Electronic Supplementary Information

Ion Beam Etching of Anodic Aluminium Oxide Barrier Layer for Au Nanorod-Based Hyperbolic Metamaterials

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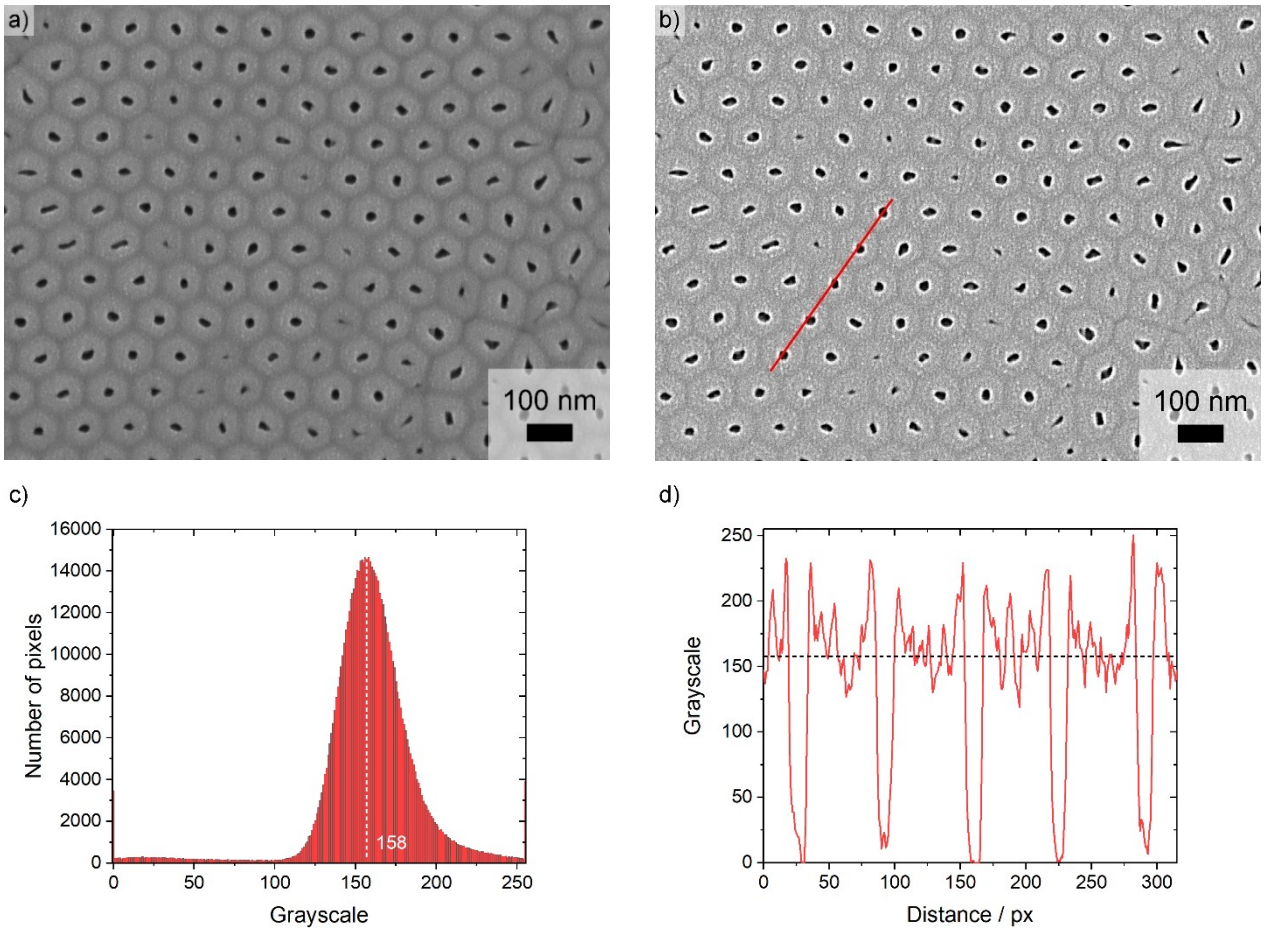

Figure S1. (a) Initial SEM image of the bottom surface of AAO prepared in 0.3 M oxalic acid at 40 V and 0 °C after 6 min ion beam etching. (b) The image after FFT Bandpass Filter (see details in the Experimental part). (c) The histogram of the image presented in panel (b). (d) The intensity profile along the red line in panel (b). Threshold is indicated by a black dashed line and corresponds to the centre of the histogram in panel (c).

