Non-planar nano-arc-gap arrays fabricated via colloidal lithography

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We report a method to fabricate non-planar nano-arc-gap arrays via colloidal lithography and shadow metal deposition. It is found that there is a localized surface plasmon resonance which results an extraordinary optical transmission. The electric field is strongly localized at the nano-arc-gap region, therefore it induces a resonance which has an ultrasmall mode volume of less than $2.44 \times 10^{-6} \mu m^3$, this would be valuable for the design of the optoelectric circuits.

Noble metal nanostructures have attracted lots of attention due to their splendid applications in the fields of sensors, biology, optoelectronic circuits. Since Ebbeson[1] found an unusual phenomenon of extraordinary optical transmission and Pendry[2] re-dug the concept of negative refractive index, lots of structures have been proposed and fabricated, for example, periodical holes, split-ring resonators, fishnet structures, and so on. Most of the structures are fabricated via electron beam lithography, focused ion beam lithography, and nano-print as well as photolithography. Colloidal lithography is a cost-effective method to prepare nanostructures; however it is rare used, even though crescent holes, crescent ring metal cups and bow-tie structures can be prepared via colloidal lithography. Here we report a novel method to prepare non-planar metal nano-arc-gap arrays based on inverted colloidal lithography[3] and shadow metal deposition. The fabricated structure is shown in Fig. 1. The gap-width at the middle is around 26 nm. Before silver evaporation, the depth of the dimple and diameter of the upper circle of the dimple are around 90 nm and 243 nm respectively, the period of the nano-arc-gap array is 285 nm. After silver evaporation, the silver thickness out of the dimple is 64 nm, and the thickness of the silver at the dimple area is various because of the evaporation angle is various due to the curvature of the dimple. The estimated thickest thickness of the silver at the dimple is around 46 nm.

It is found that there exists an extraordinary optical transmission (EOT) in transmission spectrum when the electric field of the incident wave is along to the gap, which is shown in Fig. 2. The EOT resonator is insensitive with the incident angle. It is confirmed that this EOT resonator is induced by a localized surface plasmon. Finite difference time domain method is used to simulate the optical transmission of this structure shown in Fig. 2 as well. It is found that each of the

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[1] T. W. Ebbesen, H. J. Lezec, H. F. Ghaemi, T. Thio, P. A. Wolff, Nature 391, 667(1998).
[2] J. Pendry, Phys. Rev. Lett. 85, 3966(2000).
[3] H. X. Xu, W. Y. Rao, J. Meng, Y. Shen, C. J. Jin, X. H. Wang, Nanotech. 20, 465608(2009).

nano-arc-gap can support a resonator with ultrasmall mode volume of $2.44\times10^{-6}\,\mu m^3$. This structure would be useful in sensors and optoelectronic circuits.

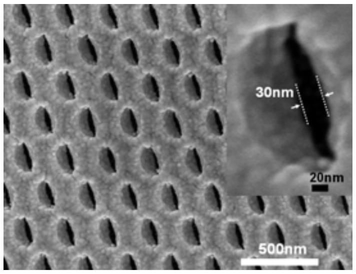

Fig. 1 Scanning electron microscope picture of non-planar nano-arc-gap array. Inset is an enlarged picture of single nano-arc-gap.

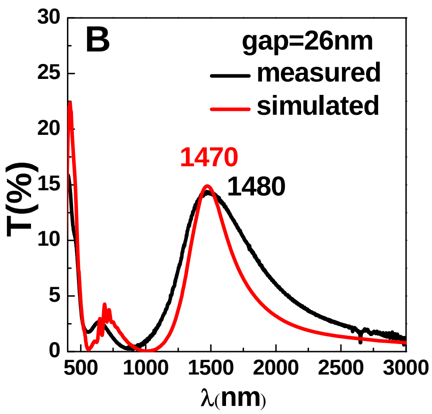

Fig. 2 Measured and simulated transmission spectra for electric field perpendicular to the gap at normal incident angle