Supporting Information

Nanowell-Based Orthogonal Submicropolarizer Array Biochip for Multiple Throughput of Fluorescence Sequencing

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Figure S1. TM transmittance and extinction ratio of Al polarizer plates. TM transmittance of the Al polarizer plates with a fixed fill factor of 0.5 and different thicknesses and grating periods at wavelengths of (a) 542 nm and (b) 612 nm. Simulations of the (c) TM transmittance and (d) extinction ratio of the large Al polarizer plates with thicknesses of 135 nm, 180 nm, and 225 nm and fill factors of 0.4, 0.5, and 0.6. Experimental results of the fabricated large Al polarizer plates compared to the simulations with actual fill factors for the (e) TM transmittance and (f) extinction ratio.

Figure S2. SEM images of the large polarizer plates and the pixelated nano/micropolarizer arrays. Top-view and cross-sectional-view SEM images of the fabricated large polarizer plates with thicknesses of (a)(b) 135 nm, (c)(d) 180 nm, and (e)(f) 225 nm. Top-view SEM images of the (g)-(l) square and (m)-(r) triangular arrangements of the fabricated nano/micropolarizer arrays with pitch sizes of 0.6 μm, 0.9 μm, 1.2 μm, 1.5 μm, 3 μm, and 6 μm. Scale bar: 300 nm in (a)-(f) and 2 μm in (g)-(r)
Figure S3. Grating profile dependence of the optical properties of the Al polarizer plate. (a) Schematic illustration of the geometry and light direction of the simulated Al polarizer plate profiles. (b) TM transmittance, (c) TE transmittance, and (c) extinction ratio of Al polarizer plates with different profiles.

Some literature\textsuperscript{1,2} has proven that the grating profile also affects the optical properties, so two sets of gratings with thicknesses of 180 nm (rectangular, Rect-180 nm, compared to an inverted trapezoid with top/bottom 165 nm/138 nm, InvertTrap-180 nm) and 225 nm (rectangular, Rect-225, compared to a trapezoid with top/bottom 144 nm/150 nm, Trap-225 nm) were simulated, as shown in Fig. S3. The results show that InvertTrap-180 nm has an ~20% increased extinction ratio compared to Rect-180 nm, and Trap-225 nm shows an ~14% decreased extinction ratio compared to Rect-225 nm.

References
Figure S4. Experimental images of excitation light transmittance of the nano/micropolarizer array chips obtained with the transmission mode of the optical system. Square arrangements of the Al nano/micropolarizer arrays with thicknesses of (a)-(f) 135 nm, (g)-(l) 180 nm, and (m)-(r) 225 nm. (s)-(x) Triangular arrangements of the Al nano/micropolarizer array with a thickness of 180 nm. Scale bar: 6 μm

Figure S5. Schematic illustration of the SNR calculation for excitation light (exSNR) and fluorescent bead emission light (emSNR).
Figure S6. Simulation results of 4 x 4 nano/micropolarizer arrays in square arrangements for 0.6-μm, 0.9-μm, 1.2-μm, and 1.5-μm pitch sizes. (a) X-Z plane of the simulation setup where the polarized light is placed in a glass substrate and 5 μm away from the surface of the nano/micropolarizer arrays, and (b)-(e) X-Y plane of the simulation setup for 0.6-μm, 0.9-μm, 1.2-μm, and 1.5-μm pitch sizes, respectively. Polarized light transmittance intensity distribution of (f)-(i) monitor 1, in which the units have a polarizer orientation parallel to the incident light, and (j)-(m) monitor 2, in which the units have a polarizer orientation perpendicular to the incident light for 0.6-μm, 0.9-μm, 1.2-μm, and 1.5-μm pitch sizes, respectively. (n)-(q) Light distribution in the X-Z plane along the cross-section labeled with the A-A’ white line in (b)-(e), respectively.

**Finite-difference time-domain (FDTD) simulation.**

Fig. S6 shows the light intensity and distribution data simulated for the square nano/micropolarizer arrays with pitch sizes of 0.6 μm, 0.9 μm, 1.2 μm, and 1.5 μm. The model of the nano/micropolarizer units was built as a 4 x 4 array. Monitor 1 is for the 0-degree units with a parallel polarization angle and monitor 2 is for the 90-degree units with a polarization angle orthogonal to the 0-degree polarized excitation light. Therefore, the simulated pixel extinction ratio can be calculated as the ratio of the averaged intensity in monitor 1 to that in monitor 2.

The light intensity distribution along the Z-direction (at A-A’ white lines) in Fig. S6b-e is plotted in Fig. S6n-q, respectively. The averaged intensities in the region 0-2 μm in height and +/- 0.5 μm in width from the center of the nano/micropolarizer unit are $1.63 \times 10^{-3}$, $2.73 \times 10^{-3}$, $3.51 \times 10^{-3}$, and $4.55 \times 10^{-3}$. For unit sizes greater than 3 μm, the diffraction point is far from the nanowell region that is 350-750 nm in height and +/- 200 nm in width (data not shown). The simulation results prove that the grating nano/micropolarizer array achieves localized enhancement in the light intensity of the units near the nanowell area, especially for the 1.2-μm and 1.5-μm arrays.
Figure S7. Experimental results of transmittance intensity decay for a nano/micropolarizer unit with different pitch sizes.

Figure S8. Simulation of the Al polarizer leveling tolerance. (a) Schematic illustration of the leveling angle shift between the two polarizer plates. (b) Extinction ratio, (c) TM transmittance, and (d) TE transmittance at leveling angle shifts ($\theta_L$) of 0, 2.5, 5, 10, 15, 30, and 45 degrees.
Figure S9. Simulation and experimental results of the light transmittance after two polarizer plates are rotated at different angles. (a) Schematic illustration of the rotation angle between the two polarizer plates. Simulation calculation of (b) extinction ratio, (c) TM transmittance, and (d) TE transmittance after two large polarizer plates are rotated at rotation angles ($\theta$) of 0, 2.5, 5, 10, 15, 30, and 45 degrees. (e) Experimental images of a 6-μm square micropolarizer array that shifts 0, 5, 10, 15, 30, 30, and 45 degrees from the large light polarizer plate.
Figure S10. The calculation method of the pitch size and the fwhm of the fluorescence signals. Fluorescent images of 1.5-μm square nano/micropolarizer array (a) without a light polarizer plate, (b) with a 0-degree light polarizer plate, and (c) with a 90-degree light polarizer plate. (d)-(f) The intensity profiles between two blue arrows labeled in (a)-(c), respectively. Scale bar: 5 μm