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Chapter 6
Conclusion

In this chapter, the overall conclusion of the research work done as a part of this thesis is summarized. The importance of our findings for broadband absorbance, short circuit current density, and solar energy harvesting applications is also highlighted. The future scope and future work to be carried out are also discussed in this chapter.

Chapter 6: Conclusion

6.1 Summary

This thesis describes, simulates, and quantitatively characterizes a variety of innovative metamaterial perfect absorber (absorption over 99%) designs. In this thesis, the amazing qualities of metamaterial were discussed, and it was backed up by a wide range of uses that were made possible by the development of metamaterial. There has been much research on metamaterial absorbers in practically all regions of the solar spectrum, although the visible frequency range has received very little attention. Most of the literature on metamaterial absorbers now in use describes single- and double-band absorbers. Additionally, there haven't been many efforts put into using the higher frequencies (visible and near-infrared). As a result, at resonance frequencies in the visible region of the solar spectrum, the metamaterial absorbers in the structure suggested in this thesis offer a wide-band absorption response. The proposed metamaterial absorber designs were polarisation angle insensitive because of their symmetry.

In this thesis, a tunable metamaterial perfect absorber structure for solar cell application was also suggested to increase the absorbance from visible and visible to near-infrared regions. All the structures delivered an absorption of more than 99% in the visible spectrum. This metamaterial absorber structure's tunability was made possible by varying the thickness of its dielectric spacer. This thesis' primary goal—discussed in every chapter—was to create a wide-band perfect metamaterial absorber that operated in the solar spectrum's visible region. The proposed wide-band metamaterial was composed of different types of resonators to generate electromagnetic resonance for each resonator. These resonances generate a broad band absorption in the visible frequency range with almost perfect absorption resonance (over 90%). As well as exhibiting wide-band resonance, the suggested metamaterial absorber also displayed significant geometrical flexibility, which was supported by its polarization angle independence.

Chapter 2 discusses the three-layer (Al-GaAs-Al) structure. In order to enhance the absorption bandwidth of the proposed metamaterial modified absorber design, aluminum was employed on the proposed structure and it was observed that the absorption bandwidth of the proposed metamaterial absorber unit cell is significantly improved. Aluminum is easily available in the market and it is also much cheaper than other metals. Keeping this in mind, we thought of creating a metamaterial structure that can be used for solar energy harvesting by absorbing maximum light in the visible region. Therefore, this structure provides good absorption with wide bandwidth in the visible region. This chapter also discusses polarization insensitive, incident angle, and other important parameters which can be helpful for solar energy harvesting applications.

In chapter 3, we have taken tungsten metal with silicon dioxide content, which covers the full visible region with nearly unity absorption as compared to the previous chapter. The impedance matching condition is very important to get the correct absorption which we have discussed in this chapter. We have checked the absorption performance with different geometry parameters, polarization angles, and incidence angles and the results show very good absorption at each geometry parameter. This chapter also enumerates other important investigation results that may be useful for solar cell applications.

To obtain greater absorption in the visible region, we have taken tungsten metal with various dielectric materials. The result is that tungsten-based structures achieve absorption in the visible regions as well as some in the infrared regions. The primary factor in the selection of tungsten as a metal and resonator layer, despite its significant intrinsic losses, is its perfect impedance match with free space in the optical domain. With a low ohmic loss, tungsten is also an excellent absorber by itself. However, tungsten is frequently a good metal for metamaterial absorbers in the optical wavelength area due to its high-temperature stability (3422 ^{o}C). As a result, the metamaterial structure provides broad absorption with wide incident angles. Finally, we have calculated the short circuit current density for solar cell application along with the conversion efficiency.

In Chapter 4, we have considered tungsten metal with gallium arsenide dielectric material, which has achieved better absorption than in the previous chapters, exhibiting nearly unity absorption in the visible to near-infrared regions. In this chapter, the absorption performance with a variety of metallic and dielectric materials is investigated. The results indicate very good absorption at each geometry parameter after testing the absorption performance with various geometry parameters, polarisation angles, and incidence angles. This chapter also lists additional important research findings that can be applied to absorption-based applications in optoelectronics.

There are many structures proposed by the researchers which are made of three-layer, four-layer, and multilayer but these structures show weak absorption which we explained in chapter 5. Therefore, the materials used in these are not only expensive but due to the multi-layered structure, these structures become very expensive. So in order to reduce the material costs we have selected a two-layered structure that is made of tungsten metal and gallium arsenide material. The split disk resonator of the gallium arsenide structure provides broadband absorption in the visible region and covers some parts of the infrared region. Various geometry parameters, polarisation angles, and incidence angles were used to test the absorption performance, and the findings indicate very good absorption for each geometry parameter.

6.2 Future Scope of the study

This thesis performed a numerical examination of various metamaterial absorber designs. However, efficiency evaluation of the created metamaterial absorber models, incorporation of the created models into solar cells for use in real-world applications, and experimental characterizations should be carried out as further study.