

Anti-Reflecting Surfaces Using Two-layer Motheye Structures for Spinel Ceramic Windows

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Abstract: We design and optimize a two-layer pyramid motheye structures for long wavelength MgAl_2O_4 spinel ceramic windows. We show that a two-layer pyramid motheye structure can achieve average transmission of 98.96% from $0.5\ \mu\text{m}$ to $5\ \mu\text{m}$. © 2018 The Author(s)

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1. Introduction

Motheye structures are period biomimetic sub-wavelength structures (SWS) that are inspired by the eyes of nocturnal moths [1]. They can be used as anti-reflecting (AR) surfaces that can significantly reduce Fresnel reflections [2]. In previous work, Busse et al. [3] demonstrated transmission larger than 90% from $0.9\ \mu\text{m}$ to $1.6\ \mu\text{m}$ with transparent MgAl_2O_4 spinel ceramic windows. In this work, we propose a two-layer pyramid motheye structure to improve the transmission at visible light wavelengths. We computationally study the dependence of the motheye structure transmission on the dimensions of the parameters of the motheye structure using the finite-difference time-domain (FDTD) method [4], and we present a design for a dual motheye structure with an averaged transmission greater than 98.96% in the wavelength range of $0.5 - 5\ \mu\text{m}$.

2. Numerical computation

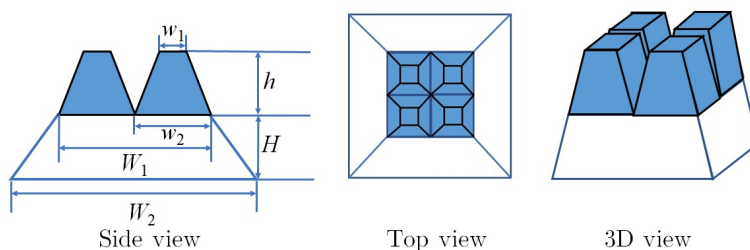


Fig. 1. Illustration of the two-layer pyramid motheye structure.

In Fig. 1, we show a schematic illustration of the two-layer pyramid motheye structures that we will consider. This structure is characterized by six parameters, including the top width of the upper motheye layer w_1 , the top width of the lower motheye layer W_1 , the bottom width of the upper motheye layer w_2 , the bottom width of the lower motheye layer W_2 , the height of the upper motheye layer h , and the height of the bottom motheye layer H . The parameters of the lower motheye layer are equal to the experimental values in [3]: $W_1 = 0.3\ \mu\text{m}$, $W_2 = 0.6\ \mu\text{m}$ and $H = 0.55\ \mu\text{m}$. The parameters of the upper motheye layer w_1 , w_2 and w_3 vary over the range, $0.03 - 0.3\ \mu\text{m}$, $0.03 - 0.3\ \mu\text{m}$, and $0.5 - 3.5\ \mu\text{m}$, respectively. The widths w_1 and w_2 are geometrically constrained by W_1 , while the lower bound of h is designed to maintain a high transmission at infrared wavelengths.

Fig. 2 shows the transmission spectra in which we vary w_1 , w_2 and h independently. We first vary w_1 from $0.03\ \mu\text{m}$ to $0.3\ \mu\text{m}$ and fix $w_2 = 0.3\ \mu\text{m}$ and $h = 3.5\ \mu\text{m}$. The transmission at visible light wavelengths increases when w_1 decreases. Next, we vary w_2 from $0.03\ \mu\text{m}$ to $0.3\ \mu\text{m}$ while fixing $w_1 = 0.03\ \mu\text{m}$ and $h = 3.5\ \mu\text{m}$. The transmission spectra with $w_2 = 0.03\ \mu\text{m}$ is smaller than that in other cases by about 4% because most of the transmission incident light directly interacts with the lower layer. However, this structure can still achieve a broad bandwidth transmission spectrum. Finally we vary h from $0.5\ \mu\text{m}$ to $3.5\ \mu\text{m}$ and fix $w_1 = 0.03\ \mu\text{m}$ and $w_2 = 0.3\ \mu\text{m}$. The transmission at the wavelengths from $0.5\ \mu\text{m}$ to $5\ \mu\text{m}$ increase as h increases. By calculating the mean transmission over wavelengths

between $0.5 - 5 \mu\text{m}$, we find that the upper layer motheye structure with $w_1 = 0.03 \mu\text{m}$, $w_2 = 0.3 \mu\text{m}$, $h = 3.5 \mu\text{m}$ has an average transmission of 0.9896.

