Metasurface based far infrared solar absorber

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***Abstract*— Metasurface based broadband solar absorber made up of gold and silver using square and rectangular resonators is proposed. This design is first analyzed by the geometrical parameters to study the solar absorption characteristics in the of infrared and visible frequency range of 150THz to 500THz. Results are analyzed in terms of reflectance, transmittance and absorption characteristics and electric field distribution is shown. The proposed design provides high and broadband absorption which can be used as solar absorber of sun irradiance spectrum in solar cell.**

Keywords— Graphene, Metasurface, Far infrared, Tunable

I. INTRODUCTION

Optical materials are mostly used due to its potential application in the field of photonics.[1].Electromagnetic properties of material can be characterized to obtain desired property by engineering material. Different electromagnetic absorber can be designed for Microwave [2], terahertz [3] and visible [4] frequency ranges. Plazmonic metamaterial based on Au/SiO_2 Nano composites is presented [5] which has broadband absorber characteristics in the visible range. Metamaterial absorber for visible frequency using four split-ring resonator is designed and high absorption is achieved for TE and TM polarization due to coupling between gold and GaAs[6]. Metasurface broadband solar absorber is analyzed for infrared and visible solar spectrum of 350THz to 700THz range. It is designed using genetic algorithm to reduce unit cell area and increase the bandwidth of absorption [7].

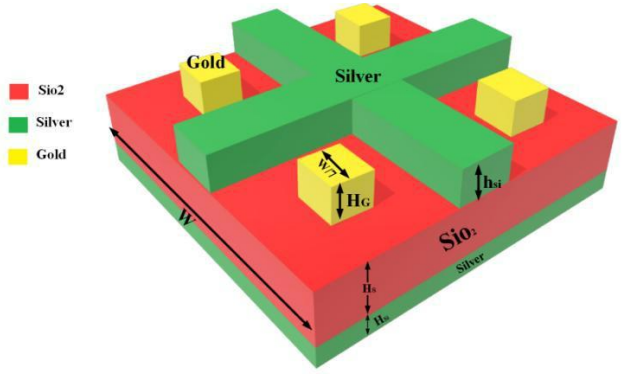

Fig. 1: Schematic of three dimensional square and rectangular shape metasurface based solar absorber structure. Substrate layer of structure set as silica material. Metasurface dimensions (nm): W = 1000, H_S = 100, H_{Si} = 50, H_G = 100 and W_G= W/7

Gold nanorods with cross-shaped metasurface based design provides enhanced multiband absorption over the entire solar spectrum[8].Mathematical analysis of metamterial solar absorbers provide an insite of 80-90% absorption of solar spectrum can be achieved with the good efficiency . Recently, many researchers have designed the graphene based different metamaterial designs for increasing efficiency[9].In this paper, we proposed metasurface based solar absorber design with square and rectangular gold and silver resonator and it is analyzed in terms of reflectance absorption and transmittance electric filed characteristics. The metasurface broadband circular gold resonator has got very enhanced result at frequency 155THz to 428THz and also extended to visible range also[11]. Also grapheme based solar absorber has achived maximum effiency upto 85% is achieved by changing the chemical potential at 0.85eV[13] The absorber is analyzed by changing the parameters and result are shown for 150THz to 500THz. The paper is described as follows. Design and modeling of the schematic that is followed by result, discussion and conclusion part.

II. DESIGN AND MODELLING

The proposed design shown in fig.1 that represent three dimensional schematic. Which has the structure composed of square and rectangular gold and silver resonator. Also ground plate of silver separated by SiO_2 substrate. The refractive index of SiO_2, gold and silver are considered to be frequency dependent and taken from the tabular data [10]. The height of square and rectangular gold and silver respectively resonator is H_G and h_{si}. Width and length of substrate and groundplate is W. The results are obtained by the proposed schematic through the finite element method based (FEM) numerical using simulations using COMSOL Multiphysics.

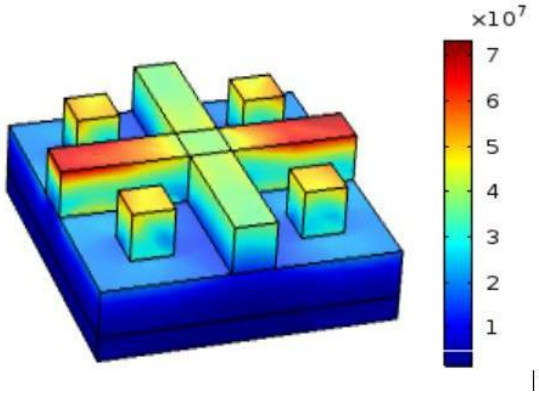

Fig. 2: Electric filed diagram of the absorber at 425 THz for the geometrical parameter W=700 nm, HS=100 nm, his=50 nm, HG=100 nm, WG=w/7. Unit of electric field is V/m

The Absorption (A), Transmittance (T) and Reflectance(R) is given by, A=1-R-T. Where R and T can be defined in terms of reflection coefficient (S_{11}) and transmittance coefficient (S_{21}) as $R=|S_{11}|^2$ and $T=|S_{21}|^2$.

