Electronic Supplementary Information for

Spin-isolated ultraviolet-visible dynamic metaholographic displays with liquid crystal modulators

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Supplementary Data 1. Mathematical description

The PB phase design methodology can be explained by Jones calculus where the jones matrix can be describes as:

$$T = \begin{bmatrix} T_f & 0 \\ 0 & T_s \end{bmatrix} \tag{S1}$$

where T_f and T_s denote the transmission coefficients for the polarized incident light along the meta-atom's fast and slow axis, respectively. For rotated meta-atom, the jones matrix T_{rot} can be expressed as in Eq. 2, where φ is the rotation and the rotation matrix $R(\varphi)$.

$$T_{rot} = R(-\varphi)TR(\varphi) \tag{S2}$$

$$T_{rot} = R(-\varphi)\begin{bmatrix} T_f & 0 \\ 0 & T_s \end{bmatrix}R(\varphi) \tag{S3}$$

If the input is circularly polarized (CP) light, then the Jones vectors for the right and left helicity can be expressed as:

$$\hat{e}(L/R) = \frac{(\hat{e}x \pm \hat{e}y)}{\sqrt{2}} \tag{S4}$$

The transferred electric field $E(L/R)$ can be derived by multiplying the jones matrix with the CP light and can be expressed as:

$$E(L/R) = T_{rot} \,.\, \hat{e}(L/R) \tag{S5}$$

After multiplication,

$$E(L/R) = \frac{T_f + T_s}{2}\hat{e}(L/R) + \frac{T_f + T_s}{2}e^{\pm 2i\varphi}\hat{e}(L/R) \tag{S6}$$

In Eq. S6, the first represent the co-polarized transmitted light with no phase change whereas the second term representing the cross-polarized transmitted light with phase shift of $\pm 2i\varphi$. From these formulation, it is observed that the full phase coverage $(0 - 2\pi)$ can be attained by changing the orientation angle of meta-atom from $0 - \pi$.

However, in our case for spin-isolated meta-holography, two distinct phase masks encoded into the nano-surface. This will require to incorporate the extra degree of freedom into the optimized meta-atoms which will enable the different information when illuminated by CP light with different handedness. Consequently, the total phase mask needed to encode into the proposed nano-surface for forward and backward direction illumination can be expressed as:

$$\phi_T = \arg\left[e^{i\phi_F}\right] + \arg\left[e^{-i\phi_B}\right] \tag{S7}$$

where ϕ_T, ϕ_F and ϕ_B denote the total phase, phase for forward direction and backward direction illuminations, respectively.

$$\phi_T = \arg\left[cos\phi_F + i.sin\phi_F\right] + \arg\left[cos\phi_B - i.sin\phi_B\right] \tag{S8}$$

By solving

$$\phi_T = \tan^{-1}\left[\frac{sin\phi_F - sin\phi_B}{cos\phi_F + cos\phi_B}\right] \tag{S9}$$

Using identities, the equation becomes

$$\phi_T = \tan^{-1}\left[\frac{sin\left(\frac{\phi_F - \phi_B}{2}\right)}{cos\left(\frac{\phi_F - \phi_B}{2}\right)}\right] \tag{S10}$$

$$\phi_T = \tan^{-1}\left[\tan\left(\frac{\phi_F - \phi_B}{2}\right)\right] \tag{S11}$$

The total phase profile encoded into the nano-surface can be written as in Equation (S12).

$$\phi_T = arg\left[e^{i\left(tan^{-1}\{\tan(A)\}\right)}\right] \tag{S12}$$

where $A = \frac{\phi_F - \phi_B}{2}$ and the Equation (S12) used to implement the spin-isolated phase profiles of two different information's into a single nano-surface for broadband UV-VIS dynamic meta-holographic displays.

