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Analysis of reflected frequency band of metamaterial grating at THz frequency: A future application of filter

Sanjay Kumar Sahu[a], Sudhakar Sahu[b], C.S. Mishra[a], G. Palai[a,*]

[a] Gandhi Institute for Technological Advancement (GITA), Bhubaneswar, India
[b] KIIT University Bhubaneswar, Bhubaneswar, India

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ABSTRACT

This paper introduces a theoretical study on metamaterial grating to realize 100% reflected band at THz frequency. Different types of grating such as polyethylene, teflon, silicon nitrate, Bakelite and Copper structure are cogitated in this investigation. Simulation results revealed that reflected signal from grating structure depends on both material properties and structural parameters. Present studies divulges that both lower band frequency, higher band frequency and reflected frequency band width decreases with increase of thickness of grating structure. Aside this it is also revealed that similar type of variation is found between afore mentioned frequencies (lower, higher and bandwidth) with respect to thickness of grating structure. However the path of variation is differed for different SNG and DNG structure of metameterials.

1. Introduction:

Metamaterial is a novel man made material which shows exotic properties over ordinary material. This material assumed to be homogeneous at microscopic scale with negative permittivity and permeability. Due this abnormal property, a peculiar characteristic is observed as phase and group velocity oriented in opposite direction [1]. This phenomena having negative refractive index is treated as left handed material. This left handed properties was first conceptualised by Vaselago but later on verified experimentally by Pendry and Smith [2,3]. The application of metamaterial depends on the interaction between material and electromagnetic radiant. The electromagnetic wave covering THz frequencies interacting with metamaterial is known as photonic metamaterial. The material employed a periodic cellular structure, is also called optical metamaterial. Basically, photonic metamaterial deals with sub-wavelength electromagnetic waves, which shows different behaviour as compared to conventional material. The sub-wavelength periodically distinguishes photonic metamaterial from photonic crystal structure [4]. In other word, periodic structure is larger than the atom but much smaller than radiated wave length. Photonic metamaterial exhibit various applications at different frequencies [5–7]. Though, different types of applications have been realised using metamaterials, this paper deals with filtering application explicitly, using metamaterial grating structure. Most of materials in nature are coming under DPS (double positive) i.e. both μ and ε are positive. But the material having only ε negative is called ENG material whereas, with only ε positive are said to be MNG material. Both ENG and MNG materials are referred to as SNG material. On the contrary of both μ and ε negative, the material is categorised as DNG material [8–10].

This paper is organised as follows: Section 2 elaborates structure of metamaterial grating, simulation result and interpretation is presented in Section 3. Finally conclusion is presented in Section 4.

2. Structure analysis

As far as structural analysis of grating is concern, here we have considered metamaterial grating having alternate layers of PS (positive) and NG (negative) materials. The schematic diagram for the same is shown in Fig. 1.

In Fig. 1, positive materials are chosen in odd layer where as negative material are considered in even layer. As far as negative material in even layer is concerned, here we have cogitated both SNG and DNG material at second and fourth position. So simulation for both SNG and DNG are carried out using analytical technique. As far as the structure parameter of the above grating is concerned, here we varied both refractive indices of the material and thickness of the grating layers. Here different layers of grating materials

* Corresponding author. Tel.: +91 9439045946.
E-mail addresses: gpalai28@gmail.com, g_pallai@yahoo.co.uk (G. Palai).

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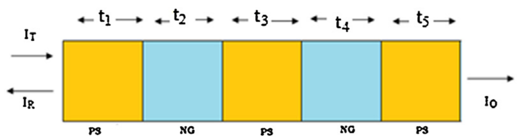

Fig. 1. Matamaterial grating structure.

such as Bakelite, Polyethylene, Teflon, Silicon Nitrate and Copper are considered. Again, considering the operational principle, here electromagnetic radiation covering THz frequency range incident on grating structure. The electromagnetic wave having certain frequency is reflected from it. The above principle is same for both SNG and DNG grating structure. The focus of this paper is to realize filtering application using both SNG and DNG structure. To envisage this, here we investigate lower and higher reflected band including width of reflected band of the electromagnetic waves corresponds to different thickness of the grating structure. The analysis for reflected band is lucidly explained in next section.

3. Simulation result & interpretation

To realize filtering application using SNG and DNG grating structure we made simulation to obtain refection with respect to frequencies that varies up to 80 THz. To obtain such reflectance, we set different structure parameter such as refractive indices and thickness of grating layers. Here thickness of grating layer is differed for different grating structure. Aside this, this paper considered both SNG and DNG at even layer where odd layers are positive. The reason for choosing such type of parameter and structure is that this paper searches for 100% reflected band corresponds to certain frequency range. So we have considered different types of material such as polyethylene, Bakelite, Teflon, Silicon nitrate and Copper to envisage 100% reflected band. Though simulation is done for SNG and DNG of all materials, result for Bakelite grating structure is shown in Fig. 2(a) and (b), respectively.

