Three-Dimensional Metallic Photonic Crystal

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Abstract:
We report experimental demonstration of a 4-layer modified-woodpile three-dimensional metallic photonic crystal with a large photonic bandgap extending from visible wavelength to infrared. This sample also shows a new kind of passband mode in the bandgap as recently predicted by theory.

Summary:
Photonic crystals have generated a lot of interest in these couple decades due to their unique optical properties and potential applications. A three-dimensional (3D) photonic crystal made by dielectric materials, showing a complete bandgap in infrared region, has been realized. To have large-bandgap 3D photonic crystals, instead of using dielectric material, metallic materials have been proposed to be used. Indeed, a tungsten 3D photonic crystal has been demonstrated and shows a large bandgap from far infrared down to near infrared. However, a 3D photonic crystal with complete bandgap in visible region has so far been elusive due to the technological challenges in fabrication. Here, we report a realization of 3D metallic woodpile-like structure that exhibits a bandgap from near infrared down to visible wavelength. In addition, as predicted by theory [1], this structure shows a passband mode in the bandgap, opening up possibilities of applications.

In principle, the sample is fabricated layer-by-layer by using electron beam (e-beam) lithography. Figure 1 shows a cross-sectional scanning electron microscopy (SEM) image of the first layer done by e-beam lithography, metal deposition, and liftoff. The Au-rod width is 100 nm, the pitch is 300 nm, and the thickness of rod is 85 nm. After finishing the first layer, the spin-on HSQ was spun-coated on this grating structure as a spacer layer between the adjacent layers. Repeating these processes, a 5 mm × 5 mm 4-layer woodpile-like structure is fabricated in this report.

Figure 2 shows a reflection spectrum of this 4-layer modified-woodpile structure taken by FTIR spectroscopy. This sample shows very high reflectance (> 90%) from visible to near infrared as well as sharp bandedge in visible (650 nm). In addition, a narrow passband mode, the dip at ~1.4 µm, is also observed as recently predicted by theory due to adding the spacer layer between two metallic gratings.

In summary, we realize a high quality woodpile-like photonic crystal with bandedge down to visible region. This sample also shows a unique passband mode in the bandgap, opening up the potential application.

References:

Figure 1: A cross sectional SEM image of the first layer of sample.
Figure 2: A reflection spectrum of a 4-layer woodpile-like photonic crystal.