[Metamaterials promise simple machines, superlenses, superfast optical networks, EMI suppression and wireless charging]

Metamaterials are artificially structured materials designed to control and manipulate physical phenomena such as light and other electromagnetic waves, sound waves and seismic waves in unconventional ways, resulting in exotic behavior that's not found in nature. They are predicted to be able to protect the building from earthquakes by bending seismic waves around it, Similarly, tsunami waves could be bent around towns, and sound waves could be bent around a room to make it soundproof.

Metamaterials (i.e., engineered electromagnetic structures), are poised to disrupt industries, create entirely new markets, and change society. The ability to design and fabricate materials with new functionalities opens the door to a new world of possibilities. They can be tailored to either augment the functionality of existing devices or create new devices with superior performances. Metamaterials are utilized in various devices including Sensors, Superlensing, Cloaking, and Light emitting diodes. Metamaterials are utilized across various applications, including high frequency battle field communication, sensor detection, improving ultrasonic sensors, solar power management, and high gain antennas and also in various remote aerospace applications.

Researchers are developing passive radiative cooling (selfcooling films) for buildings and power plant cooling; electronically scanned array platform for drones and self-driving cars; smart metamaterial antennas for 5G networks and satellites; metasurfaces for molding the flow of light; thermal barriers for energy-efficient single pane windows; RF energy harvesting platform for IoT; peripheral nerves/brain focused magnetic stimulation (FMS) technologies; thermophotovoltaics devices; multispectral imaging chemical sensor; and a state-of-the-art computational electromagnetics simulation platform.

Military is also interested in metamaterials primarily for cloaking, to make their platforms, weapons and persons invisible from electro-optic sensors, radars and sonars. They may also be used for camouflage making one object look like another, looking to disguise fighter jets as freighters. Applications shall lead to new means of signature control, the development of low-probability intercept active sensors, the application of high-resolution planar lenses, and the use of compact antennas.

According to the new market research report on the "Metamaterial Market by Material Type (Electromagnetic, Terahertz, Photonic, Tunable, and FSS), Application (Communication Antenna, Windscreen, Solar Panel, Sensing, Display, and Medical Imaging), Vertical and Geography – Global Forecast to 2025", this market is expected to be valued at USD 4,634.8 Million by 2025, at a CAGR of 63.1% between 2017 and 2025. The major factors driving the growth of the metamaterial market include variety in design functionalities, anti-glare coating applications, and invisibility cloak for stealth aircraft.

"The idea behind metamaterials is to mimic the way atoms interact with light, but with artificial structures much smaller than the wavelength of light itself," said Boris Kuhlmey from the University of Sydney. This way, their properties are derived from both the inherent properties from their base materials as well as the way they are assembled, such as the design of their shape, geometry, size, orientation and arrangement. Thus optical properties are no longer restricted to those of the constituent materials, and can be designed almost arbitrarily.

Typically, metamaterials include several classes of electromagnetic composites including negative index materials, photonic crystals, zero index materials, low index materials and chiral metamaterials. Some of the prominent modeling methods of metamaterials are finite difference time domain (FDTD) method, finite-element method (FEM), and transmission line method (TLM).

Engineers at the University of California San Diego have fabricated the first semiconductor-free, optically-controlled microelectronic device. Using metamaterials, engineers were able to build a microscale device that shows a 1,000 percent increase in conductivity when activated by low voltage and a low power laser. The device consists of an engineered surface, called a metasurface, on top of a silicon wafer, with a layer of silicon dioxide in between. The metasurface consists of an array of gold mushroom-like nanostructures on an array of parallel gold strips.

The gold metasurface is designed such that when a low DC voltage (under 10 Volts) and a low power infrared laser are both applied, the metasurface generates "hot spots"—spots with a high intensity electric field—that provide enough energy to pull electrons out from the metal and liberate them into space. “This certainly won’t replace all semiconductor devices, but it may be the best approach for certain specialty applications, such as very high frequencies or high power devices,” leder of the group and electrical engineering professor Dan Sievenpiper at UC San Diego Sievenpiper said.

On 29 September 2015, thirty experts from Ministries of Defence, European Commission, NATO staff, industry and academia participated in an European Defence Agency (EDA) seminar to address the future impact of metamaterials technologies on defence capabilities. The main outcome of the seminar is the identification of radar antennas and absorbers as the most promising defence applications. On the other hand, wide-band tunable surfaces are the most wanted applications of metamaterials, although they are far to be achieved.

Super lenses

Researchers at Michigan Technological University in continuation of work done by Durdu Güney, a professor of electrical and computer engineering have found a way to pass light waves to pass through the lens without getting absorbed. They utilized metamaterials based on thin silver films tweaked at the subwavelength scale so that light waves pass through instead of reflecting off the metal.

“Aluminum and silver are the best choices so far in the visible light spectrum, not just for a perfect lens but all metamaterials,” Güney says, explaining that metamaterials have been successfully created with these metals, although they still tend to absorb light waves. “Loss—or the undesired absorption of light—is good in solar cells, but bad in a lens because it deteriorates the waves," he explains.