Fig. 2(a) and (b) represents the variation of reflection for Bakelite SNG and DNG structure with respect to THz frequency. In this figure reflection (Arbi unit) is taken along vertical axis where as frequency in THz is taken along horizontal axis. Also lower band, higher band and bandwidth frequencies are shown by putting arrow marks. It is also seen that reflection is one (100%) corresponding to certain range of frequencies. So from Fig. 2(a), it is found that lower frequency is 3.855 THz and higher frequency is 79.72 THz. After finding this frequency we computed bandwidth with taking difference between higher bands to lower band, resulting 75.855 THz. Using similar technique, we calculated lower band, higher band and bandwidth of DNG Bakelite(from Fig. 2(b)) which is found to be 3.34 THz, 79.91 THz and 76.57 THz, respectively. Apart from these results we also made simulation for other grating structure with respect to thickness (0.5 nm, 1.5 nm, 2 nm, 2.5 nm, 3 nm, 4 nm, 4.5 nm, 5 nm, 15 nm, 25 nm, 35 nm, 45 nm, 50 nm, 100 nm) of above SNG and DNG grating structures. From those figures we found lower band frequency, higher frequency and frequency band of all grating structures. Using these results a graph is plotted for SNG Bakelite grating and DNG Bakelite grating, which is shown in Fig. 3(a) and (b).

Fig. 3(a) and (b) represents the variation of lower frequency, higher frequency and frequency band width for SNG and DNG Bakelite grating structure, respectively. From these figures, it is seen that lower and higher frequency band in THz is taken along vertical axis, where thickness of grating in nm is taken along horizontal axis. Aside this, the inset figure in this graphs are represented as variation of reflected bandwidth with respect to same thickness. As far as result is concerned, it is observed from Fig. 3(a) that lower band frequency decreases from 3.8665 THz to 1 THz and higher

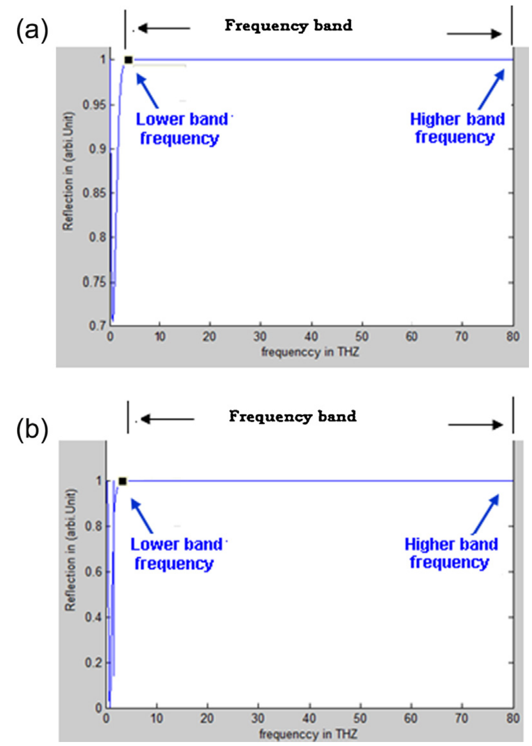

Fig. 2. (a) Variation of reflectance of SNG Bakelite grating structure with respect to frequency. (b) Variation of reflectance of DNG Bakelite grating structures with respect to frequency.

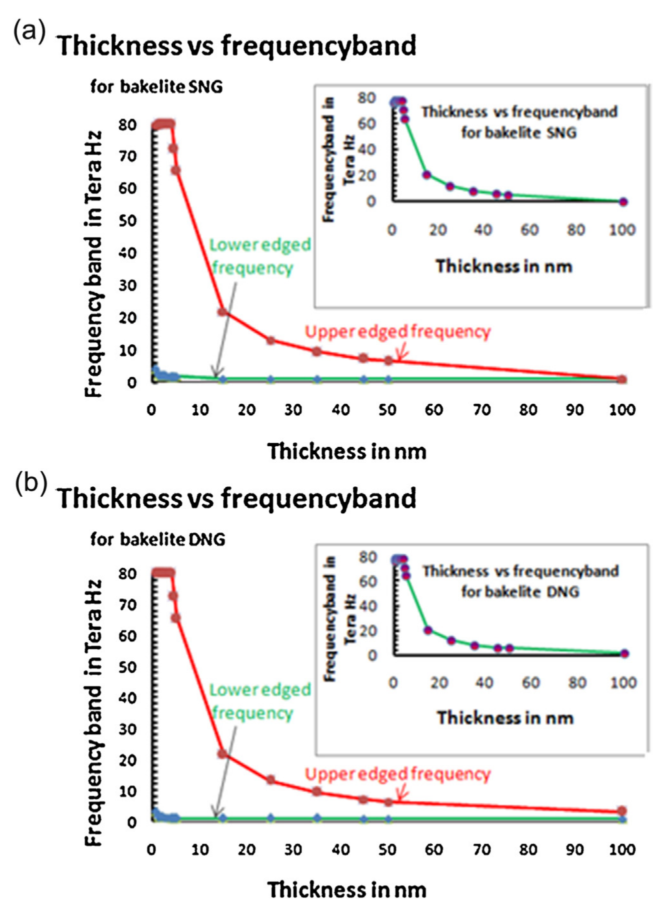

Fig. 3. (a) Variation of lower reflected band, Higher reflected band and reflected bandwidth SNG Bakelite grating structure. (b) Variation of lower reflected band, Higher reflected band and bandwidth DNG Bakelite grating structure.