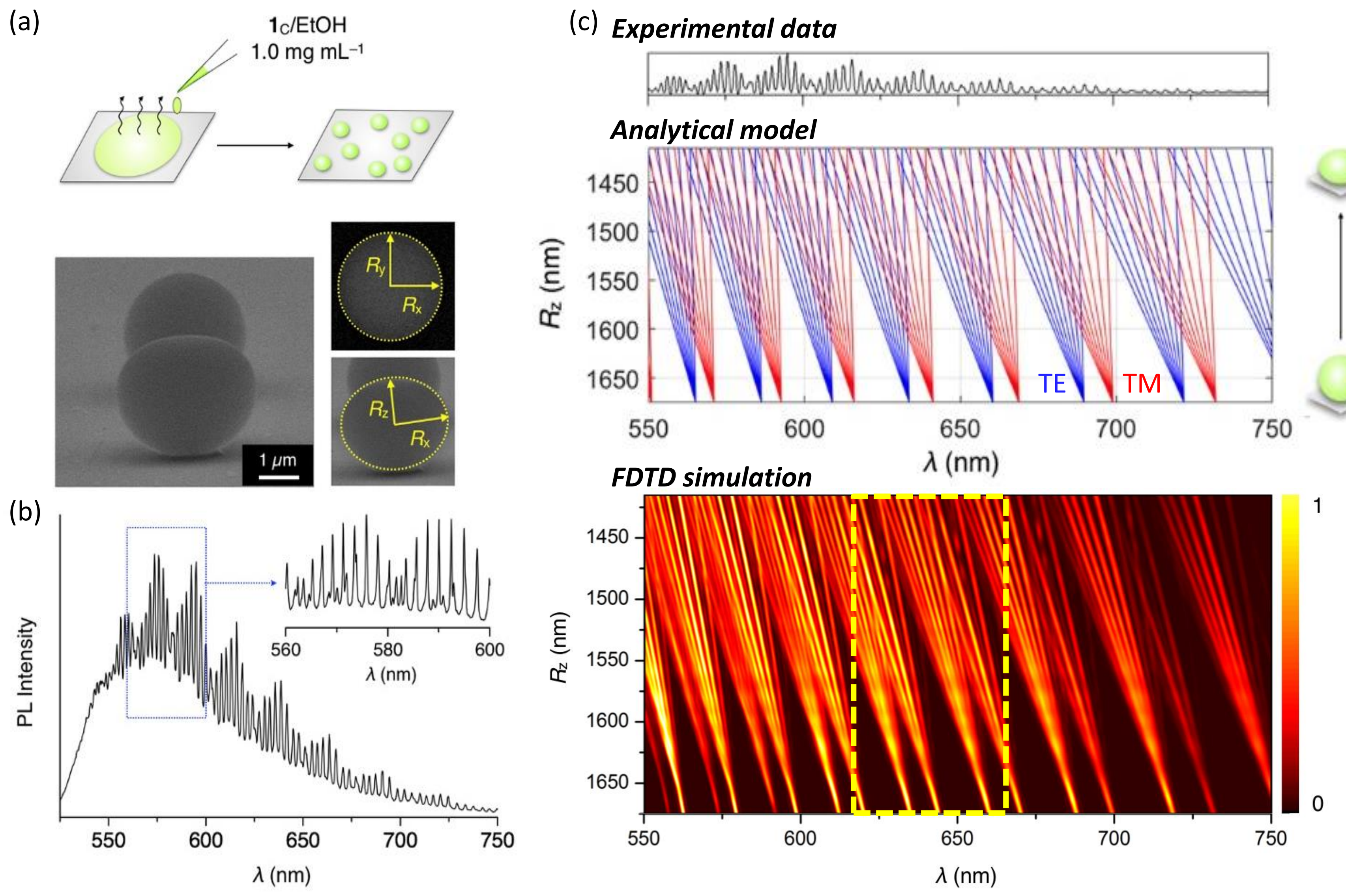


Figure. 4 WGM splitting of an oblate micro-ellipsoid of **1**. (a) Schematic of the oblate microsphere formation process and SEM micrographs. (b) PL spectrum of a single oblate microsphere, with the inset showing the high-resolution PL spectrum. (c) Experimental PL spectrum in (b) without fluorescence background (top), and the analytically model (middle) as well as numerically simulated (bottom) peak positions of splitting WGMs of spheres with various Rz from perfect sphere (1675 nm) to oblate sphere (1415 nm).

