NIST tunes 'metasurface' with fluid in new concept for sensing and chemistry

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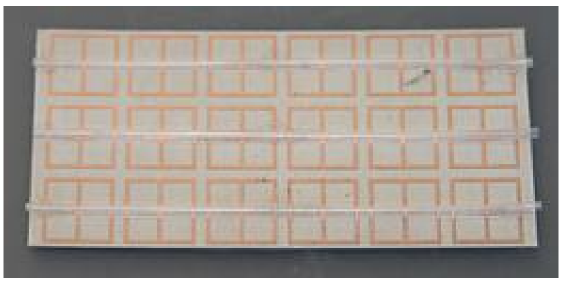

NIST's fluid-tunable "metasurface" consists of copper structures and plastic tubing mounted on composite board. The presence of water in the tubing changes the resonant frequency at which the metasurface absorbs and stores energy. Credit: NIST

(PhysOrg.com) -- Like an opera singer hitting a note that shatters a glass, a signal at a particular resonant frequency can concentrate energy in a material and change its properties. And as with 18th century "musical glasses," adding a little water can change the critical pitch. Echoing both phenomena, researchers at the National Institute of Standards and Technology (NIST) have demonstrated a unique fluid-tuned "metasurface," a concept that may be useful in biomedical sensors and microwave-assisted chemistry.

A metasurface or metafilm is a two-dimensional version of a metamaterial, popularized recently in technologies with seemingly unnatural properties, such as the illusion of invisibility. Metamaterials have special properties not found in nature, often because of a novel structure. NIST's metasurface is a small piece of composite circuit board studded with metal patches in specific geometries and arrangements to create a structure that can reflect, store, or transmit energy (that is, allow it to pass right through).

As described in a new paper, NIST researchers used purified water to tune the metasurface's resonant frequency—the specific microwave frequency at which the surface can accumulate or store energy. They also calculated that the metasurface could concentrate electric field strength in localized areas, and thus might be used to heat fluids and promote microwave-assisted chemical or biochemical reactions.

The metasurface's behavior is due to interactions of 18 square copper frame structures, each 10 millimeters on a side (see photo). Computer simulations help design the copper squares to respond to a specific frequency. They are easily excited by microwaves, and each one can store energy in a T-shaped gap in its midsection when the metasurface is in a resonant condition. Fluid channels made of plastic tubing are bonded across the gaps. The sample is placed in a waveguide, which directs the microwaves and acts like a kaleidoscope, with walls that serve as mirrors and create the electrical illusion that the metasurface extends to infinity.

Researchers tested the metasurface properties with and without purified water in the fluid channels. The presence of water shifted the resonant frequency from 3.75 to 3.60 gigahertz. At other frequencies, the metasurface reflects or transmits energy. Researchers also calculated that the metasurface, when in the resonant condition, could concentrate energy in the gaps at least 100 times more than the waveguide alone.

Metasurface/fluid interactions might be useful in tunable surfaces, sensing and process monitoring linked to changes in fluid flow, and catalysis of chemical or biochemical reactions in fluid channels controlled by changes in microwave frequency and power as well as fluid flow rates. NIST researchers are also looking into the possibility of making metamaterial chips or circuits to use for biomedical applications such as counting cells.

More information: J. Gordon, et al. Fluid interactions with metafilm/metasurfaces for tuning, sensing, and microwave assisted chemical processes. *Physical Review B* 83, 205130 (2011). Posted online May 25, 2011.

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