Photo-Pens: A Simple and Versatile Tool for Maskless Photolithography

Chuanhong Zhou, Pradeep Ramiah Rajasekaran, Justin Wolff, Xuelian Li, and Punit Kohli*

Department of Chemistry & Biochemistry

Southern Illinois University

Carbondale, IL 62901

*pkohli@chem.siu.edu

Derivation of Equation 3. The emission intensity I_e is proportional to the fraction of the red-PDA (N_p) in the patterns since quantum yield of the blue-PDA is negligible. [1] We have modeled the emission intensity of patterns formed in our experiments. Assuming that the total number of diacetylene monomers present is N_t, then polymerization equations can be expressed by,

$$\frac{dN_p}{dt} = \rho \dot{N_t} \qquad \text{Eq. 1S}$$

where $\dot{N_t} + N_p = N_t$, N_p is the number of photo-polymerized diacetylene chains; ρ is the polymerization probability. Considering ρ is proportional to the exposure dose $E_p = I_p t = nh\upsilon_p t$, where I_p is the exposure intensity, n is the photon number per unit area. In general, I_p and n are position dependent are depicted by $I_p(r)$ and $n(r)$. υ_p is the photon frequency ($h\upsilon_p$ is the energy of photons, h is Plank's constant), and t is the exposure time. Thus, we have:

$$N_p = N_t\left(1 - e^{-anhgt}\right) \qquad \text{Eq. 2S}$$

where a is a polymerization coefficient that depends upon the interaction of photons with diacetylene monomers. Since the emission intensity (I_e) is directly dependent upon the degree of photopolymerization, we have:

$$I_e = Kh\upsilon_e N_t\left(1 - e^{-an(r)h\upsilon_p t}\right) = I_{es}\left(1 - e^{-aI_p(r)t}\right) \qquad \text{Eq. 3S}$$

where υ_e is the emission frequency, K is a constant which accounts for red-PDA fraction, and $I_{es} = KN_t h\upsilon_e$ is the saturated emission intensity.

In Figure 5A of the main text, the emission intensities dependent on exposure time are shown. The red line is the fitting curve satisfies with $I_e = 1234(1 - e^{-0.087t})$. We measured the intensity of the incident UV light is I_{inc}=15μW/cm^2, so the polymerization coefficient can be approximately derived by $a = 0.087/I_{inc}$=5.8×10^3 cm^2/J. It is qualitatively validated by the high polymerization efficiency of UV light to polydiacetylene reported by references.[1,2] Furthermore, the experimental fitting curve fits well with the theoretical model (Figure 5).

References:

1. B. Tieke and G.Wegner, Makrmol.Chem.179, 1639-1642, (1978).
2. R. W. Carpick,D. Y. Sasaki, M. S. Marcus, M. A. Eriksson, A. R. Burns, J. Phys.: Condens. Matter. 16 R679-R697 (2004).