

Effect of Scattering on the Transmission of Si Nanorod Arrays

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Abstract

The effect of scattering on the transmission of subwavelength Si nanorod arrays is investigated. It is found that the distance between the nanorods has important effect on the transmission because the scattered light varies largely with it. When the nanorods are close to each other, the back-scattered light and the light reflected by the surface of substrates interfere destructively and lead to a high transmission. When the distance of the nanorods increases, the intensity of the scattered light decrease and this makes the transmission decrease. The reflection and the transmission of the nanorod arrays can be adjusted by changing the distance between the neighbouring nanorods.

Keywords

Nanorod, Transmission, Interference, Back-Scattered

1. Introduction

In past decades, subwavelength nanorod arrays attracted much attention because they can lower largely the reflection of light [1] [2] [3] [4]. A lot of works have been done in this area, involving materials [5] [6] [7], structures [8] [9] [10] [11] and fabrication [12] [13] [14] [15], etc. In order to understand their light-trapping mechanism, many efforts have also been done to explain the anti-reflection of the nanorod arrays [16]-[21].

In this work, we investigate the effect of scattering of light on the transmission of the subwavelength nanorod arrays. By changing the distance between the neighbouring nanorods, the interference between the light scattered by the nanorods and the light reflected by the surface of substrates is adjusted. As a result, the transmission of the nanorod arrays varies with the distance between the neighbouring nanorods.

2. Theoretical Model

Figure 1(a) and **Figure 1(b)** shows the schematic of the periodic nanorod arrays and the simulated model, respectively. In the simulation, Si nanorods are located on Si substrates. The radius of the nanorods is set as 50 nm, and their height is 135 nm. The top and bottom ends of the model are perfect matched layer (PML) to eliminate the influence of the reflection at the both ends. The other four faces have periodic boundary conditions. To avoid the effect of diffraction, incident wavelength is set as 1 μm , much longer than the period of the nanorod arrays. The real part of the refractive index of Si is 3.57 and its imaginary part is 0.001. The direction of the incident light is perpendicular to the surface of the substrates.

3. Results and Discussion

Figure 2 gives the transmission of the nanorod arrays with the different distance between neighbouring nanorods. It can be seen that the transmission increases at first. After the distance between the neighbouring nanorods rises to 11 nm, the transmission turns down. This may be explained by the interference between the light back-scattered by the nanorods and the light reflected by the surface of the substrates.

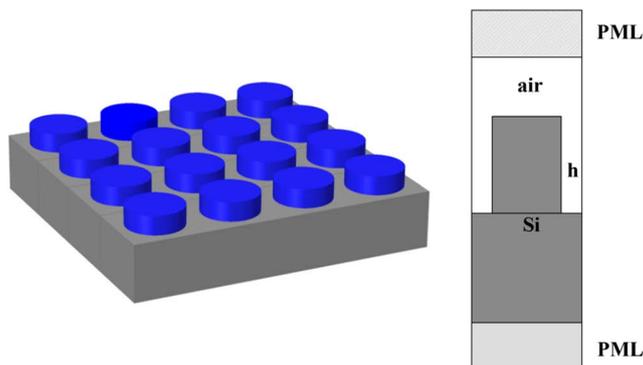


Figure 1. (a) Schematic of periodic Si nanorod arrays on Si substrates and (b) simulated model.

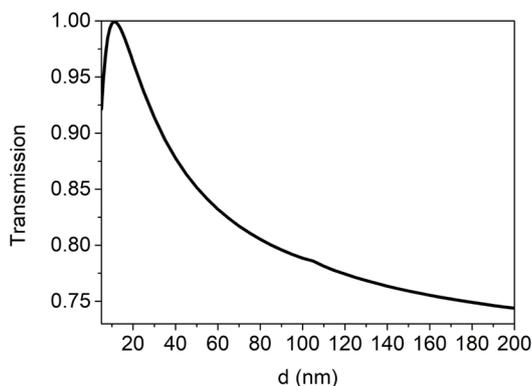


Figure 2. Transmission of the nanorod arrays with the different distance between neighbouring nanorods.