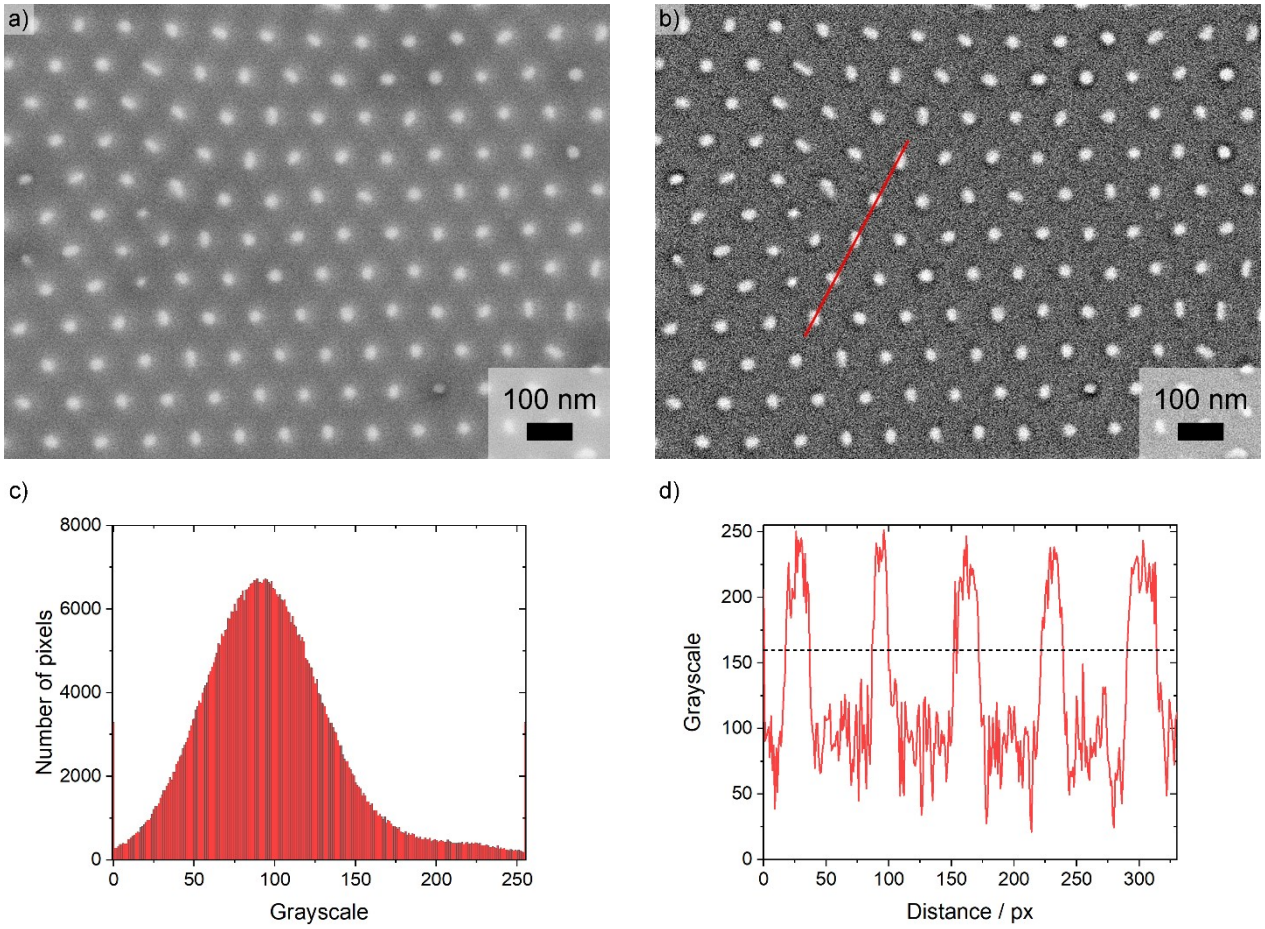

Figure S2. (a) Initial SEM image of the bottom surface of Au/AAO nanocomposite based on the template prepared using 10 min ion beam etching. (b) The image after FFT Bandpass Filter (see details in the Experimental part). (c) The histogram of the image presented in panel (b). (d) The intensity profile along the red line in panel (b). Threshold is indicated by a black dashed line.

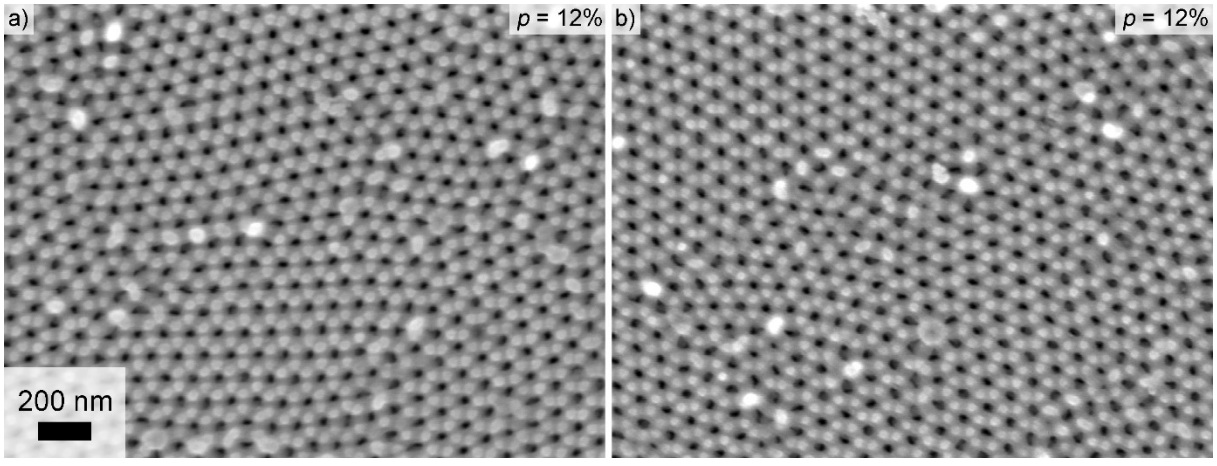

Figure S3. SEM images of the top surface of AAO prepared in 0.3 M oxalic acid at 40 V and 0 °C before (a) and after (b) 60 min ion beam etching.