Supplementary Data 2. Fabrication procedure

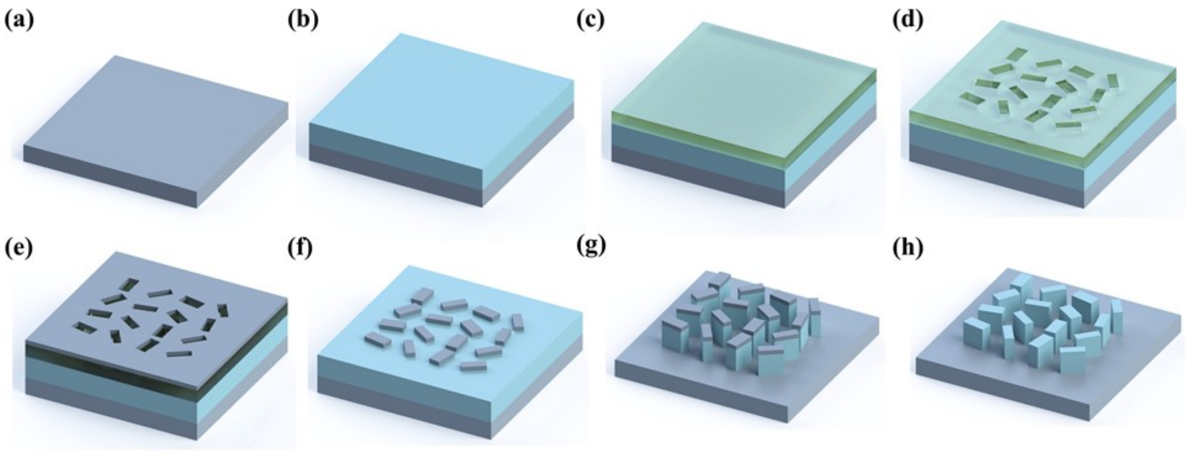

Figure S1. Fabrication procedure of the designed UV-VIS spin-encrypted meta-platform. (a) Glass substrate. (b) Film generation of Si_3N_4 using plasma-enhanced chemical vapor deposition (PECVD). (c) Photoresist coating. (d) Nano-pattern generation using electron beam lithography (EBL). (e) Generation of chromium (Cr) mask using e-beam evaporator. (f) Lift-off process using acetone. (g) Etching Si_3N_4 using reactive-ion etching (RIE). (h) Wet etching Cr mask using Cr etchant.

Supplementary Data 3. LC fabrication procedure

The LC cell was fabricated on glass plates coated with indium tin oxide (ITO) and polyimides (Nissan Chemical Korea) alignment layers. The polyimides were spin-coated at 1000 rpm for 10 s and 2500 rpm for 30 s. The spin-coated layer was baked at 230 °C for 60 min. The polyimides layer was rubbed to form a unidirectional alignment of LCs. Two ITO-glasses were assembled using a mixture of glass spacer and UV-glue (Norland Products Inc., NOA 65).

The used neamtic LC has zero absorption at working wavelegnths of UV and visible regime with external voltage value 1.2 V for RCP and 1.5 V for LCP.

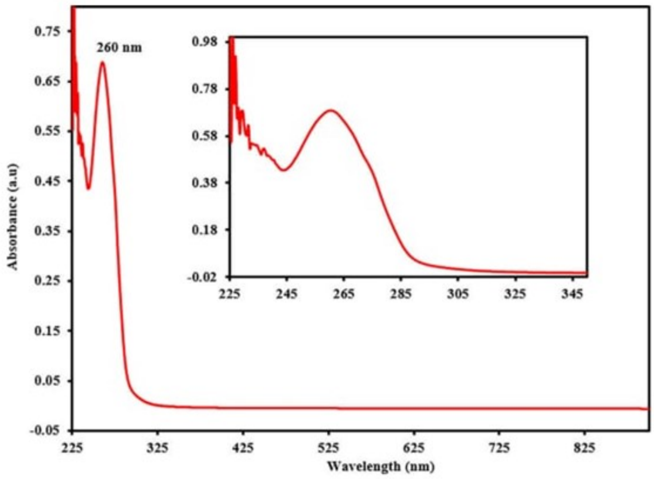

Figure S2. Absorbance for the liquid crystal cell at the UV-VIS regime.

Supplementary Data 4. Additional measurement of metahologram

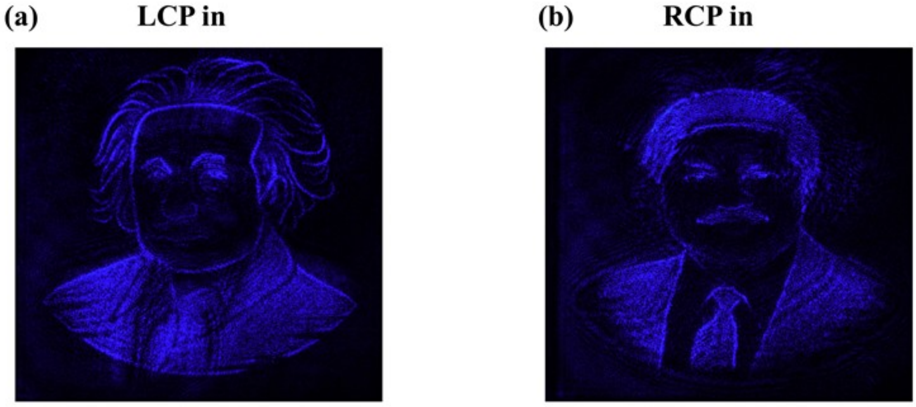

Figure S3. Measured results at the wavelength of 450 nm for (a) LCP (b) RCP incident light.