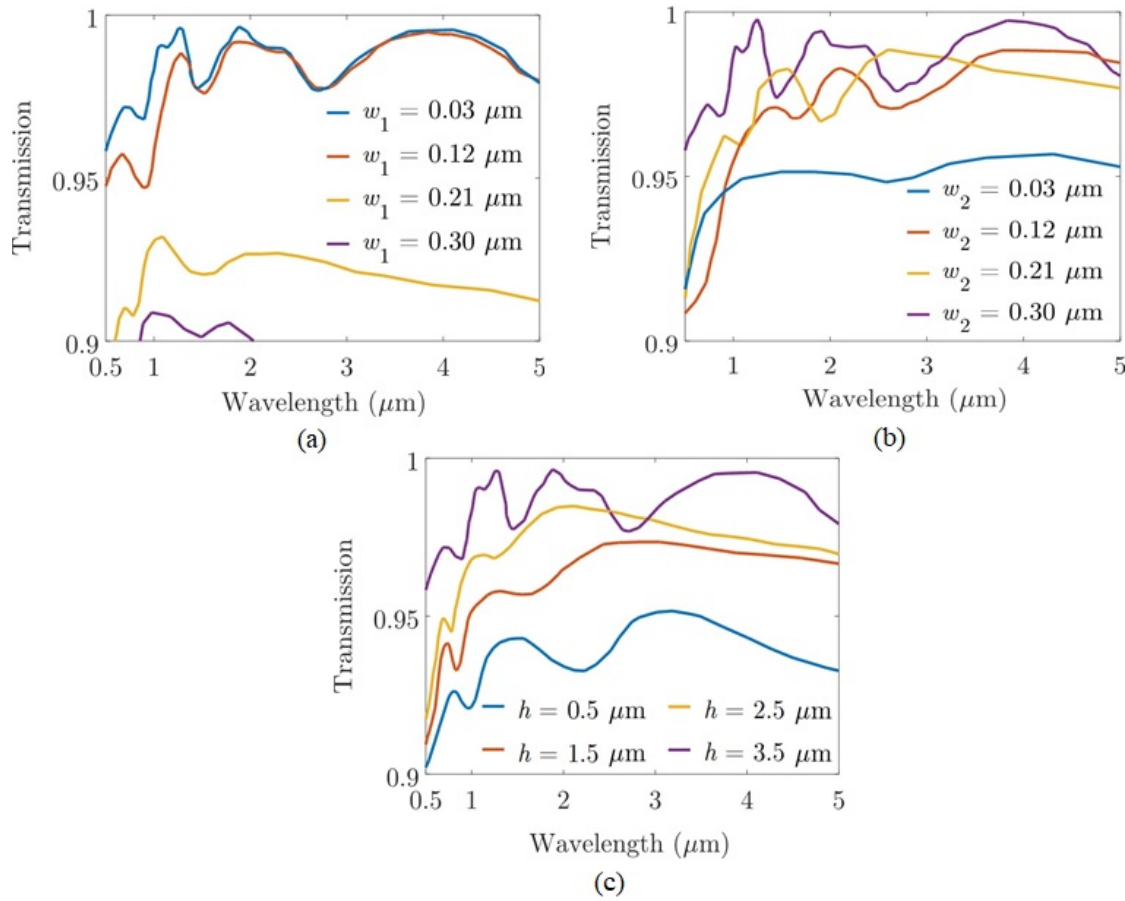


Fig. 2. The transmission spectra varying different parameters: (a) $h = 0.28 \mu\text{m}$, $w_2 = 0.3 \mu\text{m}$; w_1 varies from $0.03 \mu\text{m}$ to $0.3 \mu\text{m}$, (b) $h = 0.28 \mu\text{m}$, $w_1 = 0.03 \mu\text{m}$; w_2 varies from $0.03 \mu\text{m}$ to $0.3 \mu\text{m}$, (c) $w_1 = 0.03 \mu\text{m}$, $w_2 = 0.28 \mu\text{m}$; h varies from $0.5 \mu\text{m}$ to $3.5 \mu\text{m}$.

3. Conclusion

We studied two-layer pyramid motheye structures for transmission in the range $0.5 - 5 \mu\text{m}$. We varied the dimensions of the motheye structures, and we showed that we could theoretically achieve almost 99% transmission over the entire range $0.5 - 5 \mu\text{m}$. Our results demonstrated that high transmission in this entire wavelength range can be obtained by adding a second motheye layer.

References

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