Depression of plasma frequency in 1D metallic-dielectric photonic crystals

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It is known that the plasma frequency of metals lies usually in the ultraviolet region. However, it has been shown by Pendry et al. [1] that a periodic structure built of metallic thin wires exhibits novel electromagnetic properties, similar to those of a bulk metal. Moreover, the effective plasma frequency of this periodic structure could be depressed into the far infrared or GHz region. Incorporated with periodically arranged metallic split rings, a metamaterial with simultaneously negative permittivity and permeability in a certain range of microwave frequencies, so-called left-handed or negative refractive index materials, can be constructed, which has some unusual features.

In this work, photonic band structures of 1D metallic-dielectric photonic crystals (MDPCs) are studied theoretically. We show that a 1D MDPC can be considered as an effective metallic medium with a well-defined effective plasma frequency. This effective plasma frequency is found to be inversely proportional to the optical thickness of the dielectric layer and is independent of either the constituent metal or the thickness of the metallic layer. By increasing the optical thickness of the dielectric layer the effective plasma frequency of a 1D MDPC can be depressed into extremely low frequencies such as far infrared or even below.

[1] J. B. Pendry, *et al*., Phys. Rev. Lett. **76**, 4773 (1996).