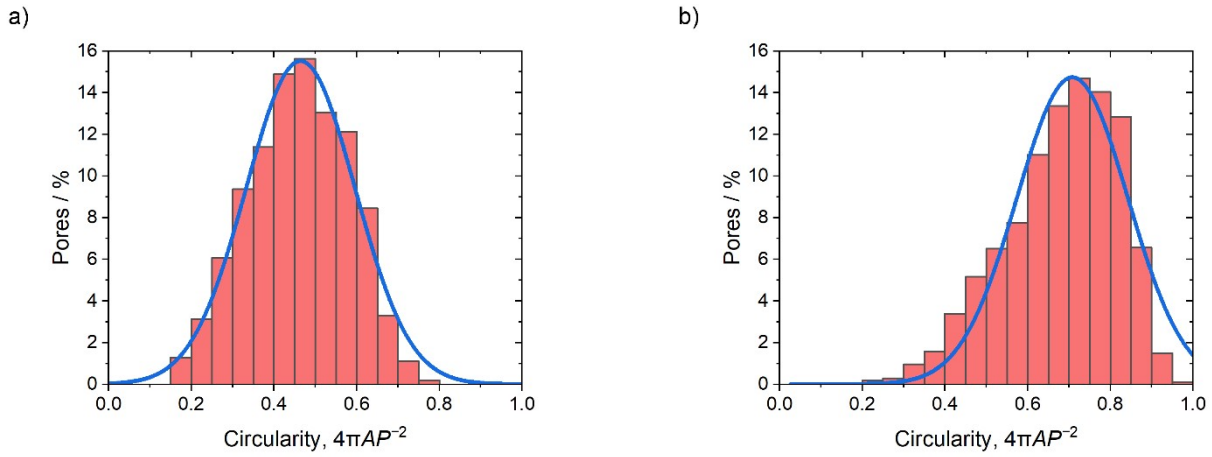

Figure S4. Distributions of pore circularity on the upper (a) and bottom (b) sides of the AAO template.

