Utilization Of Different Metamaterial Types For Solar Absorbers

Victor Du John H, Jackuline Moni D

Abstract: Natural materials are a mixture of individual atoms and molecules that are combined into a chemical bonding mechanism. The major three phenomena like absorption, reflection and transmission of the material are obtained by the hitting of sunlight i.e. electromagnetic radiation. If the material is accepting some light then it is called as absorption, if the material is not absorbing some portion of light then it is called as reflection, and finally some portion of light neither accepted nor reflected then it is called as transmission. All these are depends on the atomic characteristics of the material. This new idea shall be used as the periodic structures for the design of solar cells. This review tells about the various parametric study, materials used and different sizes of the unit cells obtained by various authors.

Index Terms: Metamaterials, SRR, SIR, CCRR, Wavelength, Solar spectrum, Dielectric.

1. INTRODUCTION

The wavelength of the Sun lies mainly between 300 nm and 3000 nm, which imply that the frequency is between 100 and 1000 THz by referring the figure 1 [1]. The working of usual solar cells operates when the light photons reach the solar panel and are absorbed by a semiconductor like silicon. Electrons are knocked loose from their atoms, letting them flow through the material to produce electricity. The electrons are moving in one direction, due to the specific composition of the solar cells. Because of this the solar cell converts Solar Power. Metamaterials are artificial materials which significantly manipulated from the incident electromagnetic waves. Metamaterials (MTM's) interesting characteristics are accomplished by the skill of its geometry, orientation, shape and size instead of its chemical composition. Metamaterials are a wide class of microstructures or nanostructures consisting of tailored construction blocks, which were implemented about decade ago. These types of sub wavelength construction blocks can be packed tightly into an efficient material which allows the synthesis of novel and odd property materials. Some of the odd properties are magnetically formed optical frequency, negative and positive refractive indices, zero reflection and perfect absorption, etc. The material properties like Negative permittivity ε and permeability μ was discussed by Veselago in 1967 he theoretically explored the propagation of plane-wave in a medium of both μ and ε which are not applicable for the conventional materials. The chromatic dispersion naturally relies on the electrical permittivity and magnet permeability of the materials it travels through. To investigate the unusual conduct of materials with simultaneous effects of μ and ε he proposed some hypothesis like assuming the material's characteristics stay unchanged irrespective of concurrent change of electrical permittivity signs and magnetic permeability. Assuming that the presence of materials containing adverse μ and ε could contrast with nature of physics. Also if there is an immediate existence of μ and ε there may be a change in original properties from positive properties.

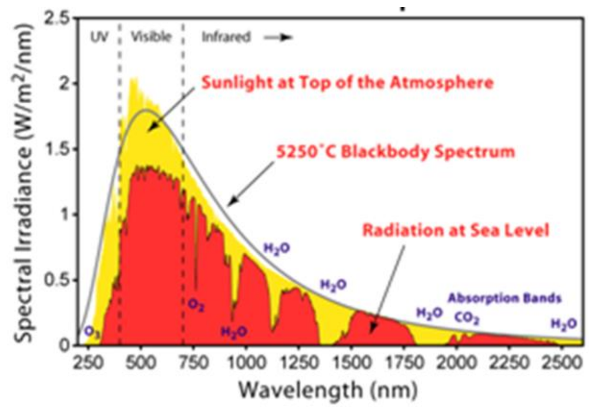

***Fig. 1**. Solar Spectrum Google images [1]*

launched in 1968 by Veselago who expected that such a medium exists in which the electrical field, E, magnetic field, H, and wave vector, k, form a left-hand orthogonal set [3]. (LHMs), also called negative index (NIMs), have simultaneous negative (μ), (ε) and (n) over a prevalent frequency range. Electrical permittivity and magnetic permeability usually play a fundamental role in the spread of electromagnetic waves in a medium because of the only presence of these parameters in the following equations [4]

$$K^2 = \varepsilon\mu n^2 \quad (1)$$

Where k is wave number and ω is frequency of electromagnetic field. This equation (1) shall be re written as

$$n = \sqrt{\varepsilon\mu} \text{ (2)} \quad (2)$$

$$\frac{k}{\omega} = n \quad (3)$$

From these equations it is clearly known that the sign does not have any impact in the material properties. The material parameters of (μ), (ε) of all possible media shall be described in the figure 2 Four types of substances are theoretically considered according to the values of ε and μ the four quadrant contains all the possible combinations of (μ) and (ε) were place in the figure. In the 1st quadrant the (μ) and (ε)

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values are kept positive and are known to be as conventional transparent materials. In the 2nd quadrant the negative (ε) value which have the direction of magnetic field are known to be as plasma materials. The negative (μ) values which have the resonance area were known to be ferromagnetic materials. And in the 4th quadrant both the (μ) and (ε) values are kept negative which propagates backward direction and this is known to be as left handed material suitable for metamaterials [4].