III. RESULT AND DISCUSSION

The result of design shows in terms of absorption, reflectance and transmittance. The first result is obtained by keeping parameters W=1000 nm, HS=100 nm, his=100 nm, Hsi=50 nm, H_G=100 nm W_G = w/7. Result indicates that as frequency increases from 150THz to 500 THz reflectance and transmittance decreases and absorption increases. In the range of 400THz to 500 THz there is maximum absorption up to 95.76% is achieved. The infterfernce theory explains that explains that destructive interefearnce caused by multiple reflections and wave overlap between the two metal layers trap light in the absorber strucutre can be explained in terms of high aborption into the proposed strucutre theory.[12]

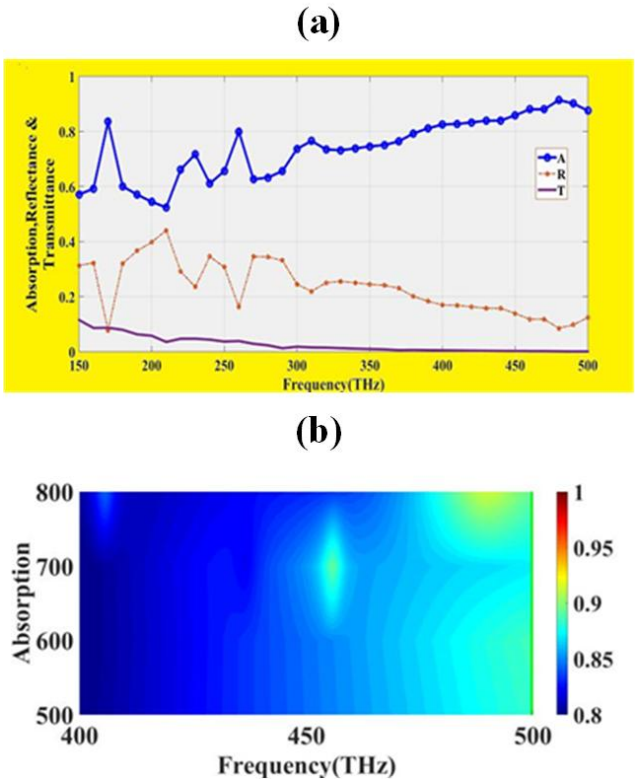

Fig. 3: (a) Reflectance, absorption and transmittance response for geometric parameters of the design as H_S=100 nm, Hsi = 50 nm, H_G=100 nm W_G=w/7 and W = 1000 nm. (b) Absorption plot of absorber for different geometrical parameters verses frequency

IV. CONCLUSION

Metasurface based broadband solar absorber is presented in terms of reflectance, absorption and transmittance and electric field characteristics. The proposed design showed high absorption characteristics and it is analyzed in the infrared region from 150 THz to 500THz. Absorption increased by changing parameters like gold and silver resonator size. Absorption increases upto 90 to 95% in the frequency range of 400THz to 500THz. Futher analysis is done with changing the geometrical parameters. The proposed designed has potential application in the filed of solar cell.

V. REFERENCES

[1]. Cai, V. Shalaev, Optical Metamaterials, Springer New York, New York, NY, 2010. doi:10.1007/978-1-4419-1151-3.

[2]. X. Shen, T.J. Cui, J. Zhao, H.F. Ma, W.X. Jiang, H. Li, Polarization-independent wide-angle triple-band metamaterial absorber, Opt. Express. 19 (2011) 9401. doi:10.1364/OE.19.009401.

[3]. B.X. Wang, Quad-band terahertz metamaterial absorber based on the combining of the dipole and quadrupole resonances of two SRRs, IEEE J. Sel. Top. Quantum Electron. 23 (2017). doi:10.1109/JSTQE.2016.2547325.

[4]. X. Duan, S. Chen, W. Liu, H. Cheng, Z. Li, J. Tian, Polarization-insensitive and wide-angle broadband nearly perfect absorber by tunable planar metamaterials in the visible regime, J. Opt. (United Kingdom). 16 (2014) 125107. doi:10.1088/2040-8978/16/12/125107.

[5]. M.K. Hedayati, M V.S.K. Chakravadhanula, V. Zaporojtchenko, T. Strunkus, F. Faupel, M. Elbahri, Design of a perfect black absorber at visible frequencies using plasmonic metamaterials, Adv. Mater. 23 (2011) 5410–5414. doi:10.1002/adma.201102646.. Javaherirahim, B. Mozooni, R. Abdelaziz, A. Tavassolizadeh

[6]. H.L. Huang, H. Xia, Z.B. Guo, D. Xie, H.J. Li, Design of Broadband Metamaterial Absorbers for Permittivity Sensitivity and Solar Cell Application, Chinese Phys. Lett. 34 (2017). doi:10.1088/0256-307X/34/11/117801.

[7]. M.H. Heidari, S.H. Sedighy, Broadband wide-angle polarization-insensitive metasurface solar absorber, J. Opt. Soc. Am. A. 35 (2018) 522. doi:10.1364/JOSAA.35.000522.

[8]. A.D. Khan, A.D. Khan, S.D. Khan, M. Noman, Light absorption enhancement in tri-layered composite metasurface absorber for solar cell applications, Opt. Mater. (Amst). 84 (2018) 195–198. doi:10.1016/j.optmat.2018.07.009.

[9]. J. Li, Y. Chen, Y. Liu, Mathematical simulation of metamaterial solar cells, Adv. Appl. Math. Mech. 3 (2011) 702–715. doi:10.4208/aamm.11-m1109.

[10]. Smith, D. Y., Shiles, E., Inokuti, M., & Palik, E. D. (1985). Handbook of optical constants of solids. Handbook of Optical Constants of Solids, 1, 369-406.

[11]. D. Katrodiya, C. Jani, V. Sorathiya, and S. K. Patel, "Metasurface based broadband solar absorber," *Opt. Mater. (Amst).*, vol. 89, pp. 34–41, Mar. 2019.

[12]. Chen, H. T. (2012). Interference theory of metamaterial perfect absorbers. *Optics express*, *20*(7), 7165-7172.

[13]. Dave, V., Sorathiya, V., Guo, T., & Patel, S. K. (2018). Graphene based tunable broadband far-infrared absorber. *Superlattices and Microstructures*, *124*, 113-120.