International Journal of Research Publication and Reviews, Vol 4, no 5, pp 4074-4077, May 2023

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

METAMATERIALS

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ABSTRACT —

A family of engineered materials known as metamaterials is created to have unusual and exotic qualities not found in natural materials. They are made up of structures that have been created artificially and are capable of extraordinary manipulations of mechanical, acoustic, and electromagnetic waves. Numerous industries, including optics, communications, energy harvesting, sensing, and cloaking, have found use for metamaterials. This abstract gives a quick rundown of metamaterials, their characteristics, and prospective uses. Additionally, it emphasises the field's current research directions and difficulties, including scalability issues, fabrication methods, and material characterization. Overall, metamaterials research is an interesting and quickly developing discipline that has the potential to revolutionise a wide range of science and technological fields.

I.INTRODUCTION

Unlike naturally existing materials, metamaterials are a class of synthetically created materials with exceptional electromagnetic and acoustic capabilities. They are made by placing subwavelength components in a regular or arbitrary pattern to produce structures with special and frequently peculiar features.The electromagnetic waves, such as light and radio waves, can be manipulated in ways that were previously not conceivable by these materials. There are numerous possible uses for metamaterials, such as better telescope and camera lenses, more effective solar panels, and invisibility cloaks that can bend light around an object to make it appear invisible.Metamaterials are a type of synthetic materials with characteristics not present in natural materials. They are created to have certain mechanical, acoustic, or electromagnetic characteristics that can be used to a number of different things, including cloaking devices, superlenses, and ultrafast switches.In most cases, metamaterials are composed of periodic structures of subwavelength components, such as wires, rods, or resonators, that interact with electromagnetic waves in a particular way. These subwavelength components' size and geometry are carefully planned to obtain the desired attributes. The capacity of metamaterials to bend and manipulate light in ways that are not conceivable with natural materials is one of its key characteristics. In addition to their special mechanical and acoustic characteristics, metamaterials can also have interesting visual characteristics. For instance, they may be made to have a negative mass density, which would cause them to defy any applied forces by moving in the opposite direction. This has effects on the creation of ultrafast sensors and switches.Additionally, metamaterials are being created for cloaking technology, which can render objects invisible to some light wavelengths. By bending light around an item, these devices give the illusion that it is not there. Although it is still at the experimental stage, this technology has a wide range of possible uses, from medical imaging to military stealth technologies. Advances in materials science and nanotechnology have made it possible to create metamaterials. Researchers have been able to develop and create metamaterials with progressively more complex features thanks to the capacity to accurately control the size and shape of subwavelength structures.But there are still a lot of difficulties with the creation of metamaterials. The capacity to produce these materials on a wide scale is one of the primary obstacles. The majority of metamaterials are currently produced utilising time-consuming, expensive methods like electron beam lithography, which restricts their useful uses.Despite these difficulties, metamaterials have a wide range of possible uses, and research in this area is still moving forward quickly. The potential applications of metamaterials are practically limitless, ranging from enhancing communications to creating new medical imaging technologies. For instance, they may be made to have a negative refractive index, allowing them to bend light in the opposite direction from what natural materials can. The development of superlenses, which can give high-resolution imaging beyond the diffraction limit of conventional lenses, may be significantly impacted by this characteristic.