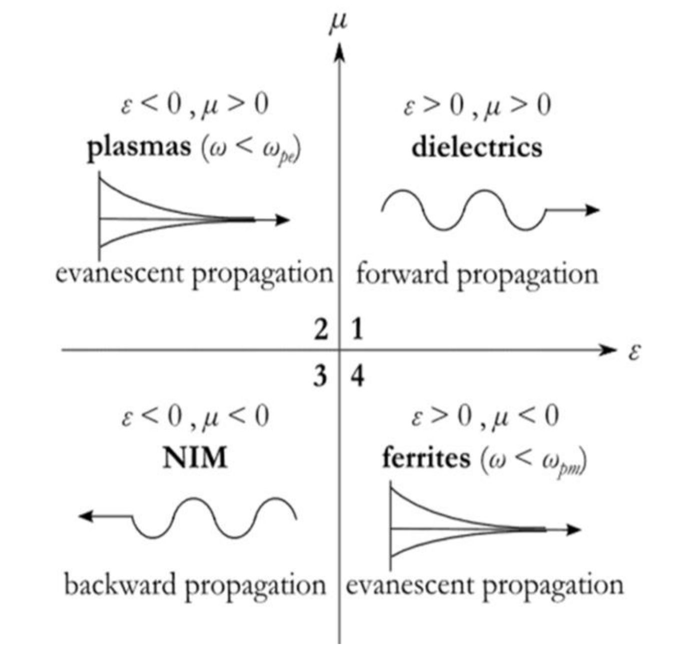

Fig. 2. *μ & ε parameter categorization [1]*

The field vectors E and D do not necessarily parallel each other in an anisotropic medium where the permittivity must therefore be a tensor, not a scalar value. Most metamaterials usually contain an anisotropic and highly dispersive characteristic that is why the frequency and direction under consideration should always be indicated when addressing effective metamaterial parameters. Considering the equation 2, ε is dielectric permittivity and μ is magnetic permeability. The material refractive index (n), being based on the μ and ε of the material, allows a material with simultaneously negative permittivity permeability to have a negative refractive index. Electric and magnetic reactions are described by dielectric permittivity and magnetic permeability in isotropic media when interacting with standard material atoms, light stays one handed. However, artificial materials can enable both light field components to be linked to metamaterial atoms, allowing for exciting new properties. The vectors E, H and k are a right-handed triplet in μ &ε> 0, and when μ &ε< 0, the vectors E, H and k form a left-handed set. From this one can understands that the left-handed substances are clearly negative group speed substances which occur in special dispersion.

3 LITERATURE SURVEY

Furkan Dincer et.al [5] tells about a new type of Metamaterial absorber is designed, characterized and analyzed for better absorption rate in the visible range and infrared range. Since solar energy is non-polluting, the value is increasing day by day. So, the usage of solar energy is improving with high demand. When the usage is increasing, it is needed to be taken efficiently. A new type of metamaterial absorber is designed for reducing the inefficiency of the solar cell. Metamaterial structures are not natural, so it can be designed and manufactured according to the application and need. To achieve perfect absorption, the reflection and transmission waves can be minimized with the rate of absorption of solar radiation. The reflection coefficient R(ω) and transmission coefficient T(ω) can be defined as follows:

$$R(\omega) = \frac{Powerreflectedfromport\ 1}{Powerincidentonport\ 1} \quad (4)$$