Figure 3 gives the oscillograms of the reflected light and the back-scattered light of the nanorod arrays with different distance between the neighbouring nanorods. The abscissa denotes the distance from a point on the axis of the nanorod to the surface of the substrates. The chosen back-scattered light propagates along the axis of the nanorod. It can be seen that, the phase differences between the back-scattered light and the reflected light is greater than three quarters of π , so the interference between the back-scattered light and the reflected light is destructively. This indicates that the nanorod arrays can improve the transmission. Furthermore, the intensity of the back-scattered light decreases with the distance between the neighbouring nanorods, and this make the intensity of the resultant waves of the back-scattered light and reflected light increase, and leads to decreasing transmission.

When the distance between the neighbouring nanorods is 11 nm, the intensity of the back-scattered light is nearly the same as that of the reflected light, and their phase difference is approximately equal to π . So they interfere destructively and the intensity of the resultant waves is nearly equal to zero. This is why the transmission at the distance of 11 nm reaches the maximum.

Figure 4 shows the pattern of the interference between the reflected light and

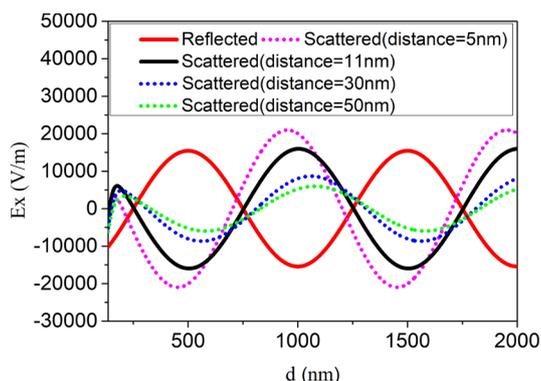


Figure 3. The oscillograms of the reflected light and the back-scattered light of the nanorod arrays with different distance between the neighbouring nanorods. The abscissa denotes the distance from a point on the axis of the nanorod to the surface of the substrates. The chosen back-scattered light propagates along the axis of the nanorod.

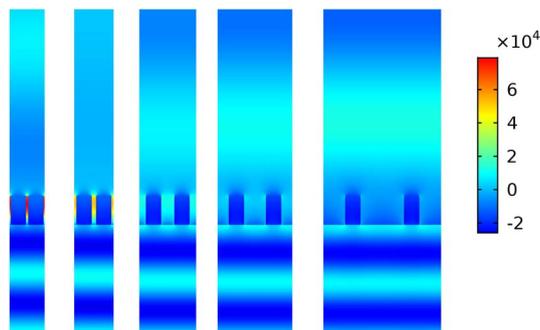


Figure 4. The pattern of the interference between the reflected light and the scattered light (the incident light is not included) of nanorod arrays with different distance between neighbouring nanorods. (a) $d = 5$ nm, (b) $d = 11$ nm, (c) $d = 30$ nm, (d) $d = 50$ nm, (e) $d = 100$ nm.

the scattered light (the incident light is not included because it does not influence the transmission) of the nanorod arrays with different distance between neighbouring nanorods. It can be seen that the different distance between the nanorods leads to the different interference. When the distance is 11 nm, the resultant wave is weaker than others. This agrees with the results in **Figure 3** where the intensity of the back-scattered light is similar to that of the reflected light and their phase difference is close to π .

It should be pointed that the above discussion is based on the fact that the scatter cross-section of the nanorods is smaller than the cross-section of the nanorods. If the scatter of the nanorods is strong enough to make the scatter cross-section become large and cover the whole surface of the substrates, the transmission will be influenced differently by the scatter. This is a complicated research work which we will focus on next.

4. Conclusion

The effect of scattering on the transmission of subwavelength Si nanorod arrays is demonstrated through the different distance between neighbouring nanorods. When the nanorods are close to each other, the back-scattered light and the light reflected by the surface of substrates interfere destructively and lead to a high transmission. When the distance of the nanorods increases, the intensity of the scattered light decreases, and this makes the transmission decrease. The reflection and the transmission of the nanorod arrays can be adjusted by changing the distance between the neighbouring nanorods.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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