Electronic Supplementary Material (ESI) for Nanoscale Advances.

Electronic Supplementary Information

Large plasmonic color metasurfaces fabricated by super resolution deep UV lithography

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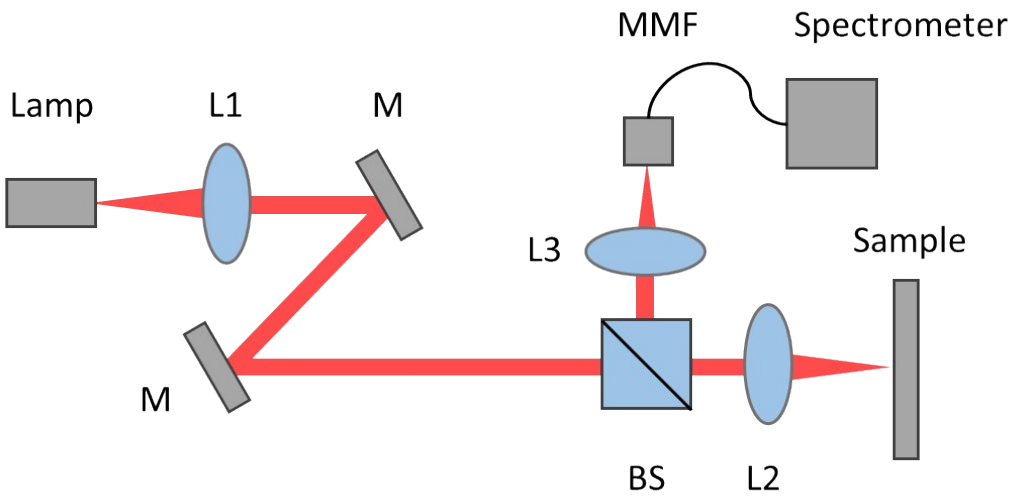

Figure S1. Schematic representation of the setup used for optical reflectance measurements. The lamp is a halogen source. L – lens, M – mirror, BS – beamsplitter, MMF – multimode fiber.

