State-of-the-art of Metamaterials

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Abstract

One of the hottest area in recent years is metamaterial. With using assemblies of multiple elements fashioned from composite materials such as metals or plastics.It has novel design concept ,the basis of it's idea is to overcome the limitations of some apparent natural laws by designing on a variety of physical structures in order to obtain extraordinary material functions.The design concept of meta materials shows that people artificially acquire 'new substances' with very different physical properties from those in nature without breaking the basic laws of physics, and bring the design and development of functional materials into a new area. [2]

Introduction

Metamaterial means a kind of material which is created with some , they always made from multiple elements and with typical structures. The concept of metamaterials stems from phenomena and theoretical predictions of the dielectric constant and magnetic permeability of negative electrode materials observed by the Soviet theoretical physicist Fresler. [1]At present, metamaterials are generally defined as artificial composite structures or composite materials having extraordinary physical properties that natural materials do not possess, and are artificial structural materials having special electromagnetic characteristics formed by arranging artificial cell structures in a specific manner.

Typical metamaterials include "left-handed materials", photonic crystals, "supermagnetic materials" and the like. Their precise shape, geometry, size,orientation and arrangement gives them their smart properties capable of manipulating electromagnetic waves: by blocking, absorbing, enhancing ,or bending waves, to achieve benefits that go beyond what is possible with conventional materials.[1]wikipedia-Metamateial

The functioning electromagnetic metamaterials was first reported in 2000,by Smith et al.Microwave frequency metamaterials are usually constructed as arrays of electrically conductive elements that have suitable inductive and capacitive characteristics.

History

The history of metamaterial could be dated back to the World War II, In 1968, Veselago first proposed the concept of "negative refractive index". A flat material with such a negative refractive index property can act like a lens, causing parallel incident rays to converge at a point.

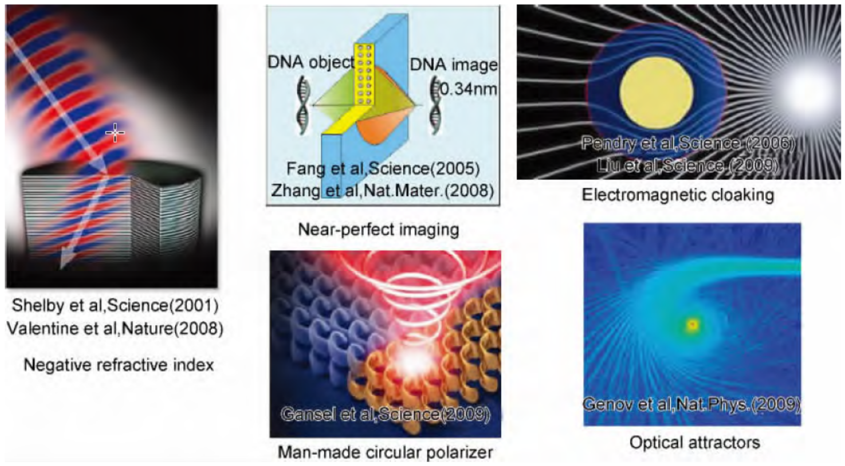

Figure 1: Fig.1 Optical metamaterials show some counterintuitive properties: negative refractive index, hyper-lenses and optical cloaks [12]

With the in-depth research on optical metamaterials, metamaterials have also been extended to the field of excitation of acoustic and other elements, such as acoustic wave metamaterials, mechanical metamaterials, and thermal metamaterials. material.[5] Combining traditional condensed matter material science with various new micro and nano-processing technologies, and targeting the next generation of information and new energy technologies, metamaterials are becoming the frontier of new disciplines in today's micro-structured materials science.

Current performance status

The research and development of metamaterial technology has attracted the attention of governments, academia and industry in developed countries. In 2010, Science magazine used metamaterials as one of 10 important scientific advances in the first decade of this century. The US Department of Defense launched a special research program on metamaterials; six companies including Intel, AMD, and IBM have established joint funds; the European Union and Japan have also established investment plans for research projects. [6]

At present, scientific basic research mainly considers how to integrate existing metamaterials with natural materials to achieve the adjustment of metamaterials in different frequency bands. In view of the novel characteristics of smart metamaterials, it can be widely applied to miniature antennas and wireless interconnects and optical electromagnetic stealth. , medical perfect imaging, smart skin for various vehicles for national defense and civilian use, other precision instrument preparation, and on-chip laboratories, etc.[11][12]

Like natural material design, metamaterials can also start from the basic structural unit, that is, the material gene, and perform accurate calculations and predictions on various physical properties of the material, revealing the relevant laws of the basic parameters of the material and macroscopic physical properties. However, as an emerging cross-application science, the structural design of metamaterials has a great deal of arbitrariness.[14] The diversity of physical processes makes the computational simulation of metamaterials, material preparation, experimental measurement and data accumulation very complicated. A variety of geometric structure forms have been proposed, but due to the failure to systematically compare and generalize, lack of overall collaborative innovation and data sharing, this development model has greatly limited the development of metamaterials to practical applications. [13]

Application

Smart metamaterials have developed at three levels: basic research, key technologies, and new product applications. The basic research of intelligent metamaterials at the scientific research level involves:

> (1) Multiphysics coupling mechanism in metamaterials, ie, the use of multi-physics coupling effects between microstructural elements to achieve the intelligent response of metamaterials; [7]
> (2) New types of artificial Atomic and artificial molecular design, that is, through the construction of new types of functional units to achieve extraordinary response; [11]
> (3) fusion of metamaterials and natural materials, that is, the use of the intelligent nature of natural functional materials and the fusion of hyper-geometric structures in order to achieve the exploration and design of extraordinary phenomena and The discovery of the new mechanism;[8][9]
> (4) Exploration of the metamaterial tunability, that is, based on the variable circuit, geometry, and material properties, changes the thermal, mechanical, and electromagnetic properties of the metamaterial;
> (5) Exploration of a new type of metamaterial, that is, Based on the characteristics of metamaterials such as local enhancement of electromagnetic fields and sensitivity to the surrounding environment, it can be used for the development of label-free bioassays.

The key technologies of intelligent metamaterials include six key directions:

> (1) Intelligent electromagnetic metamaterials, using a micro-structured unit similar to the 0/1 switch property of computers, for non-periodic arrays to achieve programmable controllable response output; [10]
> (2) Intelligent mechanical metamaterials, three-dimensional network of metal solid structure, but similar to the ideal fluid, easy to flow, so as to achieve two-dimensional fluid response performance; [12]
> (3) intelligent thermal metamaterials, external heat source can be perceived, active response of the artificial composite Materials and structures, potentially applied to the thermoelectric conversion of micro-nanostructures;
> (4) Smart-coupled metamaterials, based on photonic circuits, through the sub-wavelength scale artificial structure to achieve local electromagnetic field regulation and displacement vector regulation;
> (5) new design of intelligent metamaterials And simulation technology;
> (6) intelligent metamaterial preparation technology and material genetic engineering.

In new product R&D ,(1) Micro-antennas and wireless interconnects; (2) Optical electromagnetic stealth; (3) Perfect imaging for medical imaging; (4) Intelligent monitoring of aerospace and transportation vehiclesLeather; (5) precision instrument processing and on-chip laboratory-integrated metamaterials. [12]

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