Metamaterial Design For Ideal Solar Absorber Using Multiscale Simulations On COMSOL Multi-physics

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Abstract

The renewable energy sector faces challenges in production processes due to geo-economic, and environmental issues. This had led to an increased interest in the use of solar energy as an alternative to fossil fuel based energy sources. In the solar energy field, significant research attention is being given to the processes of collection and storage, either in the form of heat or by direct conversion to electricity. The most important part of solar collectors is the solar selective coatings, which directly affect the efficiency of the system. The ideal solar absorbers totally absorb the electromagnetic radiation over the visible range and totally reflect radiation below infrared and most importantly to be thermally and chemically stable at extreme operating temperatures. This work proposes a new metamaterial (MTM) nanostructure design for efficient solar cell absorbers. The MTM absorber model consists of layers of nano-engineered dielectric topped bianisotropic omega resonators, and a ground metal layer at the bottom. COMSOL wave optic simulation studies on the proposed design to show a wideband with very high absorption response in the visible frequency region of the solar spectrum. The proposed MTM absorber design is an outstanding candidate for high temperature, concentrated solar power cells.
To account for the physics phenomena and key design parameters, we used COMSOL Multi-Physics software to model the interaction of electromagnetic waves with nanostructure resonators. We used the wave-optics module with frequency dispersive materials models.
We will present the numerical model of the solar absorber layer that has been set up in COMSOL Multi-Physics. We studied the reflection and transmission spectrum in optical range of a unit representative cell that consists of Silver omega resonator over a composite dielectric in figure1. The Nano-Omega resonator has an arm's length of 200nm, a loop's radius of 200nm, a gap of 25nm and the dielectric thickness is 200nm. The material parameters of the dielectric composite were numerically modelled using a homogenisation technique by retrieving the refractive index from the S-parameters calculated over a unit-cell that consists of Aluminium Nitride (AlN) as a matrix and a 20nm spherical inclusion of Titanium Nitride (TiN) with a volume fraction of 20%. The simulation results in figure 2 show the characteristics of the sought optical filter which makes the MTM a good choice for building the full stack of the ideal solar absorber.

