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Transparent electrodes in the terahertz regime – a new approach

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Abstract-We suggest a new possibility for obtaining a transparent metallic film, thus allowing for completely transparent electrodes. By placing a complementary composite layer on top of the electrode, we can cancel the back-scattering of the latter thus obtaining a perfectly transparent structure. For ease of fabrication, we performed the first experiments in the THz regime, but the concept is applicable to the entire electromagnetic waves spectrum. We show that the experiments and theory match each other perfectly.

Using the effective medium theory, the permittivity of a composite 2D layered material where the electric field is perpendicular to the layers is given by [1]:

$$\frac{1}{\varepsilon_{AB}} = \frac{1}{\varepsilon_A}\frac{W_A}{P} + \frac{1}{\varepsilon_B}\frac{W_B}{P} \tag{1}$$

Where W_A, W_B are the widths of each material, $P = W_A + W_B$ is the periodicity of the structure and ε_A, ε_B are the permittivities of each layer. With the advent of the metamaterials field, at least one of the initial ε values can be negative thus hugely expanding the range the composite material permittivity can reach.

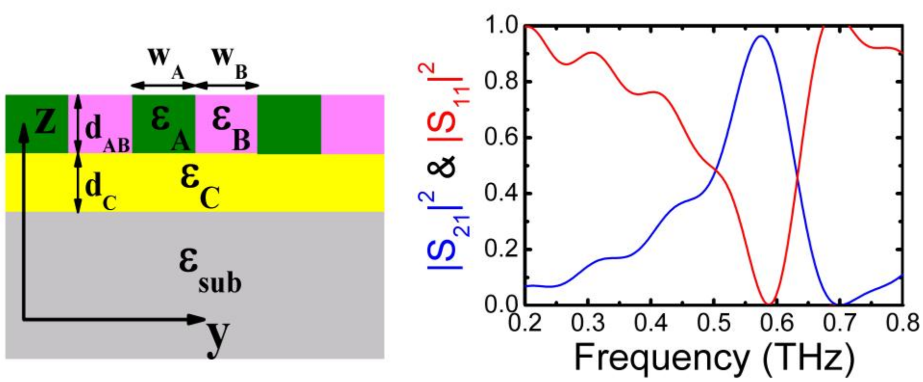

Figure 1. (a) the design considered for simulations; The A layer is silica, the B one is the composite mesh while the C is the electrode. The polarization is parallel to the y axis. (b) S-parameters results showing high transmittivity at 0.6THz

In this example, we defined the B layer as a metallic mesh with, in the THz regime; a permittivity $\varepsilon_B = 3.85 - (3.06/f)^2$ and the A layer as a dielectric with a constant permittivity of 3.85. This resulted in a dielectric function of the composite material as: $\varepsilon_{AB} = 3.85 + 4.19/(0.74^2 - f^2)$. The widths of the stripes were 10 and 30μm for the A and B layers respectively (see figure 1(a)) and f is the frequency in THz.

Employing the standard transfer matrix method [2] and considering the C layer a uniform metallic mesh with

$\varepsilon_C = 3.85 - (4.98/f)^2$ we obtain, for a frequency of 0.6THz, perfect transmission through a complex structure placed on a Si substrate (see figure 1(b)).

The simulated structures were fabricated using aligned optical lithography and thin layer depositions. The fabrication flow will be presented during the conference. Figure 2 shows the fabrication results for the C mesh as well as the AB complex layer. [3]

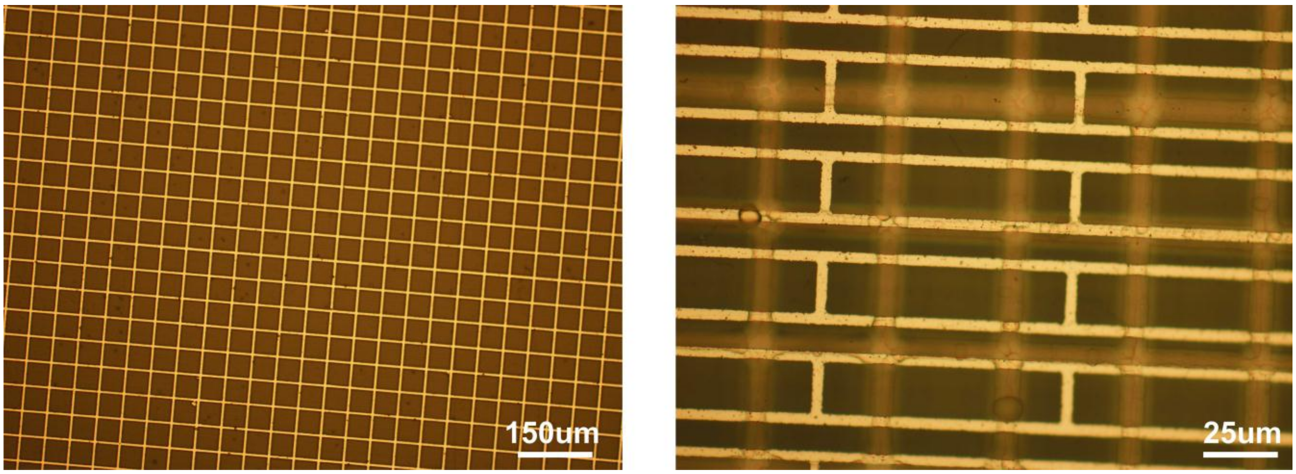

Figure 2. Fabricated structure showing high alignment accuracy and high quality of the structure.

The obtained experimental results are in almost perfect match with the predicted theory ones thus showing that our approach for designing such structures is viable. The experimental results as well as the challenges in measurements will be discussed during the conference.

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