$$T(\omega) = \frac{Powerdeliveredtoport\ 2}{Powerincidentonport\ 1} \quad (5)$$

This designed structure consists of a resonator having a square shape with gapes in the unit cell in the microwave range. The dimensions of the unit cell are varying concerning the regions like visible, infrared and microwave. A silver sheet is used in the top and bottom substrate, which has very low resistivity for infrared and visible ranges and copper is used for microwave range. The designed absorber has a simple structure and it gives better absorption rate in the microwave range and even in higher frequencies. For all resonances, the simulated and absorption values are close to unity. The proposed structure is simulated based on the finite integration method. The independency in polarization angle is also well demonstrated in all range of frequencies. The electric field distribution and surface current distribution is also obtained for the regions like microwave, infrared and visible. With this advantage, it can be used for many applications like satellite communication, medical imaging, some Wi-Fi devices, etc. Joachim Muller et.al [6] tells about the cost reduction of the photovoltaic cells is important since it is widely used in many sectors. One of the ways to reduce the investment is by reducing the thickness of the solar cell. Thin-film solar cells are used to improve the efficiency factor, to make increment in the incoming light path. The path length of the incoming light will determine the device performance. This paper is more concentrating on the efficient method to trap the maximum amount of light. For getting the better scheme to trap the incoming light, an oxide called Transparent Conductive Oxides (TCO) are used as a front contact, which is transparent in solar cells like silicon p-i-n. With the magnetron spluttering method, applying aluminium doped zinc oxide got more concentration and followed up with more chemical steps. The transparent conductive oxide (TCO) is used as a layer in the electrode, which is in the front and also in areas of reflector in the backside. This TCO can improve the properties of optics and also able to act as a barrier of diffusion. So these kinds of oxides will play a major role to improve the path length of the oncoming lights. The chemically etched and sputtered films of ZnO are classy to study the different properties of TCO in the performance of the device. With this, it is possible to conclude that, the thin-film solar cells are more efficient and cost-effective when the absorber thickness got reduced and improves the efficiency in light trapping. Yu.A. Akimov et.al [7] tells about the recent studies within the swiftly emerging area of plasmonics has proven the capability to noticeably decorate light trapping inside thin-film sun cells with the aid of the usage of steel nanoparticles. The plasmonic improvement of optical absorption by silver nanoparticles in amorphous silicon solar is illustrated in this newsletter. On the basis that the surface plasmon methods are evaluated, it has been shown by a great deal how spatial locations of surface plasmons influence the plasmonic improvement of thin-film sun cells. Through predictive 3-d modeling, we check the effect on the improvement of higher order methods. Finally, we propose the optimization by optimizing the parameters of the nanoparticles array which can be applied to the corresponding surface plasma modes in flip music. The plasmonic effects of silver nanoparticles deposited on the pinnacle surface of the thin film hydrogenated sun cell have been studied. It has been shown that the power transmitted to the amorphous silicon layer, as well as lower optical absorption, in large nano particles surface plasmon resonances, can be increased through the excitation of higher order plasmon Resonances. The overall optical absorption in the photo-energetic coating can then be advanced extensity. The effects of the nanoparticle matrix parameters on effectiveness and the relative improvement of optical absorption in the cellular have been studied based on the numerical complete-wave response, on the efficacy of better-order plasmon ground mode coupling. This can lead to the brand new age of green and reasonably priced plasmon cells, too, if the nanoparticles array parameters are properly adjusted and the better order plasmonic mode is taken into account. Hai-Long Huang et.al [8] tells about a solar unit cell is designed with an absorber, which is ultra-thin. The usage of applications related to energy harvesting is increasing day by day. So it is necessary to design a solar cell with good absorber, to get more absorption rate. This proposed design is having four layers. The top layer is the gallium arsenide (GaAs), and four resonators which are ring-shaped are encrusted in the top conducting layer. This proposed design is providing a perfect absorption in a range of frequencies. The metal gold and the material gallium arsenide are having an effect of coupling in between them. The total thickness of the proposed design is very thin. The mechanism and features of the absorber are explained with the electric area and floor current distribution. Because of the effective electromagnetic resonance, the amount of energy used in the metamaterial absorber ensures a good absorption level and wider bandwidth. The ultra-thin absorber based on hybrid substances in the top conducting layer is proposed in the region of visibility. The coupling effect between gold and gallium arsenide is providing a high absorption rate and better bandwidth. The analysis based on the current distribution and electric field gives more details about the waves like TE and TM. And more important is that this design can be used as a sensor for valuing the permittivity factor. Since this proposed design is giving a better absorption rate and bandwidth, it is perfect for solar cell applications. Mohammad Jakir Hossain et.al [9] discussed solar power collection is a significant method and must be more effective and absorbed at a large pace. The fresh high-fractional bandwidth (HFB) perfect metamaterial absorber (PMA) is examined and verified for the collection of thermal intensity. The FDTD approach is a completely CST simulator used to maintain the model and absorbance parameters. The FDTD approach is a CST simulator. In methods that include conventional electric motorized (TE) and coil magnet (TM), the constructed PMA can reach very elevated absorption height. Moreover, during these frequency phases the structural absorption changes have provided a brand new type of sensor bundles. The advised metamaterial absorber therefore offers optimal absorption for visible