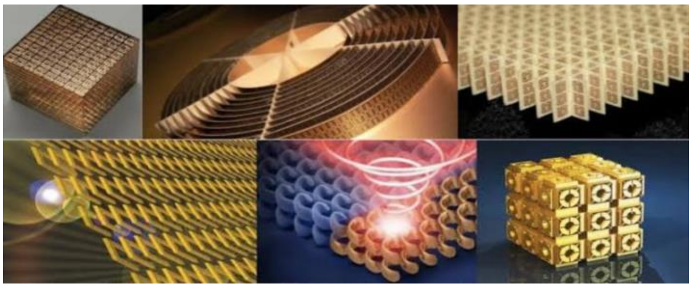

Fig 1: block diagram of Metamaterials

II.WORKING

Metamaterials are substances that have been designed to possess characteristics not present in normal substances. These substances are created to interact in a special way with electromagnetic waves, sound waves, or other forms of waves, which can result in amazing results. Metals, polymers, and ceramics are just a few of the materials that can be used to create metamaterials**.** Metamaterials' distinctive structure, which is made to interact with waves in a specific way, serves as the foundation for how they function. A recurring pattern of sub-wavelength elements, which are ordinarily smaller than the wavelength of the waves the material is intended to interact with, makes up the structure of metamaterials. Typically, a bigger, artificial structure is formed by the arrangement of these sub-wavelength components, allowing for wave interactions that are not feasible with natural materials. For instance, the sub-wavelength components in electromagnetic metamaterials are typically conductive or dielectric structures that are intended to interact with electromagnetic waves in a particular manner. Metamaterials can be made to exhibit special electromagnetic properties, such as negative refractive index, which means that the material can bend light in the opposite way from what it would in natural materials, by modifying the geometry, size, and orientation of these elements. The sub-wavelength elements in acoustic metamaterials are typically tiny structures having predetermined interactions with sound waves. Acoustic metamaterials can be created to regulate the propagation of sound waves by varying the size, shape, and spacing of these structures, which can result in special acoustic features like sound cloaking or sound absorption.
Waves in ways that were not feasible with natural materials can be made using them.

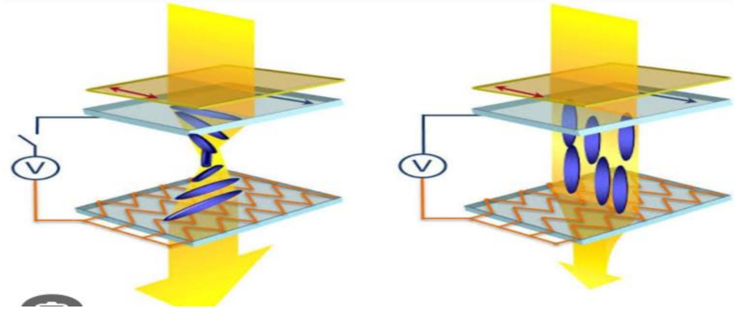

Fig 2: Design of Metamaterials

III. METAMATERIALS TYPES

A. *Electromagnetic Metamaterials*

Materials with a new subfield within electromagnetism and physics are known as electromagnetic metamaterials (EM). Band-pass filters, lenses, microwave couplers, beam steerers, and antenna radomes are just a few examples of optical and microwave applications where EM is used.

B. *Chiral Metamaterials*

Chiral metamaterials are made up of metallic or dielectric planar arrays on a substrate. When a linearly polarised light strikes the array, it interacts with the gammadions with the same handedness as the gammadion itself to become elliptically polarised.

C. *Terahertz Metamaterials*

Terahertz metamaterials, still in research, are a synthesis of synthetic materials that interact at terahertz (THz) frequencies. Passive materials are those metamaterials that can produce the desired magnetic response with negative values of permeability. In order to develop a new response, "tuning" is therefore accomplished by constructing a new material with slightly altered dimensions. Terahertz waves range from the far end of the infrared band to just after the microwave band's beginning.

D. *Photonic Metamaterials*

The category of electromagnetic metamaterials known as optical metamaterials includes photonic metamaterials, which are created to interact with optical frequencies. Optical wavelengths are emitted from the source by photonic metamaterials [14]. Additionally, the photonic metamaterials are distinguished from the photonic band gap structure by the sub wavelength period. This is due to the fact that the optical features originate from an interaction at a subwavelength with the light spectrum rather than from photonic band gaps. The current focus of optical material research is on metamaterials that have zero index of refraction (ZIMs) and negative values for index of refraction (NIMs).

