Extended Abstracts of the 2011 International Conference on Solid State Devices and Materials, Nagoya, 2011, pp242-243

Enhanced localized surface plasmon resonance in a stacked structure

Hung-Hsin Chen, Yi-Tsung Chang, Chih-Wei Yu, Shao-Yu Huang, Fang-Tzu Chuang and Si-Chen Lee*

Graduate Institute of Electronics Engineering, Department of Electrical Engineering, National Taiwan University, Taiwan

Phone: +886-2-33663700 #440; E-mail:sclee@ntu.edu.tw.

1. Introduction

Surface plasmons (SPs) have attracted much attention due to its unique properties such as extraordinary optical transmission (EOT) [1], biosensor, mid-infrared thermal emitter [2] and surface enhanced Raman spectroscopy (SERS). The SPs waves are induced at the interface between the perforated metal film and the neighboring dielectric material. By coupling the thermal radiation and the surface plasmons in perforated metal film, high power narrow bandwidth tri-layer metal/dielectric/metal plasmonic thermal emitter was demonstrated by Tsai *et al* [2]. Not only SPs but also localized surface plasmon (LSP) modes were observed as the top perforated metal film replaced by one-dimension (1D) grating [3] or micro-disk [4]. Different from the SPs waves propagating a long distance at the metal/dielectric interface, the localized surface plasmon was confined at the metal edges and formed a Fabry-Perot resonance [4]. The resonant wavelength of the localized surface plasmon in tri-layer structure red-shifted due to the coupling of two metal/dielectric interfaces resulting in the higher effective refractive index in the dielectric layer [3]. As the thickness of dielectric layer increased, the coupling decreased and the localized surface plasmon resonance became weaken. It is reported in this paper that the localized surface plasmon resonance can be enhanced in a stacked structure. The reflection spectra and the dispersion diagram of the LSP were measured.

2. Experiments and results

The device structures were shown in Fig. 1(a)-(b). A 3 nm titanium (Ti) film was deposited on the silicon (Si) wafer followed by 150 nm gold (Au) film. Then the SiO_2 layer with a thickness of 600 nm was deposited by plasma enhanced chemical vapor deposition (PECVD). A periodic gold 1D grating with a thickness of 50 nm was formed on the SiO_2 layer. The period and the metal width of the Au grating were 3 and 1.5 μm, respectively. This is sample A as shown in Fig. 1(a). Next, another top SiO_2 layer was deposited on the grating for samples B, C, D and E by PECVD. A 12 nm gold film was deposited on the samples C, D and E. The samples parameters were listed in Table I. A Bruker IFS 66 v/s system was used to measure the reflection spectra. The sample was defined to lie in the (x, y) plane rotating around the y axis in 1° increments from $\theta = 12°$ to $\theta = 65°$, where θ is the incident angles of light to the normal of the metal surface (z axis).

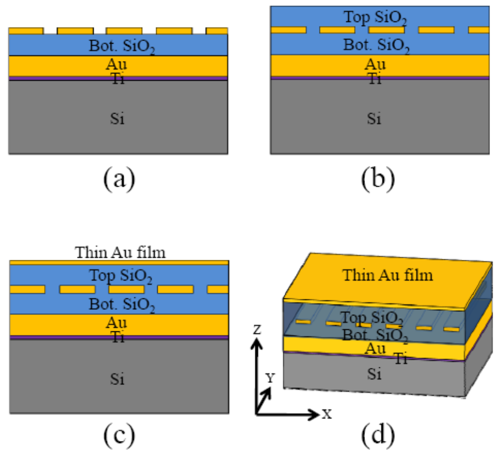
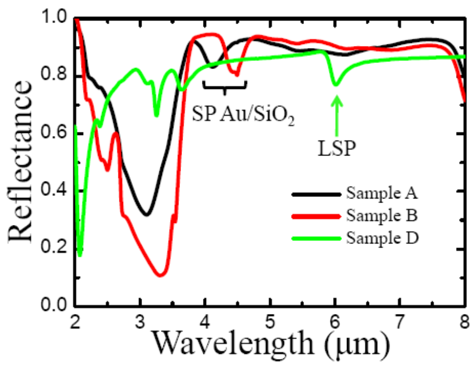


Fig.1 Side view of samples (a) A. (b) B, (c) C, D and E. (d) Tilt views of samples C, D and E.

