All-dielectric Nanoantenna Sensors

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1. Introduction

All-dielectric nanostructures [1] having both electric and magnetic resonance that could be used in near-fields optics, surface enhanced Raman spectrometers (SERS), or sensor applications. Optical sensor criteria, like narrower full-width half maximum (FWHM), and larger figure of merit (FOM) are important. However, the FWHM in plasmon resonance of metal nanostructures could not be very small because of the intrinsic loss of metal [2].

In this study, it is observed that the FWHM of silicon nanoantennas (Si NAs) is narrower than gold nanoantennas (Au NAs). Combining with the advantage in low cost and CMOS compatible process, silicon nanoantenna could be a good candidate in bio-sensing application.

2. Results and discussion

Finite-difference time-domain (FDTD) modeling (Lumerical, Inc.) is used to calculate the transmittance spectra of Si and Au NAs. The grid-spacing is 5nm and the periodic boundary is used. The period of Si and Au NAs are both 400 nm, and the thickness are both 65 nm with the x-y aspect ratio as 1.5:1. The electric field is oscillated in short-axis (y direction) of NAs.

The transmittance spectra of Si NAs with different refractive index of the surrounding medium from 1.33 (Water), 1.36 (Ethanol) to 1.39 (Glucose solution) are shown in Fig.1. It is observed that when the refractive index of the surrounding medium increases, the resonance wavelength shifts from 652 nm to 658 nm. The calculated FWHM of Si NAs is 15 nm, and the FOM is 6.667.

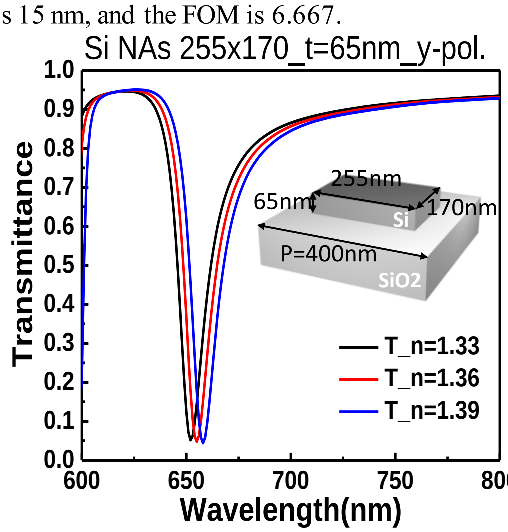

Fig.1 The transmittance spectra of Si NAs with different refractive index of the surround medium from 1.33 (Water), 1.36 (Ethanol) to 1.39 (Glucose solution).

The transmittance spectra of Au NAs with different refractive index of the surrounding medium from 1.33 (Water), 1.36 (Ethanol) to 1.39 (Glucose solution) are shown in Fig.2. The resonance wavelength shifts from 669 nm to 682 nm. Compared with the simulation results of Si NAs, it is observed that though the $\Delta\lambda/\Delta n$ of Au NAs is larger than Si NAs, but because the narrower FWHM of Si NAs, the FOM of Si NAs are ~ 3 times better than Au NAs.

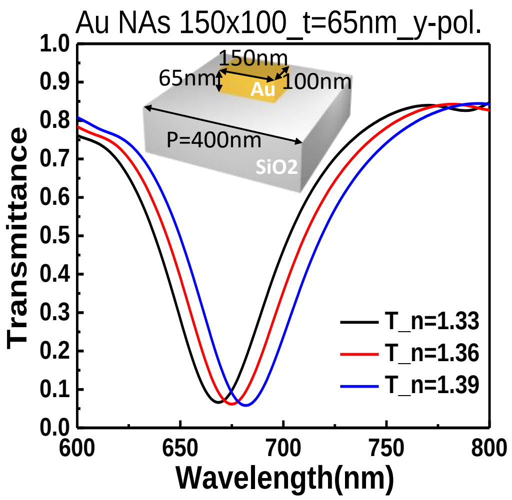

Fig.2 The transmittance spectra of Au NAs with different refractive index of the surround medium from 1.33 (Water), 1.36 (Ethanol) to 1.39 (Glucose solution).

The summary of sensitivity comparison of Si and Au NAs arrays is shown in Table 1. The figure of merit (FOM) defined as $(\Delta\lambda/\Delta n)/\mathrm{FWHM}$ is introduced to determine the quality factors of different nanoantenna sensors.

Table.1 Summary of sensitivity comparison of Si and Au nanoantenna arrays.

	Δλ/Δn(nm)	FWHM(nm)	FOM
Si	100	15	6.667
Au	216.62	62	3.494

3. Conclusions

In this study, an optical sensor with narrower FWHM and a lager FOM can be achieved by using Si NAs arrays. From the viewpoint of manufacturing, Si is low cost and COMS compatible. Because of these advantages, Si NAs will be a good candidate in future sensors developments.

References

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[2] Y.-H. Chen, K.-P. Chen, M.-H. Shih, and C.-Y. Chang, Appl. Phys. Lett. **105**, 031117 (2014).