Fabrication of periodic bowtie structure on vanadium dioxide by nanosphere lithography for smart window applications

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1. Introduction

Nanophotonics has been extensively researched in the past decades owing to the rapid development of the precision nanofabrication techniques, such as focused-ion beam milling and electron-beam lithography. However, it was limited by some disadvantages, such as high cost and low productivity. Therefore, a facile and economics method, nanosphere lithography (NSL) [1], for fabricating multiple nanostructures has been reported. Polystyrene nanospheres, with diameters of several hundred nanometers, were aligned into a monolayer. By using close-packed polystyrene nanospheres array as a mask, periodic metal bowties can be fabricated after metal evaporation and nanospheres lift-off.

VO_2(M), which could undergo a reversible metal-semiconductor-transition (MST) with the phase transition temperature (T_c) at 68ºC [2]. Above the T_c, metallic phase VO_2(R) could reduce the transmittance of the infrared light and has been applied to smart window for energy-saving. However, there was still high transmittance in the wavelength from 700 to 1000 nm which is the main heat source from the sunlight. Therefore, the purpose of this work was to fabricate the large-area and high periodic bowtie structure to reduce the transmittance in the wavelength from 700 to 1000 nm through a low-cost and high productivity method. Finite-difference time-domain (FDTD) method was used to find the best size and gap of bowtie structure to enhance the reflection of VO_2 in the infrared region and the simulated transmittance and reflectance were compared to experimental measurements.

2. Results and discussion

The close-packed monolayer polystyrene nanospheres with diameters of 1000 nm shown in Figure 1(a) were fabricated by drop-casting method. After the silver deposition with thickness of 30 nm by e-beam evaporation and polystyrene nanospheres lift-off, the bowtie nanostructure was successfully obtained in our experiment, as shown in Figure 1(b).

Lumerical FDTD Solutions was used to perform the simulations of the transmittance (T%) and reflection (R%) for the as-obtained bowtie structure on the rutile vanadium dioxide (VO_2(R)). The periodic Ag bowtie nanostructure, with the size and gap of 250 nm and 100 nm, respectively, was attached to the surface of VO_2(R) with thickness of 30 nm. From Figure 1(c), it was indicated that the main difference between systems with and without Ag bowtie nanostructure was in the wavelength from 600 to 900 nm for both transmittance and reflectance, relating to the plasmonics effect of periodic Ag bowtie nanostructure. Therefore, the result could be applied to smart window for blocking infrared light from sunlight.

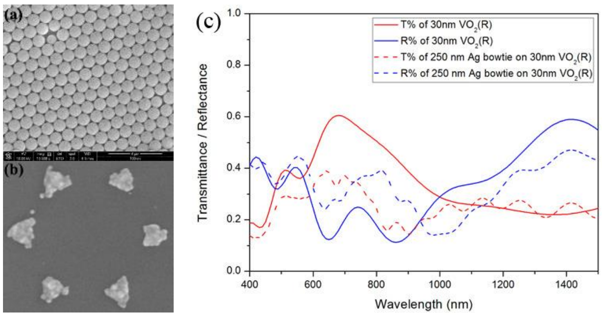

Figure 1. SEM images of (a) 1000 nm polystyrene nanosphere and (b) Ag bowtie nanostructure with thickness of 30 nm. (c) the FDTD simulation results of transmittance and reflectance for the 30 nm rutile vanadium dioxide film with and without Ag bowtie nanostructure.

3. Conclusions

The Ag bowtie nanostructure was successfully obtained by nanosphere lithography. Using the obtained structure, it could help to reduce the transmittance of rutile vanadium dioxide in the infrared region from the simulation results, which could be applied to smart window for energy-saving.

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