E. *Tunable Metamaterials*

These are the metamaterials that can modify a refractive index's frequency at random. These metamaterials have varied responses to incident electromagnetic waves. This involves the interaction of an incident electromagnetic wave with a metamaterial used for remote control. It is feasible to modify a device while it is in use thanks to the tunable metamaterials' real-time adjustable structure [15]. By adjusting the permittivity of nematic liquid crystal, one may tune in the near infrared range. The tuning range for the metamaterials includes negative, zero, and positive index values. Additionally, negative index values can be made larger or smaller.

F. Nonlinear Metamaterials

Artificial materials with nonlinearity are known as nonlinear metamaterials. This is because the electromagnetic source's macroscopic electric field is less intense than the inclusions' microscopic electric field [15]. The reaction of electromagnetic radiation is described by the material's permeability and permittivity. Additionally, it might be created using a particular kind of nonlinear metamaterial having the ability to modify the power of an incident wave.

IV.TECHNOLGY

- Nanofabrication: To pattern objects on the nanoscale, advanced nanofabrication methods, such as electron beam lithography, are frequently used in the production of metamaterials.
- Composites: To make metamaterials, various materials are frequently combined, such as metal and dielectric, to produce a composite structure with specialised properties.
- Plasmonics: The study of how light interacts with metallic nanoparticles is known as plasmonics. A crucial technology for developing metamaterials with a negative refractive index is plasmonics.
- Electromagnetic simulations: Electromagnetic simulations are frequently used in the design of metamaterials to forecast their behaviour.
- 3D printing: Additive manufacturing methods like 3D printing can be utilised to make sophisticated geometrically precise metamaterial constructions.
- By optimising the material's structure and composition, machine learning techniques can be utilised to create metamaterials with precise qualities.
- In general, a variety of technologies, such as nanofabrication, composites, plasmonics, electromagnetic simulations, 3D printing, and machine learning, are used in the development of metamaterials. As a result of the ongoing development and evolution of these technologies, new and more sophisticated metamaterials with numerous potential uses are being created.
- Computer Vision Algorithms: Gait recognition systems use computer vision algorithms to extract features from the video footage of an individual's walking pattern. These algorithms use various techniques such as edge detection, motion estimation, and pattern recognition to analyze the gait features.
- Machine Learning Algorithms: Machine learning algorithms are often used in gait recognition systems to classify the gait features extracted by the computer vision algorithms. These algorithms can be supervised or unsupervised, and can use techniques such as neural networks, support vector machines, and decision trees.

V. ADVANTAGES

- Metamaterials have peculiar electromagnetic properties that make it possible for them to bend, reflect, or transmit electromagnetic waves in ways that are not conceivable for natural materials. They can be used for a variety of purposes because of this, including cloaking devices, super lenses, and antennas.
- Improved acoustics: Metamaterials' ability to modify sound waves makes them beneficial for noise reduction, soundproofing, and acoustic imaging.
- Many metamaterials are robust and lightweight, which makes them helpful in aerospace and defence applications including the development of improved composites for aeroplanes and spacecraft.
- Metamaterials can be created with tunable properties, which means that they can vary their behaviour in response to outside factors like temperature, light, or magnetic fields. They can be used as sensors and actuators as a result.
- Energy harvesting: Metamaterials can be made to collect energy from a range of sources, including radio waves, sound waves, and sunlight. They can be used in energy-harvesting devices as a result.

V. CONCLUSION

A family of synthetic materials known as metamaterials has special electromagnetic and acoustic characteristics that are not present in natural materials. They are created by designing their structure at the subwavelength scale, enabling the development of materials with peculiar features.Telecommunications, energy, and the medical industry are just a few of the industries that metamaterials have the potential to revolutionise. They have been utilised to make high-performance antennas, cloaking devices, and ultra-thin lenses. Additionally, metamaterials are being investigated for their potential to bend, absorb, and redirect light. If successful, this research could result in improvements in solar power and energy efficiency. Despite the numerous exciting developments in the field of metamaterials, there are still a number of problems that need to be solved. Scaling up production to make these materials more available and affordable is one of the main obstacles. Furthermore, there is still a great deal to learn about how these materials interact with the environment and how to incorporate them into real-world uses.

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