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1 **Electronic supplementary information:**

2 Fabrication of plasmonic opposite metal spindles in 3 nanowells by shadow deposition for sensing

4 Lingxiao Liu, Feifei Wu, Dongyang Xiao, Fei Teng, Daren Xu, Lei Feng and Nan Lu*

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6 State Key Laboratory of Supramolecular Structure and Materials, College of Chemistry, Jilin
7 University, Changchun 130012, P. R. China.

8 Corresponding author. E-mail: luenan@jlu.edu.cn;

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10 **Contents**

11 Detailed experimental section;

12 Scheme of the fabrication of the mold for NIL;

13 SEM images of the mold and PMMA nanowells;

14 The detailed parameter of samples;

15 Distribution of EF of sample A.

1 **Experimental section**

2 **Chemicals and materials**

3 Chemicals and solvents of reagent quality were used without further
4 purification. Analytical reagent-grade ethanol, acetone, chloroform, sucrose
5 were purchased from commercial sources. The PMMA powder (molecular
6 weight Mw=96700), tridecafluoro-1, 1, 2, 2,-tetrahydrooctyl-trichlorosilane,
7 rhodamine 6G and the Au wire (99.999%) were purchased from Sigma-Aldrich.
8 The monodispersed PS spheres of 538 nm in diameter with less than 5%
9 diameter variation were obtained from Wuhan Tech. Co.. The quartz slices and
10 one side polished n-type (100) oriented Si wafers were obtained from Beijing
11 Zhongjingkeyi Tech. Co., China.

12 **Preparation of nanopillar mold**

13 The Si wafer was cut into 1×1 cm^2 slices and subsequently cleaned by sonicating
14 in acetone, chloroform, ethanol and deionized water for 3 min respectively to remove
15 organic contaminants. Then the Si slides were dried under nitrogen gas flow before
16 use. A monolayer of PS spheres was prepared onto the Si slices. An reactive ion
17 etching (RIE) process was conducted to reduce the diameter of PS nanospheres on a
18 Plasmalab 80 Plus (ICP65) system (Oxford Instruments Co., UK). The etching time
19 was 8 min under a RF power of 30 W, an ICP power of 30 W, a pressure of 40 mTorr
20 and O_2 flow rate of 20 sccm. Then the residual PS nanospheres were used as masks
21 for creating Si nanopillars with RIE. The etching process was performed using a 2:15
22 mixture gas of SF_6 and CHF_3 at total flow rate of 51 sccm, pressure of 10 mTorr, RF

1 power of 25 W and ICP RF power of 100 W. The etching time was set at 3 min. Then
2 the residual PS nanospheres were removed by sonicating in acetone and ethanol for 3
3 min, respectively. Then a monolayer of tridecafluoro-1, 1, 2, 2,-tetrahydrooctyl-
4 trichlorosilane was assembled on the samples by vapor phase deposition to lower the
5 surface energy.

6 **Preparation of PMMA nanowell arrays**

7 The quartz slices (1.5×1.5 cm^2) were cleaned with acetone, chloroform and
8 ethanol in an ultrasonic bath for 5 min respectively. A 200 nm PMMA layer
9 was spin-coated onto the substrate. The NIL process was carried out on a 2.5-in.
10 Nanoimprinter (Obducat AB, Malmö, Sweden). NIL process was performed at
11 175 °C, under 30 bar for 600 s. Following the embossing time, the substrate was
12 cooled down to 80 °C and the mold was peeled off from the PMMA layer. The
13 residual PMMA was removed with RIE process with a gaseous of oxygen for 1
14 min.

15 **Preparation of arrays of opposite metal spindles in nanowells**

16 The arrays of opposite metal spindles were fabricated by conducting two
17 shadow deposition processes at opposite directions on a commercial vacuum
18 thermal evaporation system (Shenyang Keyou Institute of Vacuum Technology,
19 China).

20 **Characterization**

21 AFM measurements were taken on a Multimode Nanoscope instrument
22 (Digital Instrument, USA). SEM images were taken using a Hitachi SU8020

1 field emission scanning electron microscope (Hitachi, Ltd., Japan) operated at
2 3.0 kV. Reflection spectra were recorded on an R1-A-UV series spectroscopy
3 meter (Shanghai Ideaoptics Instrument Co, Ltd, China). Raman spectra were
4 measured on a system under excitation wavelength of 633 nm. The data
5 acquisition time was set to 20 s for each measurement. A silicon wafer was
6 used to calibrate the spectrometer.

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

8 Lumerical FDTD Solution software was used to simulate the
9 electromagnetic field intensity and the spectrum of the structures. The dielectric
10 coefficients of all materials used were obtained from Palik's handbook.
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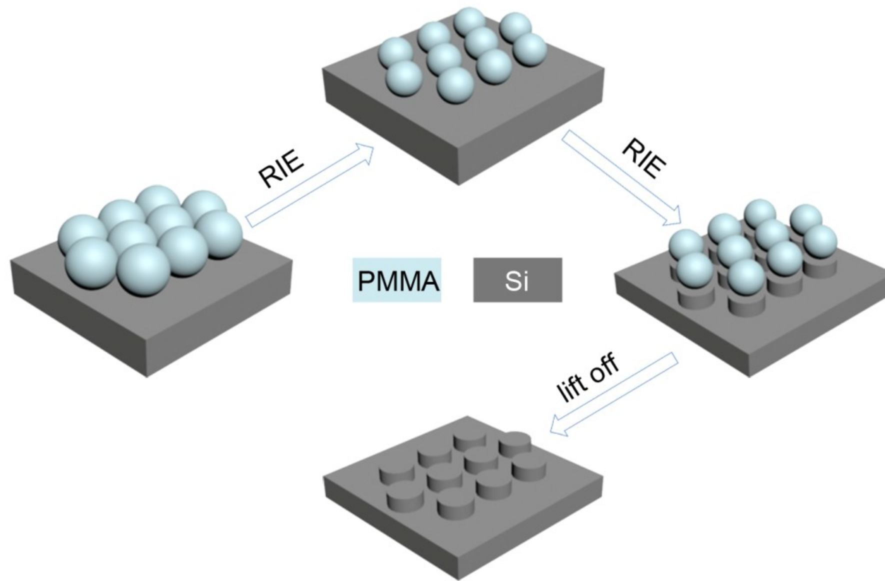

2 **Fig. S1.** Schematic illustration of the process for fabricating Si mold.