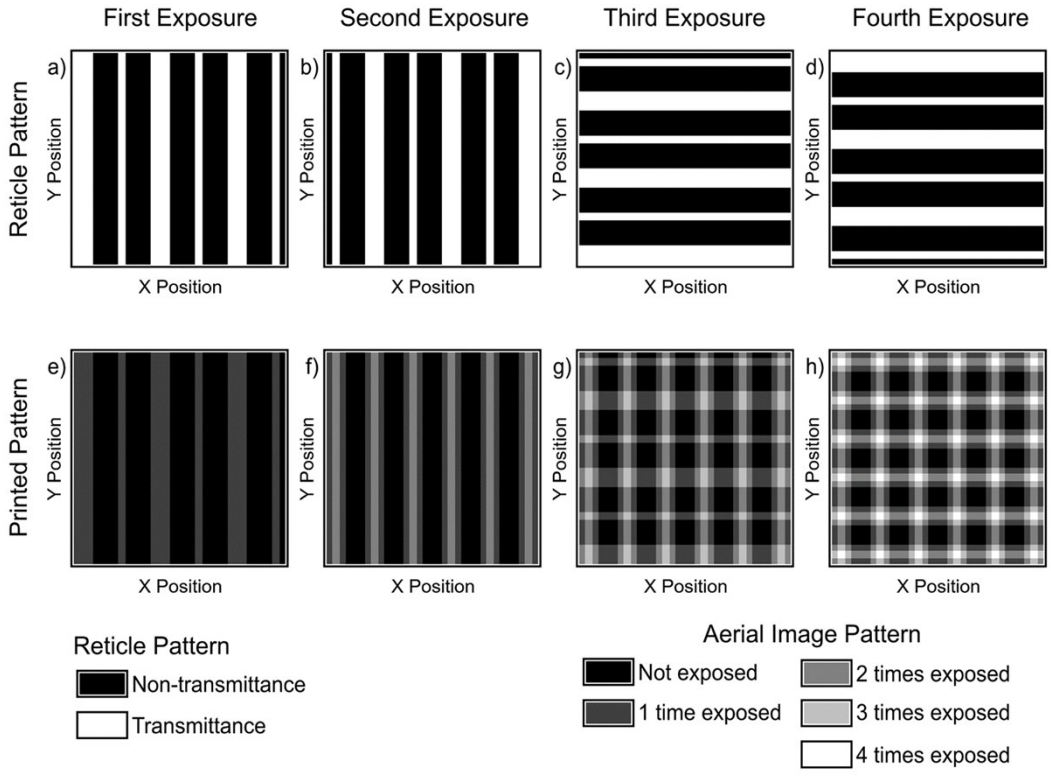

Figure S2. a-d) Mask (reticle) pattern with 150 nm trench width, 100 nm assist feature width and 600 nm pitch and e-h) corresponding simplified illustrations of aerial images (as a superposition of the different mask patterns) of the printed patterns after subsequent exposure steps. The pitch after four the exposures, two in horizontal, and two vertical direction is 300 nm.

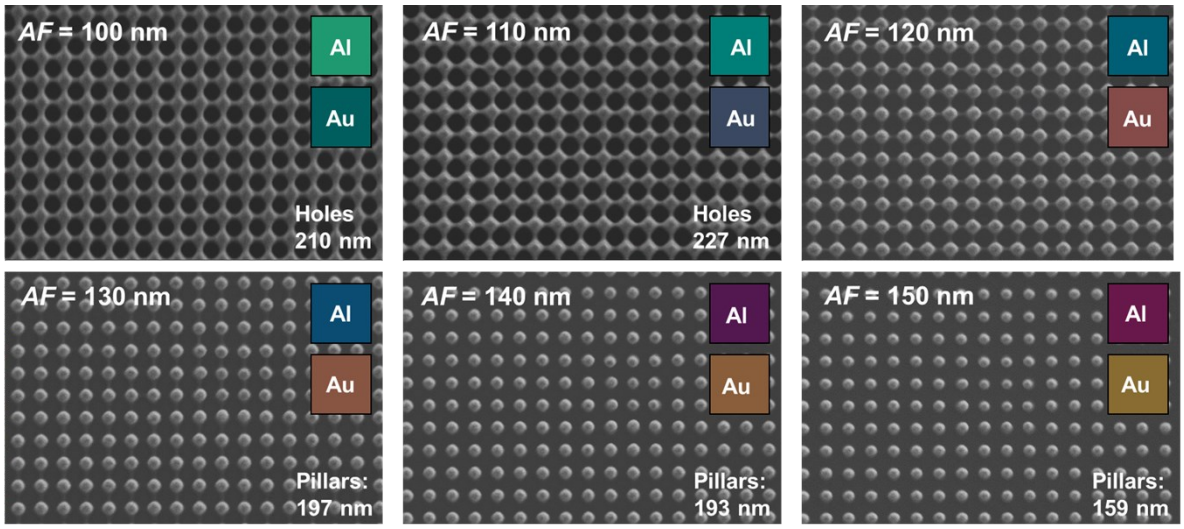

Figure S3. Scanning electron micrographs of patterns obtained using the off-axis illumination double exposure / cross exposure approach with assist feature (AF) lines of different widths included in the mask patterns. The dose was kept constant at 65 J/m^2 and the focus offset was 0.

