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Current situation and trend of fabrication technologies for three-dimensional metamaterials

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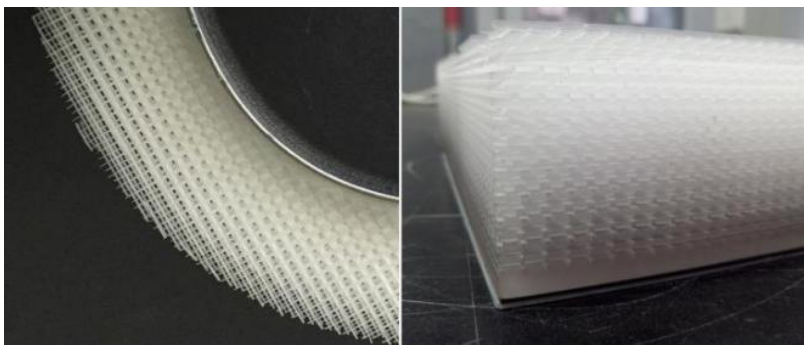

Three-dimensional Electromagnetic Metamaterials.

Abstract: Three dimensional (3D) metamaterials are artificial micro-structures periodically arranged in three-dimensional space. The lattice constant of metamaterial is much smaller than the wavelength of the incident EM wave, so the metamaterial can be treated as an artificial effective medium for the propagating of the EM waves. By controlling the geometrical parameters of its lattice, the metamaterials can be developed with properties never found in nature, which can be utilized to manipulate the propagation of EM waves, such as blocking, absorbing, capturing, or bending waves. With these magic properties, 3D metamaterials get bright prospects for applications in stealth technology, communication technology, optical imaging and sensing technology.

The principles for metamaterials are firstly discussed. There are two kinds of metamaterials with difference in the electromagnetic responses. They are metallic resonant metamaterials and dielectric non-resonant metamaterials. Metallic resonant metamaterials are normally constructed by split-ring resonator, metal continuous line, metal break line and so on, to get negative effective permeability and negative permittivity by magnetic and electric resonance. Non-resonant dielectric metamaterials obtain their arbitrary permeability and permittivity by specific distribution of the dielectric materials.

The recent developments of the structure design and manufacturing process in 3D metamaterials are sorted out, which include printing circuit board and assembly technology, machining and assembly technology, micro-nano manufacturing technology and 3D printing technology. Printing circuit board and assembly technology are suitable for metallic resonant metamaterials. Machining and assembly technology are fit for dielectric non-resonant microwave metamaterials. Micro/nano-manufacturing technology can be used to fabricate simple and small scale optical metamaterials. 3D printing technology can be used in fabricating metamaterials from gigahertz to terahertz, and its process capability in fabricating complex micro and macro-structure is very useful for metamaterials.

The representative devices of 3D metamaterials are also discussed to show how the 3D metamaterials control the electromagnetic-wave, including electromagnetic cloaks, lens antennas, absorbing structure and flexible metamaterials. According to the problems in manufacturing process and structure innovation, several developments trends have been predicted, such as trans-scale manufacturing technology for complex micro/macro-structure, multi/material manufacturing technology, manufacturing technology for multi-function coupling structures, smart metamaterials design and fabricating with 4D printing technology etc.

Keywords: three dimensional metamaterial; electromagnetic-wave control; 3D printing; metamaterial device

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