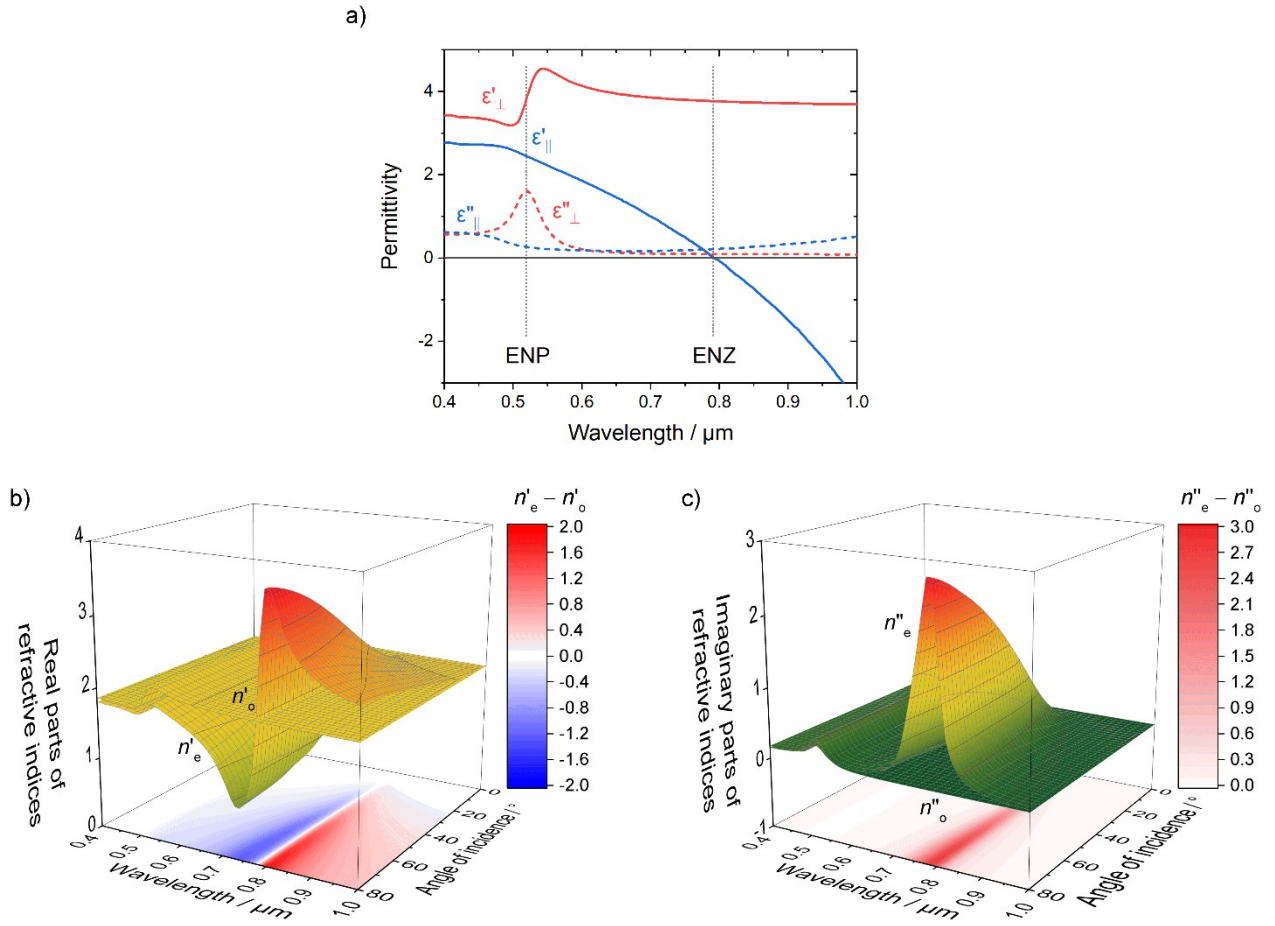

Figure S5. The spectrum of the dielectric permittivity tensor components (a) and frequency-angular spectra of the real (b) and imaginary (c) parts of the refractive index for ordinary (n_o) and extraordinary (n_e) waves, calculated within the effective anisotropic medium approximation for a hyperbolic metamaterial with a metal volume fraction of 8% and a length of Au nanorods of 170 nm. The difference between real and imaginary components of n_e and n_o is displayed as projections in panels (b) and (c), respectively.

$$L_{\parallel} = \frac{1-e^2}{e^2}\left[\frac{1}{2e}\ln\left(\frac{1+e}{1-e}\right)-1\right], \qquad \text{(S1a)}$$

$$L_{\perp} = \frac{1 - L_{\parallel}}{2}, \tag{S1b}$$

where $L_{\parallel}$ and $L_{\perp}$ are the components of depolarization tensor in the direction parallel and perpendicular to the axis of nanorods, respectively, $e^2 = \left(1 - d_{nr}^2\right)/l^2$, where d_{nr} and l are the average diameter and the length of nanorods.