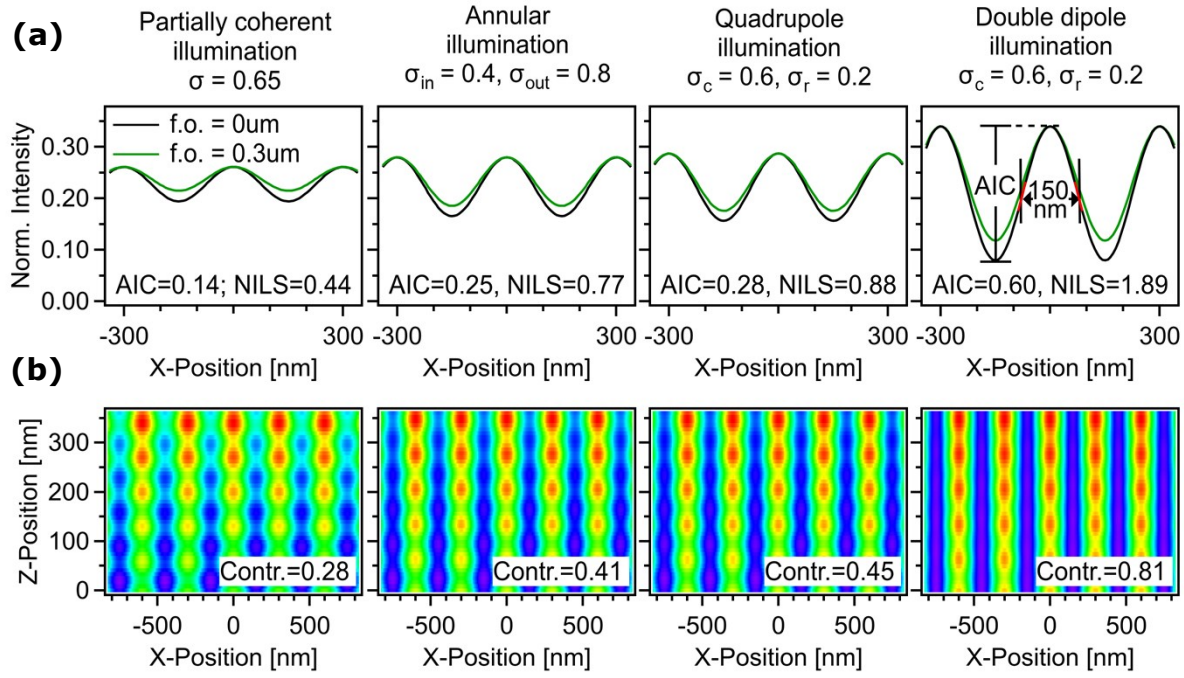

Figure S4. a) Sequences of aerial image simulations of 300 nm-pitch pillar patterns produced with the double line cross exposure process with assist features (DLCE-AF) and with $\sigma_C =$ 0.6, $\sigma_R =$ 0.2 along the direction of pillars when a positive tone resist is used. The aerial images are simulated in focus and with 0.3 µm defocus using mask pattern having 600 nm pitches, 150 nm trench widths and 140 nm assist feature widths. **b)** Corresponding optical images of cross sections through a 360 nm thick resist on 65 nm BARC on Silicon. The figure compares different illumination source

shapes; partially coherent: $\sigma =$ 0.65, annular: $\sigma_{in} =$ 0.4, $\sigma_{out} =$ 0.8, quadrupole: $\sigma_C =$ 0.6, $\sigma_R =$ 0.2, and dipole: $\sigma_C =$ 0.6, $\sigma_R =$ 0.2.

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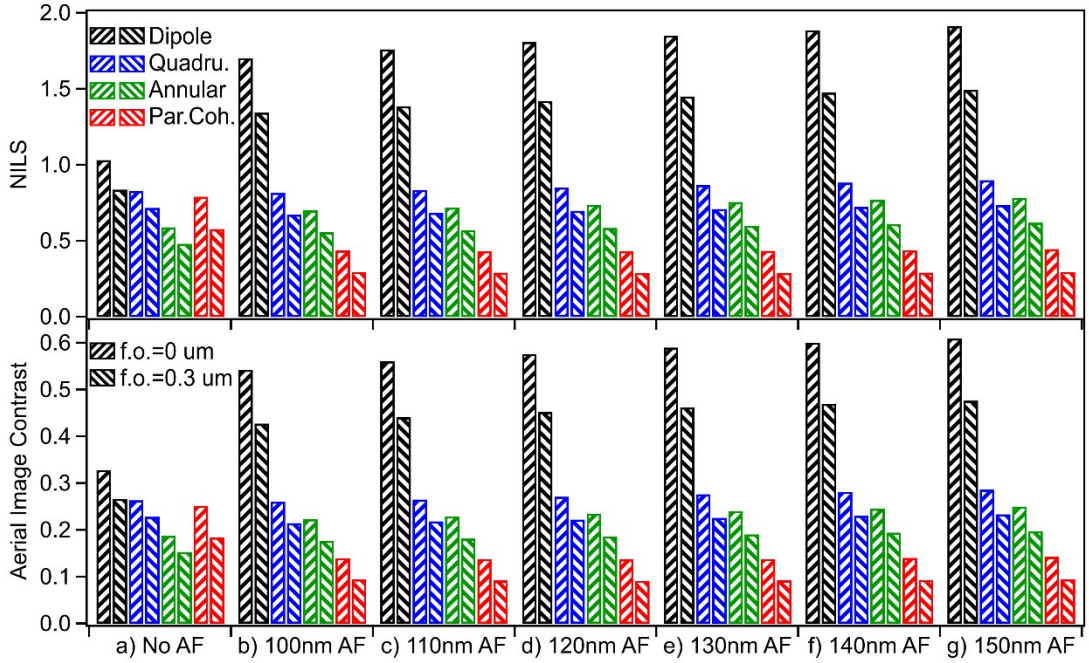