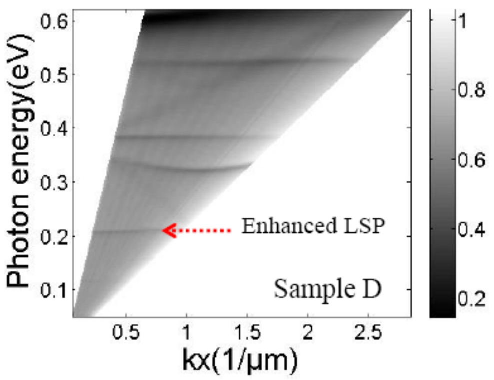
Table I. samples parameters

Sample	Top thin Au layer thickness (nm)	Top SiO_2 thickness (nm)	Bottom SiO_2 thickness (nm)
A			600
B		600	600
C	12	400	600
D	12	600	600
E	12	800	600

Figure 2(a) shows the reflection spectra of the samples A, B and D. Sample A is an Au-grating/SiO_2/Au tri-layer structure. As described in the Ref. [3], the localized surface plasmon was weak as the thickness of the SiO_2 layer reaches 600 nm for sample A (black curve). After the top SiO_2 layer with a thickness of 600 nm deposited on the grating structure (sample B), the localized resonance around 6 μm still weak (red curve). However, when a thin gold film with a thickness of 12 nm was deposited on the top SiO_2 layer (samples C, D, E) as shown in Fig. 1(c) and 1(d). The structure can be described as two Au-grating/SiO_2/Au tri-layer structures reversely stacked and shared the same gold grating. The localized surface plasmon (LSP) was enhanced as shown in Fig. 2(a) (green curve) and the Fig. 2(b) demonstrated that the dip at 6 μm is a localized resonance. The resonance wavelength was longer than that predicted in Ref. [3] due to the weak lateral confinement in the SiO_2 layer when the SiO_2 layer became thick [5]. This is because the effective resonance length under the metal became broader than the metal width due to the leakage of resonance mode as the SiO_2 layer became thicker. Although the refractive index return to the ideal value as the SiO_2 layer reaches 600 nm [6], the effective resonance length increases which leads to the redshift of the resonance wavelength.



(a)



(b)

Fig. 2 (a) The reflection spectra of the samples A, B and D. (b) The dispersion diagram of reflection spectra of sample D.

Since the localized surface plasmon resonance can be enhanced and its resonance wavelength can be controlled by the SiO_2 layer thickness. Fig. 3 shows the resonance wavelength of samples C, D and E. It is clear that the LSP mode redshifts as the top SiO_2 layer increases from 400 nm to 800 nm while the bottom SiO_2 thickness keeps at 600 nm. It is believed that the resonance wavelength of the stacked structure as shown in Fig. 1(c) was determined by the localized resonance wavelength of the top and bottom Au-grating/SiO_2/Au tri-layer structures. Since the resonance wavelength was shorter (longer) at one side, the resonance wavelength in stacked structure was shorter (longer).

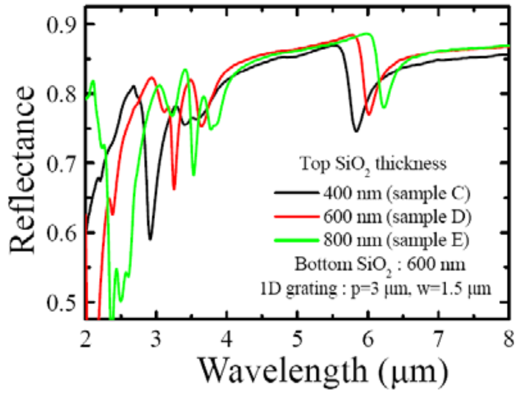


Fig. 3 The reflection spectra of the samples C, D and E

3. Conclusions

Localized surface plasmon resonance can be enhanced in a stacked structure. The resonance wavelength of the stacked structure was determined by the localized resonance wavelength of the top and bottom Au-grating/SiO_2/Au tri-layer structures. The resonance wavelength can be easily controlled by the SiO_2 layer thickness at both sides of 1D grating.

References

1. T. W. Ebbesen, H. J. Ghaemi, T. Thio, and P. A. Wolff, Nature (London) **391**, (1998) 667.
2. M. W. Tsai, T. H. Chuang, C. Y. Meng, Y. T. Chang and S. C. Lee, Appl. Phys. Lett. **89**, (2006) 173116.
3. Y. H. Ye, Y. W. Jiang, M. W. Tsai, Y. T. Chang, C. Y. Chen, D. C. Tzuang, Y. T. Wu, S. C. Lee, Appl. Phys. Lett. **93**, (2008) 033113
4. M. N. Abbas, C. W. Cheng, Y. C. Chang, M. H. Shih, Hung-Hsin Chen and S.C. Lee, Appl. Phys. Lett. **98**, (2011) 121116
5. Y. Todorov, L. Tosetto, J. Teissier, A. M. Andrews, P. Klang, R. Colombelli, I. Sagnes, G. Strasser and C. Sirtori, Optics Express, **18**, (2010) 13886
6. C. Y. Chen, M. W. Tsai, Y. W. Jiang, Y. H. Ye, Y. T. Chang, and S. C. Lee, Appl. Phys. Lett. **91**, (2007) 243111