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3D Microscale Isotropic Metamaterials

Technology No. 20170289

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Microscale Metamaterial for Orientation-Invariant Sensing

A new sensor design features a three-dimensional (3D) metamaterial consisting of microcubes patterned with split-ring resonators (SRR). The SRR sensor consists of a polymer cube, with a gold “X” patterned on each side of the cube, and 3D splits at the corners between the “X” patterns. The 6 faces of the cube together to form an octagram split-ring resonator (OSRR). The sensor exhibits an isotropic response to THz radiation when rotated about its z-axis. Furthermore, simulations confirm an isotropic response for all angles of rotation and predict the ability for ultra-high sensitivity sensing by using changes in the amplitude of the resonant response. The sensor is designed for applications where orientation invariant sensing is required (i.e., in-vivo and in-situ biological or chemical sensing where the relationship between sensor and probe is unknown). The technology, made from biocompatible materials, features a perfectly isotropic transmission response that is invariant under rotation, and can be used for fast, non-contact, label-free chemical or biological sensing.

3D Isotropic Metamaterials

The 3D cube features X-shaped resonators that create SRRs with splits at the corners. Because the splits are three-dimensional, they are equally affected by all the parameters of light. Therefore, the 3D cube, with its octagram resonators (3D star), acts as an isotropic metamaterial that can be used for highly sensitive detection of foreign particles. The strong 3D coupling of each resonator segment to its neighbor enhances the overall sensitivity of the octagram. The strong coupling and using amplitude as a marker for low concentration foreign materials provide the 3D octagram with a much higher sensitivity compared to 2D sensors. The polymer-based fabrication of the cube also makes it transparent to light apart from the metal structure, so no disturbance in measurement takes place.

Superior Performance of 3D Micro Devices Compared to 2D Structures

This technology—a 3D SSR with “X” patterns on each face—overcomes many of the limitations of anisotropic metamaterials. SRRs have been studied for developing high sensitivity, small sized, low power sensors for fast and label-free detection of chemical and biological substances, but the anisotropy of their 2D structure presents a major disadvantage when the orientation of the structure cannot be controlled. This 3D isotropic octagram split-ring resonator (OSRR) overcomes the anisotropic response of the 2D structure, leading to a single, polarization invariant transmission response.

The new design generates isotropic transmission response independent of temperature and pressure, allowing for orientation invariant sensing. Its sensitivity is 16 times higher than 2D SRR and is fabrication, from biocompatible materials, is simple and cost-effective.

BENEFITS AND FEATURES:

- 3D metamaterials
- Superior performance of 3D micro devices compared to traditional 2D structures
- Microcubes patterned with split-ring resonators (SRR)
- Gold “X” patterned on each side of the cube
- 3D splits at the corners between the “X” patterns
- Isotropic response for all angles of rotation
- Isotropic response to THz radiation when rotated about z-axis
- Isotropic transmission response invariant under rotation
- Ultra-high sensitivity sensing ability using changes in the amplitude of the resonant response
- In-vivo and in-situ biological or chemical sensing
- Fast, non-contact, label-free chemical or biological sensing
- Sensitivity is 16 times higher than 2D SRR
- Made from biocompatible materials
- Simple and inexpensive fabrication
- Small size (e.g., antenna)
- Biocompatible with minimal modifications

APPLICATIONS:

- Sensors and optical devices
- Biosensor or sensor in telecommunication (antenna)
- In-vivo sensing where sensor orientation is uncontrolled
- In-vivo biological or chemical sensors
- Small scale biocompatible sensors implanted subcutaneously for in-vivo measurement of biological species
- In-situ measurement of chemicals present in any liquid
- Continuous glucose monitor (CGM)
- Potential for assessing aging of meat products (based on moisture loss)

- Isotropic metamaterials:
  - biological or chemical sensors
  - subcutaneous implant for in-vivo measurement of biological species while they flow in the blood
  - in-situ measurement of chemicals present in any liquid

Phase of Development - Prototype development

Device fabricated, isotropic resonant response characterized, sensitivity demonstrated experimentally.

Researchers

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Publications

Three-Dimensionally Coupled THz Octagrams as Isotropic Metamaterials
ACS Photonics, 2017, 4 (10), pp 2436–2445

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