Figure S5. NILS and AIC comparison for different AF sizes when using different exposure modes on the DUV stepper. Sequences of NILS (at 150 nm target critical dimension) and AIC simulations in focus and with 0.3 µm defocus of 300 nm-pitch pillar patterns produced with the DLCE-AF processes using mask patterns having 600 nm pitches and 150 nm trench sizes. The assist feature widths is varying a) to g) from 0 nm (no AF) to 150 nm. The figure compares different illumination source shapes; dipole: $\sigma_C =$ 0.6, $\sigma_R =$ 0.2, quadrupole: $\sigma_C =$ 0.6, $\sigma_R =$ 0.2, annular: $\sigma_{in} =$ 0.4, $\sigma_{out} =$ 0.8 and partially coherent: $\sigma =$ 0.65.

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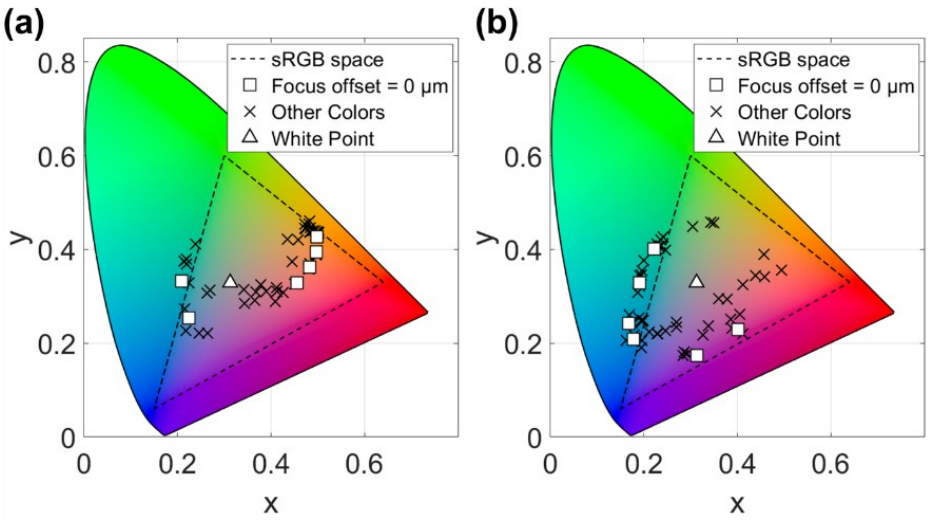

Figure S6. CIE diagrams showing the measured colors for (a) Au- and (b) Al-coated structures obtained with unpolarized normal incidence illumination.