frequency phases and can be used for renewable apps in solar energy processing. Each year the energy consumption in the global energy can be achieved by means of electromagnetic radiation within one hour. The supplies of PMA consist of two layers of stack that can be Al (Aluminum) separated by the GaAs (Arsenide-Gallium) layer in the form of a dielectric Gallium arsenide (GAA) substrate. The GaAs fabric is used because of the many critical housing that make it insensitive to warmth and temperature, including unnecessary saturated electron speed, elevated electron mobility and a large band holder. An elevated FBW hexagonal PMA has been transformed into a study project that has numerical effects on solar energy absorption and detecting qualities. The supplied form became extremely basic and showed significant uptake in the seen frequency spectrum with increased FBW. The separate PMA variable is of first rate performance and spherical harmony is the absorption estimate. The structure of the metamaterial is now miniature in the measurement and absorbance of the cohesion, which makes it perfect for collecting solar power, sensors and Wi-Fi. Hailong Huang et.al [10] investigated theoretically and numerically in areas near-infrared (NIR) is examined the theoretically and digitally about the size-efficient tunable metamaterial absorber (MA) made up of mobile metallic leaf, graphene layer, silicone substrate, and the bottom metal film. By using multiple dimensional parameters of the apex glass coating in same spectral fields the single-band can truly be turned into dual-band elevated intake. And it is also examined in order to optimize the effect of this geometric parameter on double-band absorption intensities. By increasing the electricity of Fermi's Graphene Layer, the high wavelength can be adjusted by regulating the outer gate voltage. The work indicates that the proposed strategy may be carried out to different layout of the dual-band shape at infrared areas. Due to a specific electromagnetic (EM) home, which could be missing in traditional materials, metamaterial absorbers (MAs) have become a study hotspot. The suggested design in this document is a MA tunable relying on almost near infra-red (NIR) graphene, the portable device is made up by a sheet-formed steel, a graphene coating and a silicone substratum and a metal rear end. It has four parts: leaves, graphic coating, silicon and silver base film. It contains four parts. The dielectric spacer is silicon of eleven performance. The metal is selected for gold (Au) purposes. In genuine apps, the method suggested is simple and fee-efficient. In addition, the intensity of dual-band absorption is significantly undermined by the associated geometrical parameter of silver shaped upper leaves. The tunability of MA is determined by regulating the external gate voltage by changing the power of the graph of Fermi level. Daniela Ionescu et.al [11] found the energy reductions through transformation power to heat have been experiments with semiconductors in the solar cell metamaterials within stainless metal. The effectiveness of the solar energy transformation can be increased by choosing correct combos of drugs and an orientated geometry. For fabric inspection, the radiation domain of NIR-to-UV ultraviolet radiation was regarded. Metamaterials and their unique properties offer the possibility to obtain new functionalities for unique applications, like solar photovoltaic, diffraction-limitless imaging, optical analog simulators, very low profile antennas, phantasm optics, and many others. We intend to produce an appearing and controlled metamaterial absorber to boost the performance of the instruments using a metamaterial for solar cells. To reduce the reflected picture, boost the density and boost the wireless intake, the cover must be designed for solar panels. Performance enhancement of the solar cells can be achieved with the use of appropriate absorber synthesis materials. An analysis is carried out of a new form of the metamaterial, with a special distribution of the inner (neural type) semiconductor segments. The wide maximum for absorbance, transformed by using overlaying the man or woman maxima, guarantees bigger broadband of absorption. Dan Li et.al [12] found the terahertz fields it is suggested to have a temperature-structured tunable absorber metamaterial (MA) relying mainly on titanium strontium (STO). The MO consists of a three-layer structure consisting of the SPRs, the silicon substratum and the metallic layer of the floor. The miles of absorption of MA can be achieved by transferring vanadium oxygen (VO2) conductivity to ambient temperature. In certain regions the suggested MA can be used for sensors, light modulators and terahertz absorbers. The precise electromagnetic (EM) properties are evident in artificial sub wave length materials, which can be termed metamaterial absorber (MAs), along with bad permittivity, permeability, and poor refractive index. The first sheet is a double SRR metasurface coating, which is created using traditional raising methods. Small strontium titanate (STO) panels (6 μm/10μm) on the SiO2 surface are placed with the SRR-patterned STO gadgets via the elevation-off, then SRR metal panels are placed on bottom of the STO plates. The second coating is the SiO2 dielectric substratum which is of t=10 μm in size and μ= 3.9 in relation to comparative allow ability. This 0.33 coating is a base stainless metal movie, positioned under the dielectric coating. The metal is bronze (Au) with a density of 0.1 μm and a conductivity of 4 μm. The absorption strength at the resonant coefficient is, along with this tunability, flexibly different when the rear steel film is changed to a VO2 part transfer cloth. A method of spinning the upper SRR coating is suggested to produce elevated concentration in two-band, without extra resonators or complex manufacturing processes in order to solve the failure to absorb single band. Contemporary ground measurements and the L-C equivalent loop model are used in the interpretation of the absorption processes. B. Mullaet.al [14] found the combination of fresh, perfect metamaterials is intended and tested for use in portable sun utility depending entirely on metallic-dielectric coating. In specific, the constructed design is provided to efficiently use solar power in the sun spectrum range. Parametric study is done to indicate the absorber with an appreciation for the magnitude of the construct. This metamaterial absorber is suitable for visual and near-infrarot frequency phases and can be used to achieve more sustainable solar cells. The framework comprises of a thick aluminum sheet that avoids propagation