Optical Computer Networks

In 2012, the Berkeley Nanosciences and Nanoengineering Institute published a paper with South Korean scientists describing a metamaterial-based electro-optical modulator made from a sheet of graphene just a single atom thick that was able to switch lightwaves at terahertz frequencies.

More recently, a group at City College of New York, led by the physicist Vinod Menon, demonstrated light emission from ultrafast-switching LEDs based on metamaterials. Together, such innovations could make possible optical computer networks far faster than today's gigabit networks.

Acoustic Metamaterials

Acoustic metamaterials are artificially fabricated materials designed to control, direct, and manipulate sound waves. More recently, the metamaterial concept has been extended to acoustic waves in a variety of scenarios of interest such as acoustic clocking, super-lensing and sound focusing and confinement.

Prof Katia Bertoldi of Harvard University also studies strange, elastic materials like this, which have a negative "Poisson ratio". This means that when you compress them, instead of squashing out to the sides and getting both flatter and wider, they actually shrink in all directions.

Then when stretched, they expand in all directions. Prof

Bertoldi’s team has engineered various useful properties into such materials, including making them absorb sound at different frequencies when squeezed. The Poisson ratio can also affect fatigue in a metal — so she has worked with Rolls Royce to design engine components with complex slits wound into them, which withstand many more cycles of compression before breaking.

For more information on acoustic metamaterials: http://idstch.com/home5/international-defence-security-and-technology/technology/materials/new-breakthroughs-in-acoustic-metamaterials-have-military-applications/

New metamaterial enhances natural cooling without power input

A team at the University of Colorado Boulder (CU-Boulder) in the US developed a new metamaterial film out of glass microspheres, polymer and silver, that provides cooling without needing a power input. Radiative cooling is the natural process through which objects shed heat in the form of infrared radiation. The challenge for the CU-Boulder researchers was to create a material that both reflects sunlight and also allows infrared emission.

For more information: http://idstch.com/home5/international-defence-security-and-technology/technology/energy/new-technologies-thermal-management-mission-critical-military-ground-sea-air-space-systems/

Laser protection

Last year, the aircraft manufacturer Airbus announced that it was joining with Lamda Guard, a Canadian company, to test a metamaterial-based coating for cockpit windows to protect pilots in commercial aircraft from being blinded by laser pointers. There are obvious markets for the technology in automotive safety and self-driving cars. Google's advanced experimental vehicles use a costly mechanical laser-based device called a lidar to create an instantaneous high-resolution map of objects around the car. Based on a rapidly spinning laser, Google's lidars still cost roughly $8,000. The radars being designed by Echodyne may soon be able to create similar maps at a much lower cost.

Metamaterial Antennas

Kymeta and Evolv Technology, are also working on other metamaterial-based applications. Evolv is pursuing higher-performance airport-security-scanning technology, and Kymeta recently announced a partnership with Intelsat to design land-based and satellite-based intelligent antennas that would greatly increase the capacity and speed of next-generation satellite Internet services.

Elena Semouchkina, a pioneer on cloaking devices at Michigan Technological University, points to screening antennas so they don't interfere with each other, protecting people from harmful radiation or acoustic pressure and even preventing buildings from destruction from seismic waves.

for more information on metamaterial antennas: http://idstch.com/home5/international-defence-security-and-technology/technology/electronics/metamaterial-based-antennas-wireless-communication-space-communications-gps-satellites-space-vehicle-navigation-airplanes/

Intel Metamaterials Breakthrough, “Sub-millimeter EMI Shunt Beats Shields”

A metamaterial breakthrough has been funded by Intel at the Electromagnetic Compatibility (EMC) Lab at National Taiwan University. By folding a metamaterial up into the third dimension (3D), a breakthrough in suppression of electro-magnetic interference (EMI) has been achieved enabling easier electro-magnetic compatibility (EMC) of next-generation high-speed interfaces.

The Intel/NTU’s breakthrough is a single sub-millimeter sized component that replaces bulky traditional shielding by suppressing noise at each source by 20dB, according to Professor Tzong-Lin Wu, an IEEE Fellow and Director of the Graduate Institute of Communication Engineering (GICE) at NTU. In addition to 20-dB noise suppression, more than one can be placed in-line with the high-speed transmission line to achieve 40db (with two), 60dB (with three) and so forth.

“Along with the vigorous development of cloud computing, it is of vital importance to enhance the bandwidth and efficiency of data centers and their communication devices for next-generation communication,” Wu told EE Times in an exclusive interview. “New high-speed signal transmission design and high-frequency noise suppression technologies are key to enabling wider data bandwidth in cloud computing and other applications.”

The tiny metamaterial components—measuring just 1.0-by-0.8-

by-0.6 millimeters—are folded like origami to suppress EMI problems in high-speed interfaces whose wavelength is much longer than the physical size of the noise suppression component. Due to a widely used ceramic or PCB manufacturing process, they are also much cheaper than tradition shielding techniques for any electronic component with external interfaces.