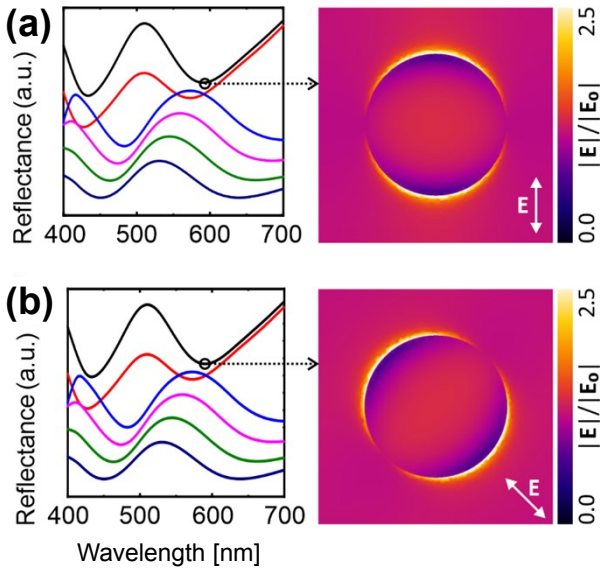

Figure S7. Finite element simulated reflectance spectra at normal incidence for the Au metasurfaces from AF = 100 nm (lowest plot) to AF = 150 nm (highest plot) in steps of 10 nm for a linear polarization of **(a)** 90° and **(b)** 45°. Right column: Corresponding cross-sectional distributions of the electric field enhancement for one period of the Au metasurface (AF = 150 nm) at its nanopillar top surface for excitation with a wavelength of 588 nm.

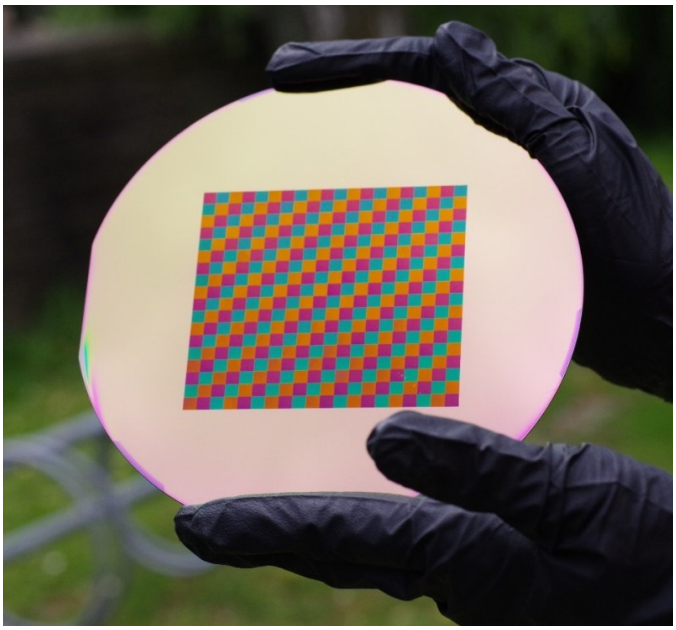

Figure S8. Checkered three-color print on a 150 mm wafer with Al metalization. The individual fields are 22×22 mm^2. The photograph is taken outdoors, in natural light. The total patterned surface area is 80×72 mm^2.

Table S1. RGB color coordinates computed for the color palettes shown in Figure 2c of the paper. The top part corresponds to the Al-coated structures, while the bottom corresponds to Au-coated structures.