through the framework at the highest. The transmission is blocked because the height of the wave length is higher than the thickness of the skin. Due to the dielectric sheet Gallium arsenide screen (GaAs) is placed on the aluminum plate apex. Aluminum sheets are integrated in the GaAs tray to avoid reflection. The entire structure's width is less than the wavelength. The mutual oscillations of autonomous electrodes at the metal and dielectric layer border result in the absorption, considered to acquire pleasant absorption within the optical place. Electric discipline and surface cutting-edge distributions are also reported. The shape has been simulated underneath distinctive polarization and incident angles. So this design is giving more efficient solar cell. Hu Tao et.al [15] tells the basis for the building of most contemporary optoelectronic devices concerning the electromagnetic reaction of artificial products bureaucracy. This EM reaction, however, is not dispensed calmly across the thermal spectrum. Electrons are the main objects that operate as the working horses of machines at frequencies of a few hundred gigahertz and reduce. On the contrary, the photon is the essential part of choice infrared through optical / UV wavelengths. There is no relatively cloth-free proximity between these two basic reaction schemes, the "terahertz gap" is usually known (zero.1-10THz, ć=3 mm-30 μ m). Although a great deal of job has been done to search for "terahertz" materials and new methods for building system additives. Although a great deal of effort has already been made. It is possible to test a wide variety of medicinal events with Terahertz (THz) instruments. In particular, an imagery-related THz detector in biology and safety fields would be useful. Patrick Rufangura et.al [16] tells an absorber relying entirely on a concentrated loop resonator (MTM) of the wideband metamaterial is discussed at visible frequencies. The suggested design provides a broadband intake response, in which the wavelength range from 537 is absorbed by more than 70 times. Hz 91 to 635.73. This analyzes the components of the proposed form are carried out to determine the starting point of broadband absorption. Furthermore, a graphene monolayer sheet is incorporated to the proposed MTM absorber to optimize its absorptivity, in which the studies show enhancement of the absorptivity of the proposed shape as much as 26% from its preliminary absorptivity. MTM absorbers of this type have potential programs in solar cells. A graphene-based mainly broadband MTMA was suggested in this examination and distinguished. Almost ideal 99.9% output has altered into resonant and resonance ranges, and the broad-band response was verified by an intake reward > 70%, which is earned for the rate of 537. THz 91 to 635.73. The components of the proposed MTMA unit cell were monitored in order to recognize their beginning and broadband absorption, and the end outcome of strong EM resonance, that stands out from the solid connection of the structure's resonator with a dielectric spacer and a metal surface of the ground, has been recognized. Since the main objective of this observation was to apply a graph sheet to boost structural absorption, the calculated effects show that the integration of a graph monolayer into the proposed MTMA unit cell improves its absorbent bandwidth to 26% without the use of graph. Patrick Rufanguraet.al [17] proposed Layout metamaterial absorber for the use of a streamlined and symmetrical framework for collecting solar electricity. A moving unit of this design consists in three vital layers, in concrete terms, of the smallest gold loss metal layer, the intermediate layer: a loss dielectric fabric made of gallium arsenide and patches made of the gold / gallium arsenide aggregation. The three main parts are structured carefully at the bottom of a dielectric spacer. The triangular form was screened for its input to intake. Because the suggested form is exquisitely symmetrical, its absorption capacity shows polarization insensitive. There are three fundamental levels of the suggested model. The back of the tray is a metal sheet, the medium part is a dielectric base, and the pinnacles are made up of three parts accountable for the EM resonance. Every layer of metal is bronze (Au) lossy, while Gallium Arsenide (GaAs) is produced of a dielectric spacer. The proposal is made and cited for the perfect metamaterial absorber depending on metal cap resonators. The structure's frequency response provides two absorption levels that are almost the highest. The geometric parameters of the suggested design are defined and discussed for the effect of the suggested PMA on absorption, where strong mobility and a greater ability for two-band absorption can be demonstrated in the presentation. The design under study. Effect corners and polarization levels of sensation of the polarised TM and TE radiation were also assessed at absorption features of the suggested PMA form at various incident angles for EM radiation. Patrick Rufanguraet.al [18] found Photovoltaic (PV) solar cell effectiveness has been one of the key challenges preventing its global implementation as a sustainable replacement for fossil-based mainly technological gas. The mainly sun cell derived metamaterial (MTM) allows for a more proximate increase of the device efficiency by improving the complete emitted solar radiation occurrences of this tool. The suggested design is simple and additionally bendy for scaling, making absorption easier. The implementation of the intended MTM framework can contribute to more effective photovoltaic solar cells effectively. The design is a powerful structure. The system is based on a gold plate for null transmission. The structure's lower part. The dielectric material is chosen to be a loss of arsenide gallium (GaAs). A cylindrical ceramic (bronze) coating with a dielectric product (GaAs) may be applied as a resonator on bottom of the substratum. At the pinnacle of the cylindrical metallic gold layer is a tumbler layer (Pyrex). The glass layer on the pinnacle is selected due to its capacity to transmit better seen mild and to resist warmth enlargement. The gold steel is chosen.A fresh MTM double band absorber has been intended and its efficiency assessed to optimize resonant frequency intake. The designed MTM absorber offers two absorption peaks with nearly solidarity absorption which can be insensitive to each TE and TM polarization angles. The proposed MTM absorber shape will cause cognizance of high efficiency solar cells and other gadgets working within the high EM frequency range with incident perspective and polarization attitude independencies.

