Optimized Ultrabroadband Absorbing Multilayer Thin Film Structure

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Abstract: We design an optimized aperiodic multilayer thin film structure with ultra-broadband absorption over a broad angular range. Using a hybrid optimization algorithm, we achieve an average 97.9% absorption from 400 nm to 2500 nm.

OCIS codes: (350.4238) Nanophotonics and photonic crystals; (260.0260) Physical optics.

1. Introduction

Highly absorbing structures have applications in diverse areas of optics such as power harvesting, thermal emission, optical sensing, imaging, and others [1-3]. An ultrabroadband absorber covering both the visible and near-infrared wavelength ranges could be particularly useful for solar or thermal applications. By leveraging a hybrid optimization algorithm that is able to optimize structural dimensions and material composition, we design multilayer thin-film absorbers effective over an ultrabroadband wavelength range with broad angular dependence.

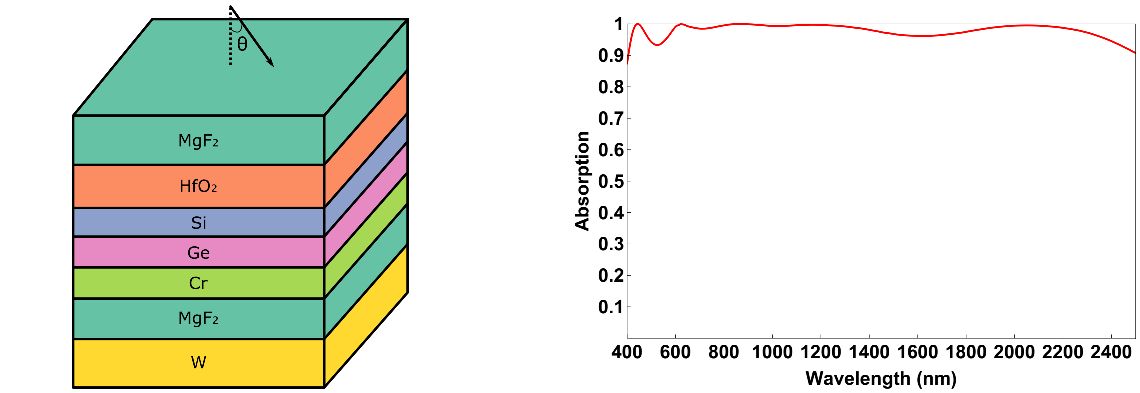
2. Design

We design the structures by extending our previously developed hybrid optimization algorithm [4-6] to be able to optimize both the geometrical dimensions of the structures as well as their material composition. Given a set of candidate materials, the algorithm first considers the material composition. Structures with stochastically chosen dimensions and materials are simulated using the transfer-matrix method. The best resulting absorbers then have their dimensions optimized using a hybrid genetic algorithm and local search method again coupled to the transfer-matrix method. As an example, by considering 15 possible materials—5 lossless dielectrics, 5 lossy dielectrics, and 5 metals—with 7 layers of at most 300 nm each, we obtain an ultrabroadband absorbing structure that uses thick lossless layers followed by thin absorbing layers and a thick metal layer at the bottom.

3. Results

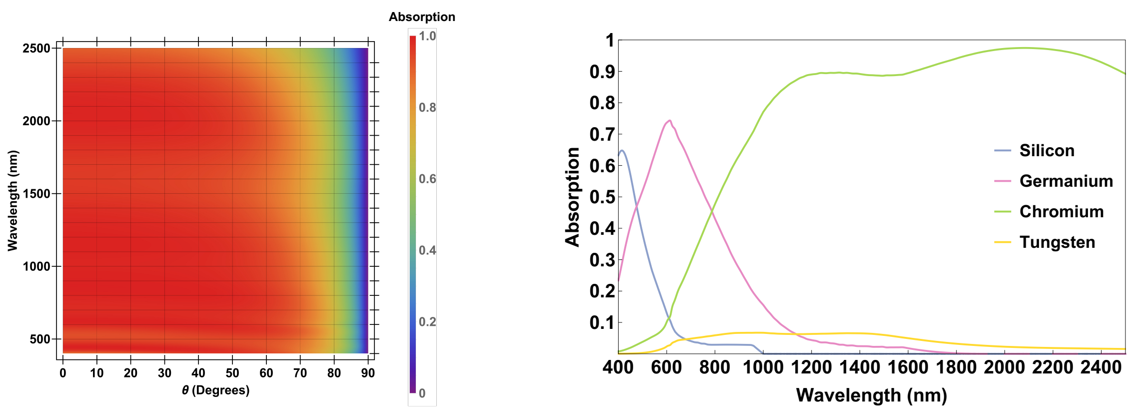
The resulting structure (Fig. 1a) has the following dimensions: 132 nm MgF_2, 60 nm HfO_2, 37 nm Si, 31 nm Ge, 29 nm Cr, 114 nm MgF_2, 190 nm W. Note that the tungsten layer is thick enough so that there is no transmission through it in the entire wavelength range of interest.

We find that the optimized structure has an average absorption (Fig. 1b) of 97.9% over the wavelength range of 400 nm to 2500 nm for normally incident light. We also find that the absorption does not decrease significantly up to an incident angle of 60° from normal (Fig. 2a). Further, we see that the different layers of absorbing material contribute to the absorption of the structure in different bands of the spectrum: the silicon layer absorbs mostly over the visible, the chromium layer absorbs mostly over the near-infrared, while absorption in the germanium layer peaks at $\sim$600 nm (Fig. 2b).



(a) (b)

Fig. 1: (a) Schematic of the ultrabroadband absorbing structure (132 nm MgF_2, 60 nm HfO_2, 37 nm Si, 31 nm Ge, 29 nm Cr, 114 nm MgF_2, and 190 nm W). (b) Absorption spectra of the structure in (a) for normally incident light.



(a) (b)

Fig. 2: (a) Absorption as a function of wavelength and angle of the structure in Fig. 1(a). (b) Absorption as a function of wavelength in each layer of the structure in Fig. 1(a). Note that absorption in the MgF_2 and HfO_2 layers is negligible.

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