		Focus Offset [µm]								
		-0.4	**-0.3**	**-0.2**	**-0.1**	**0**	**0.1**	**0.2**	**0.3**	**0.4**
AF [nm]	**100**	(0.5849,0.6108,0.3318)	(0.5838,0.6241,0.3274)	(0.0833,0.6148,0.4617)	(0.0000,0.6193,0.4696)	(0.0000,0.6163,0.4672)	(0.0000,0.6245,0.4582)	(0.1331,0.6256,0.4404)	(0.2075,0.6284,0.4269)	(0.5624,0.6111,0.3314)
	110	(0.0000,0.5127,0.4275)	(0.0000,0.4977,0.4647)	(0.0000,0.4804,0.4925)	(0.0000,0.5135,0.5046)	(0.0000,0.5090,0.4970)	(0.0000,0.5240,0.4863)	(0.0000,0.5263,0.4705)	(0.0000,0.5447,0.4521)	(0.0000,0.5298,0.3955)
	120	(0.0517,0.3049,0.5044)	(0.0000,0.3397,0.4790)	(0.0000,0.3926,0.5038)	(0.0000,0.3748,0.4534)	(0.0000,0.3828,0.4806)	(0.0000,0.3771,0.4745)	(0.0000,0.3828,0.4816)	(0.0000,0.3911,0.5043)	(0.0547,0.3809,0.4983)
	130	(0.3376,0.1754,0.3354)	(0.1281,0.2448,0.3789)	(0.0000,0.2776,0.4246)	(0.0000,0.3364,0.4867)	(0.0000,0.3136,0.4702)	(0.1783,0.2716,0.4191)	(0.2337,0.2523,0.4097)	(0.2736,0.2411,0.3998)	(0.3181,0.2346,0.3947)
	140	(0.4113,0.2000,0.2301)	(0.3570,0.1080,0.2087)	(0.3026,0.0599,0.2678)	(0.2724,0.1196,0.3281)	(0.3037,0.1081,0.3298)	(0.3081,0.1190,0.3353)	(0.3149,0.1398,0.3456)	(0.3783,0.1202,0.2937)	(0.4241,0.1667,0.2867)
	150	(0.6810,0.3743,0.2391)	(0.5528,0.3169,0.2922)	(0.3995,0.2669,0.3758)	(0.3808,0.1282,0.2851)	(0.3874,0.1010,0.2995)	(0.3616,0.2010,0.3594)	(0.3678,0.3092,0.4452)	(0.5215,0.2774,0.3526)	(0.6007,0.3295,0.3225)

		Focus Offset [µm]								
		-0.4	**-0.3**	**-0.2**	**-0.1**	**0**	**0.1**	**0.2**	**0.3**	**0.4**
AF [nm]	**100**	(0.2987,0.2720,0.3880)	(0.2694,0.3243,0.3460)	(0.1405,0.3290,0.3942)	(0.1364,0.3654,0.3655)	(0.0000,0.3730,0.3675)	(0.0631,0.3813,0.3449)	(0.0652,0.3845,0.3358)	(0.0416,0.3861,0.3346)	(0.1481,0.3761,0.2987)
	110	(0.4845,0.2814,0.2955)	(0.4189,0.2574,0.3196)	(0.2809,0.2374,0.3639)	(0.2211,0.2546,0.3766)	(0.2269,0.2891,0.3815)	(0.3009,0.3168,0.3566)	(0.4133,0.3017,0.3329)	(0.4365,0.2832,0.3254)	(0.4603,0.2713,0.3184)
	120	(0.5173,0.3699,0.2190)	(0.4700,0.2603,0.3057)	(0.4869,0.2525,0.2885)	(0.5156,0.2811,0.2861)	(0.5212,0.2927,0.2891)	(0.4852,0.2573,0.3177)	(0.4442,0.2993,0.3590)	(0.4773,0.3166,0.3290)	(0.5178,0.3491,0.2622)
	130	(0.5317,0.4340,0.1563)	(0.5405,0.3451,0.2152)	(0.5402,0.3405,0.2267)	(0.5366,0.3278,0.2635)	(0.5381,0.3331,0.2615)	(0.5382,0.3337,0.2686)	(0.5404,0.3427,0.2531)	(0.5358,0.4365,0.1886)	(0.5374,0.4300,0.1735)
	140	(0.5277,0.4448,0.1971)	(0.5386,0.4079,0.1711)	(0.5397,0.4038,0.1754)	(0.5419,0.3641,0.2265)	(0.5423,0.3684,0.2281)	(0.5426,0.3716,0.2358)	(0.5423,0.3899,0.2256)	(0.5158,0.4911,0.2324)	(0.5147,0.4938,0.2338)
	150	(0.5275,0.4474,0.1997)	(0.5216,0.4686,0.1911)	(0.5352,0.4277,0.1801)	(0.5390,0.4091,0.1930)	(0.5371,0.4223,0.1946)	(0.5363,0.4286,0.1949)	(0.5311,0.4506,0.1927)	(0.5288,0.4580,0.1883)	(0.4626,0.5668,0.3862)