$$\alpha_{\sigma} = \frac{\varepsilon_{Au} - \varepsilon_{AAO}}{L_{\sigma}(\varepsilon_{Au} - \varepsilon_{AAO}) + \varepsilon_{AAO}}, \tag{S2a}$$

$$\varepsilon_{\sigma} = \varepsilon_{AAO}\left(1 + \frac{\chi\alpha_{\sigma}}{1 - \chi\alpha_{\sigma}\gamma_{\sigma}}\right), \tag{S2b}$$

where ε is the dielectric permittivity, $\sigma = \parallel, \perp$, χ is the metal volume fraction, $\gamma_{\sigma} \approx 1/3$ [doi: 10.1103/PhysRevB.73.235402].

$$n_o = \sqrt{\varepsilon_{\perp}}, \tag{S3a}$$

$$n_e = \sqrt{\varepsilon_{\perp} + \sin^2\theta\left(1 - \varepsilon_{\perp}/\varepsilon_{\parallel}\right)}, \tag{S3b}$$

where n_o and n_e are the refractive indices for ordinary and extraordinary waves, respectively, θ is the angle of incidence.

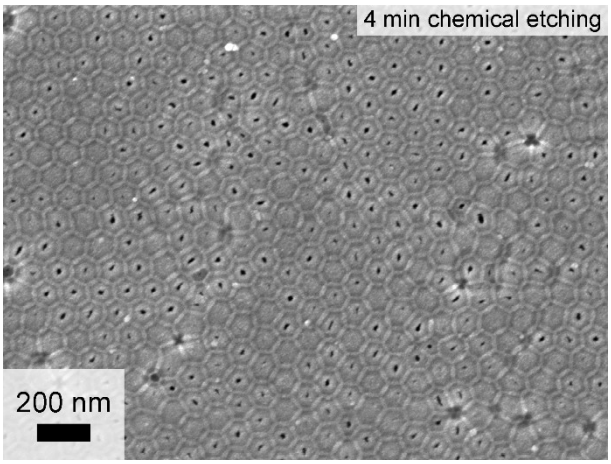

Figure S6. SEM image of the bottom surface of AAO prepared in 0.3 M oxalic acid at 40 V and 0 °C after 4 min chemical etching.