The NTU EMC Lab claims to be the first to use the invention of planar electromagnetic band-gap (EBG) power planes to suppress switching noise of packaged circuits, and now has a new claim—the first use of metamaterial differential transmission lines to virtually eliminate common-mode noise in high-speed differential signals.

Wireless charging

The next likely consumer use of metamaterials could be in the wireless charging of devices, an area attracting keen industry attention. Samsung Electronics has filed several patents related to metamaterials and wireless charging.

Mechanically Programmable Materials

Bastiaan Florijn, a final-year PhD student at Leiden University in the Netherlands, demonstrated what he calls the first ever mechanically “programmable” material. It is a surprisingly low-tech looking slab of rubber, punched with an array of holes. But those holes, of two sizes, are specifically designed so that they can compress either vertically or sideways – and that switch is controlled by adding a small clamp.

The end result is a sort of oversized sponge that can be stiff, or soft, or flit between the two at a specific stage of the squeeze. If it switches to become softer while still under pressure, this is known as “negative stiffness” – a property so weird that Mr Florijn said he still hasn’t worked out an application for it.

But the slabs have another property that could be immensely useful: they absorb energy. “Imagine a car bumper that you can program – for instance, if you drive in a neighbourhood with a lot of small kids, you want to have a very soft bumper,” Mr Florijn said. “But then if you’re going fast on the highway, you want it to be stiff.” He and his colleagues are also talking to shoe companies, who are interested in producing soles that adjust to different terrain.

Digital Metamaterials

Cristian Della Giovampaola and Nader Engheta from the University of Pennsylvania propose using just two subunits with opposing properties. Called “metamaterial bits,” these are like the 1s and 0s in a binary code. They used nano-sized pieces of silver and silica, which interact with light in very different ways: One’s a metal, the other’s an insulator.

The duo used a computer simulation to create layered structures that constitute bytes of increased functionality and complexity. Once they were “digitized,” the resulting material had its own unique properties, distinct from its constituent subunits.

Metamaterials based Simple Machines by 3D Printing

“So far, metamaterials were understood as materials—we want to think of them as machines. We demonstrate metamaterial objects that perform a mechanical function,” says Hasso Plattner Institute, Potsdam, Germany. Such metamaterial mechanisms consist of a single block of material the cells of which play together in a well-defined way in order to achieve macroscopic movement. Our metamaterial door latch, for example, transforms the rotary movement of its handle into a linear motion of the latch. Our metamaterial Jansen walker consists of a single block of cells—that can walk. The key element behind our metamaterial mechanisms is a specialized type of cell, the only ability of which is to shear.

“In order to allow users to create metamaterial mechanisms efficiently we implemented a specialized 3D editor. It allows users to place different types of cells, including the shear cell, thereby allowing users to add mechanical functionality to their objects. To help users verify their designs during editing, our editor allows users to apply forces and simulates how the object deforms in response.”

Metamaterial-enabled devices have a wide range of applications in the RF, THz, IR, and visible spectrum.

Chinese Breakthroughs

China has begun to make breakthroughs in its research into metamaterials, inching closer to the People’s Liberation Army’s dream of developing an “invisible” aircraft, reports the Beijing-based Sina Military Network. China’s 863 Program (State High-Tech Development Plan), 973 Program (National

Basic Research Program) and the National Natural Science Foundation of China are all receiving government funding to explore the field.

According to the report, the potential applications and projects of metamaterials being considered by Chinese researchers are extremely broad, and include notebook-sized satellite antennae, flexible ceramics, defensive walls that can reduce the impact of earthquakes and tsunamis, smart shoes capable of sensing terrain, and of course, invisible planes.

Meta-RF

One of the breakthroughs achieved by Liu Ruopeng, president of the Shenzhen-based Kuang-Chi Institute of Advanced Technology and his team is Meta-RF technology. Based on a complex electromagnetic structure design, the technology controls and modulates the transmission of electromagnetic waves with high accuracy. This has allowed China to gain a leg-up over competitors in the metamaterials sector, Sina Military said.

Using Meta-RF technology, Kuang-Chi has developed electromagnetic metamaterial antennas, which can launch energy into free space and has applications in wireless communication, space communications, GPS, satellites, space vehicle navigation and airplanes. Using a circuit board that can be folded to the size of a notebook, the technology enables devices to connect to satellite broadband internet from airplanes, trains, boats and cars from remote locations. The advantage of the antennae is that they can detect satellites anywhere, unlike traditional dish-shaped antennae that are locked in to point at one particular satellite.

Kuang-Chi already tested the technology in 22 Chinese provinces as early as three years ago, while the US is only starting to be commercialize the technology this year. Founded in 2010, Kuang-Chi has applied for more than 2,800 patents, 86% of which are linked to the metamaterials materials industry.

The article sources also include:

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