Figures used in the abstract

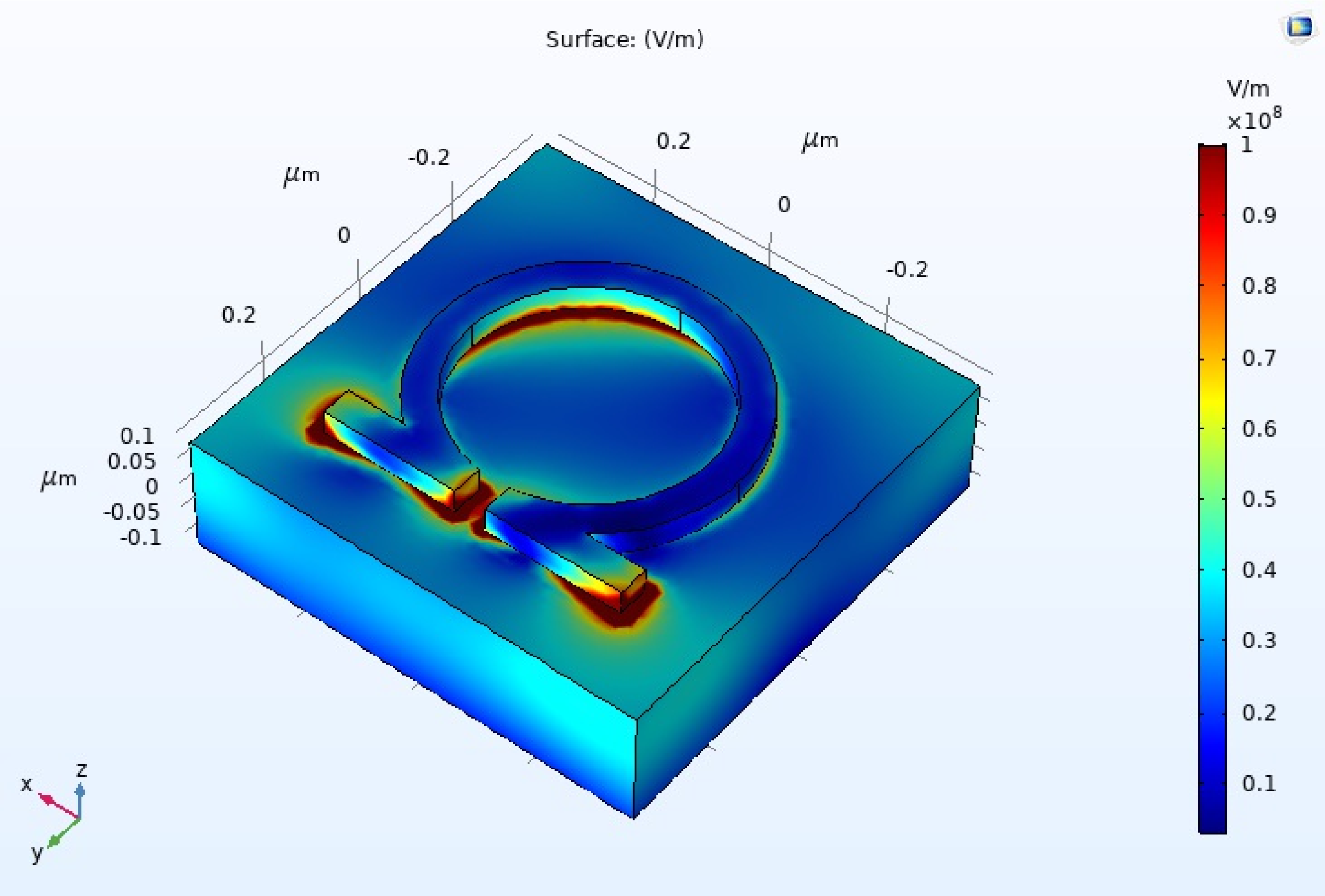

Figure 1 : Figure 1 Contours of electric field norm on unite representative cell of MTM

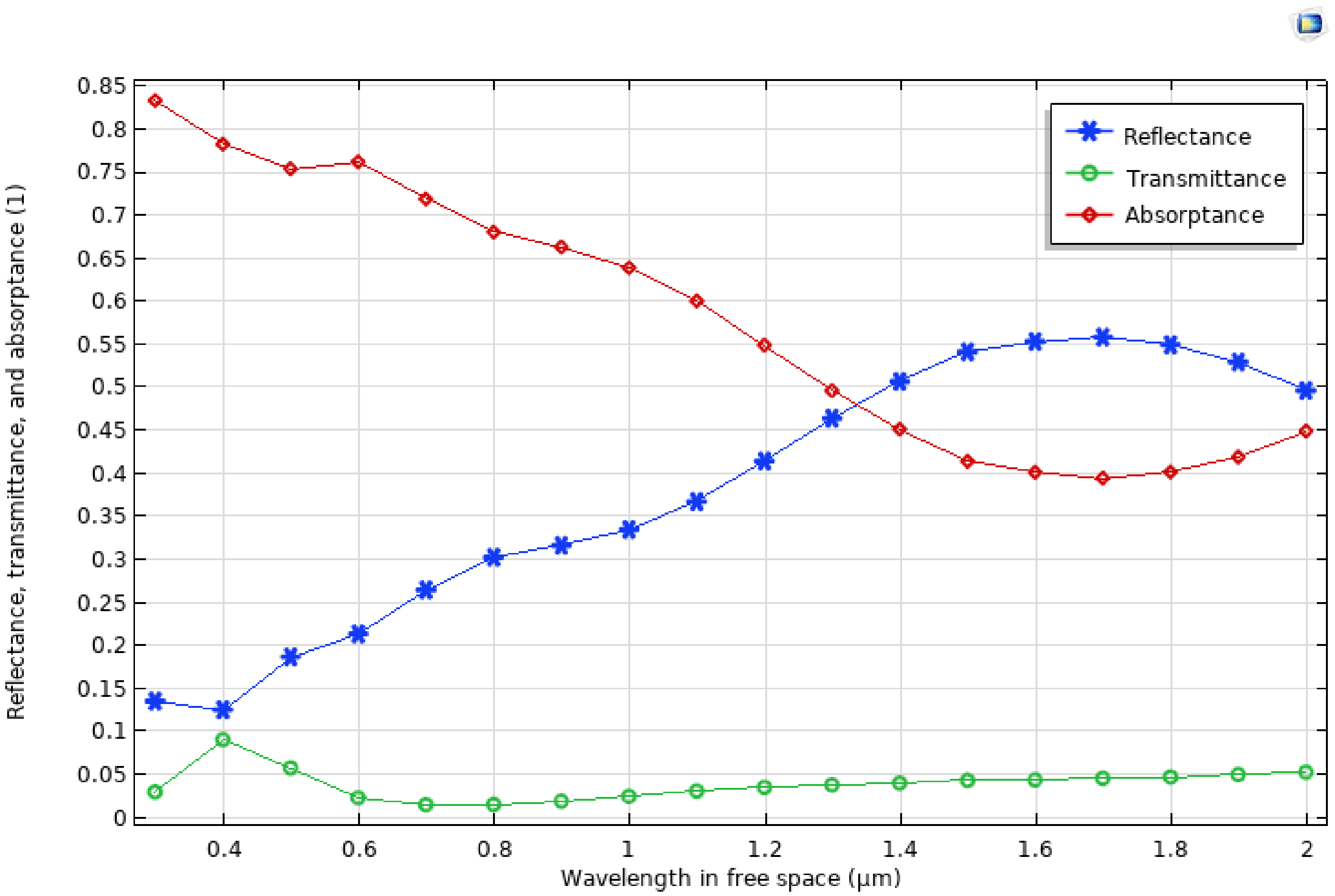

Figure 2 : Figure 2 Simulated absorption characteristics of the MTM nanostructure