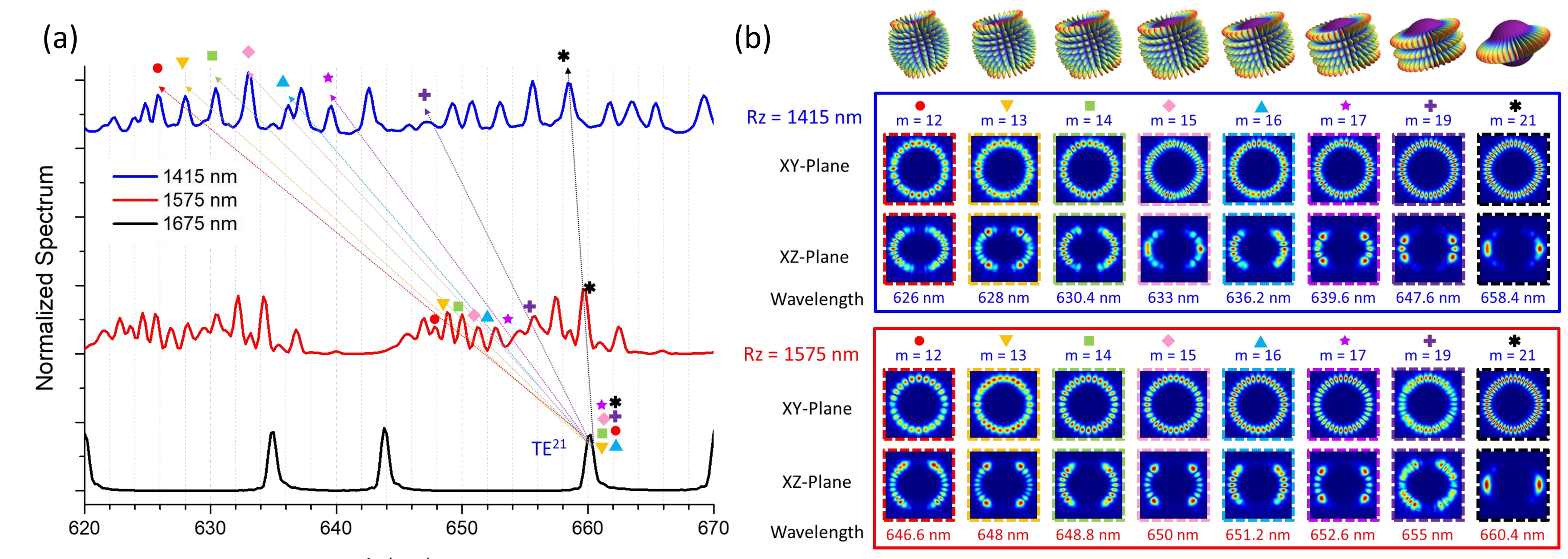


Figure. 5 (a) Simulated emission spectra showing peaks of WGMs in a perfect microsphere with Rx = Rz = Ry = 1675 nm (black trace) and two oblate spheres with Rx = Rz = 1675 nm but Rz = 1575 nm (red trace) and Rz = 1415 nm (blue trace). (b) 2D modal field intensity profiles simulated by FDTD at the peak wavelengths of the spectra. The spherical harmonics with same *l* quantum number are inserted on top for reference. The colored symbols are assigned to track specific modes and are marked out in the spectra shown in the left panel.

Conclusion

We utilize optical fingerprints from self-assembled microresonators and construct micrometer-scale optical microarray patterns that are hard to be replicated. Surface self-assembly of photochromic molecules on hydrophobic/hydrophilic micropattern affords highly integrated micro-hemisphere resonators, whose spectral fingerprints from each pixel are different with one another. The resultant micropaint, drawn by UV irradiation through a patterned photomask, is the only one, which is unreplicable including the spectral fingerprint patterns of each pixel.