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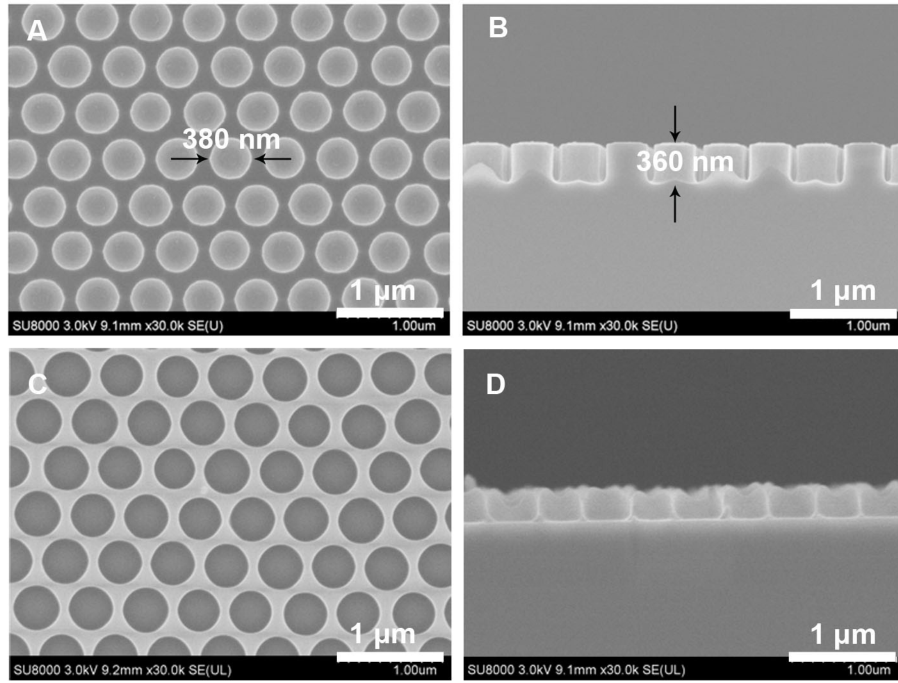

2 **Fig. S2.** (A) Top view and (B) cross-sectional SEM images of the Si mold. (C) Top
3 view and (D) cross-sectional SEM images of the PMMA nanowells after removing
4 the residual layer.

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6 Table S1. Parameters of the spindles created with different deposition angles.

	A	B	C
Deposition angle (°)	30	45	60
Long axis (nm)	330	280	250
Short axis (nm)	135	120	80
“gap” (nm)	75	100	150

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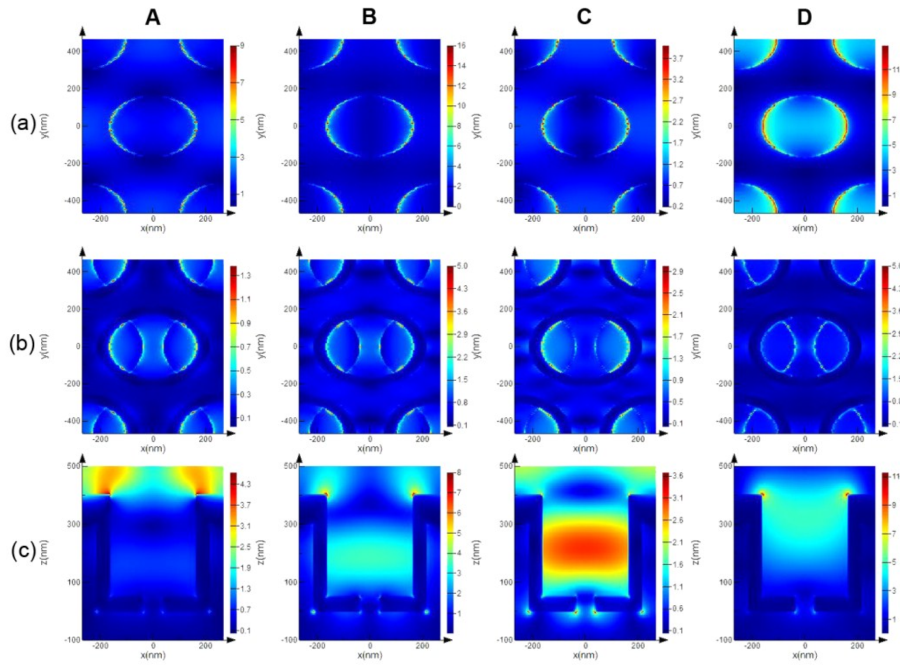

Fig. S3. The distribution of electromagnetic field of sample A at the wavelength of P1 (line A), D1 (line B), P2 (line C) and D2 (line D). Row (a) and (b) represent the distribution of electromagnetic field of XY plane on the top and bottom of the nanowell. Row (c) represents the distribution of electromagnetic field of XZ plane.