Dual-Band Terahertz Reflectarray Integrated on a Silicon Substrate

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Abstract **– We report the design, fabrication and measurement of a dual-band polarization-independent terahertz reflectarray surface integrated on a silicon reflective substrate. The proposed device opens an important avenue for the integration of tunable elements in terahertz reflectarrays.**

Index Terms **— Reflectarray antenna, terahertz, multiband antenna, silicon.**

1. Introduction

Terahertz technology is currently a very active research topic due to the exciting prospect it offers for sensing, security, radioastronomy and broadband communications [1]. Recently reflectarray antennas [2] have been experimentally demonstrated for terahertz frequencies [3-5] enabling, for instance, polarization or frequency control which are not possible with a simple reflector. These demonstrations, however, are based on an organic dielectric spacer between the reflector and the pattern. The reason is that the spacer needs to satisfy stringent requirements in terms of losses and thickness, which strongly limits the available materials.

In [6, 7] we presented a technological solution to enable the use of high resistivity silicon as spacer, by bonding a thin (15 µm) silicon SOI device layer to a metal reflector supported by glass. Here we use the same technological process to design, fabricate and measure a dual band reflectarray operating at 0.7 THz and 1 THz. We also discuss the possibility of including tunable elements for reconfigurable reflectarrays at terahertz frequencies.

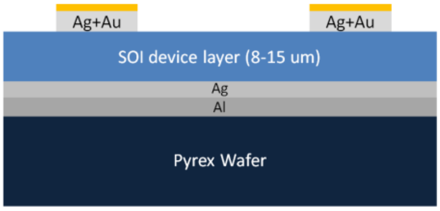

Fig. 1. Cross-section of the terahertz dual band reflectarray.

2. Design and fabrication

The structure of the reflectarray is illustrated in Figures 1 and 2. The reflectarray is supported by a pyrex wafer. The metal reflector is composed of 100 nm aluminum bonded to the pyrex with anodic bonding and 100 nm of silver which acts as a reflector. The high resistivity silicon device layer (15 µm) acts as a dielectric, and structures are fabricated in silver and gold on the surface using e-beam lithography [6].

Independent control of the reflected beam at the two design frequencies (0.7 THz and 1 THz) is obtain intercalating two cross elements resonating at different frequencies. The reflectarray surface is designed to reflect an incident beam coming from 30° from the normal direction to the normal at the two design frequencies. The final device is shown in Figure 3.

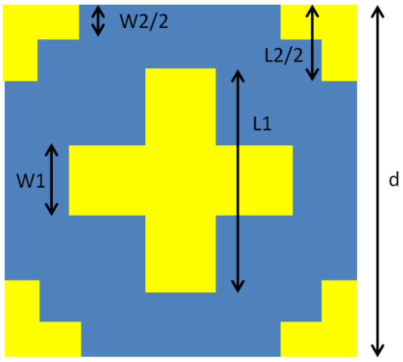

Fig. 2. Unit cell of the terahertz dual band reflectarray. d=100µm, W1=W2=10 µm, L1=[60-75] µm, L2=[40-50].

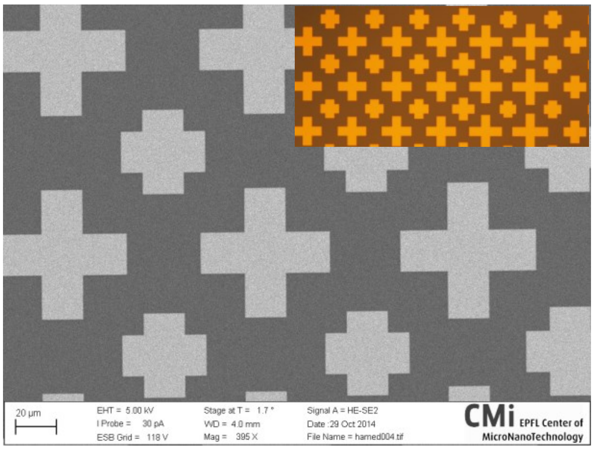

Fig. 3. SEM picture of the final reflectarray device. The inset shows the corresponding optical image.

3. Measurement

The device was measured with a time domain fiber coupled terahertz spectroscopy setup (Menlo system TERA K15). The transmitter antenna was fixed to 30° from the normal, while the receiving one was moved from the normal direction to the -30° specular direction. Both measures were normalized with the specular reflection of a calibration gold mirror. The specular reflection spectrum (Figure 4) shows two evident absorption dips at the working frequencies, where anomalous reflection is observed instead (Figure 5), confirming that the reflectarray is working correctly.

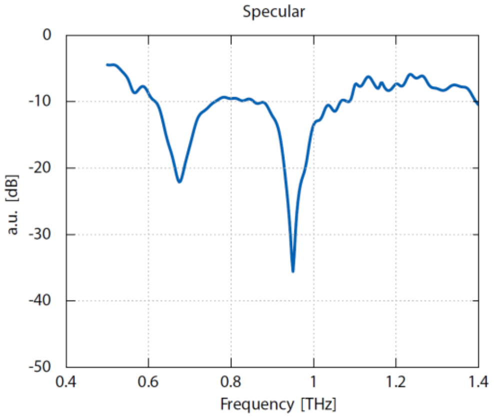

Fig. 4. Reflection coefficient for specular reflection

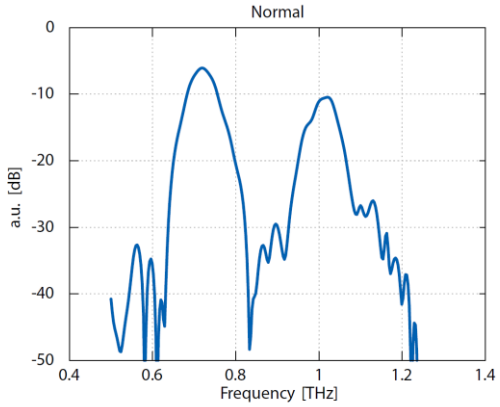

Fig. 5. Reflection coefficient for anomalous reflection along the normal to the surface.

4. Prospects for reconfigurable terahertz reflectarrays

The successful integration of a fixed beam terahertz reflectarray on a silicon substrate opens many avenues to achieve beam steering at terahertz frequencies. The reason is that, unlike the organic substrates used in previous works, silicon is compatible for a variety of fabrication processes, which are needed to integrate the tunable component at fabrication time.

One example is given by graphene, which possesses a tunable conductivity upon electric field gating [8]. Gating is usually performed through silicon oxide or alternative insulators such as Al_2O_3, whose deposition is compatible with silicon but not with organic materials, given the deposition temperature.

Another example of a possible technology for reconfigurable terahertz antennas is vanadium dioxide (VO_2) [9]. This is a phase-change material, which switches from an insulating to a conducting state for temperatures higher than approximately 67 °C in its bulk form. The phase transition temperature can be modified by material engineering introducing strain or doping. Switching can be induced also by electrical excitations, in current- or voltage-actuated VO_2 junctions. It must be noted that our process is fully compatible with this technology, providing a stable substrate able to resist to high temperatures used in VO_2 sputtering [10]

Finally, also microelectromechanical systems (MEMS) can be considered, since they can be fabricated directly on the high-resistivity silicon substrate [11].

5. Conclusion

We demonstrated experimentally a dual band terahertz reflectarray on a silicon substrate and introduced examples of compatible reconfigurable technologies. More details on the device and on prospects of these technologies will be given during the presentation.

Acknowledgment

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