TABLE 1

COMPARISON OF VARIOUS MTMS

Parameters	[1]	[4]	[5]	[6]	[7]	[8]	[9]	[11]	[13]
MTM	Silver	Gold	Al	Graphene	STO	Gold	Al	Graphene	Gold
Absorption rate %	99	97	99.6	91.6	99	99	99.99	537.9	543
Frequency THz	540	520	523.8	120nm(wavelength)	1.23	0.5	403	99	99
Cell Size nm	1200 x 1200	520 x 520	320 x 320	320 x 320	100 x100	150 x 150	420 x 420	530 x 530	520 x 520
Band	Wide band	Broad band	Dual	Dual	Dual	Single	Single	Broad	Dual
Resonator type	SRR	SRR	Hexagonal	square	SRR	SRR	SRR	CCRR	Cylindrical

CONCLUSION

The investigation has been carried out throughout this study from several papers and it has been identified that the MTM based solar cells are now coming to the industry for obtaining best efficiency. Here the metamaterials are acting as an absorber layer in the solar cell design. Also the some semiconductor materials like GaAs and silicon and the top conducting layer like Silver and gold are providing more absorption. The SIR, SRR, Circular and Hexagonal based MTM absorbers are also giving more impact on the absorption factor. The size of the investigated papers are lying under 400nm to 550nm range which makes the optimized size of the unit cell.

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