Enhancement of Terahertz Emission By AuGe Nanopatterns

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Abstract

Improving the Terahertz (THz) emission efficiency of the THz sources has been a major research goal for several years. Photoconductive Emitters (PCEs) are one of the popular methods to generate THz radiation. We present here an approach to increase the efficiency of a THz Photoconductive Emitter (PCE) fabricated on a Semi-Insulating Gallium-Arsenide (SI-GaAs) substrate by patterning the substrate with Gold-Germanium (AuGe) nanostructures. Optimization of the structural properties of these nano-structures and simulation for incidence of 800 nm wavelength laser on the patterned SI-GaAs substrate and electrostatic field was performed using COMSOL Multiphysics®, which highlighted the effect of nanostructures on laser light coupling and localized electrostatic field enhancement. Experimental results reflect the simulation results to show an increase in the THz emission power by a factor of around 4.

Terahertz photoconductive emitters work on the principle of acceleration of the photo-excited carriers. A 10 femto-second pulsed laser is focused on SI-GaAs between two Gold-Germanium (Au-Ge) electrodes having a gap of few micro-meters in between them (Figure 1). Laser excited carriers are generated in the SI-GaAs substrate, which are then accelerated towards the electrodes. This acceleration of carriers produces radiation in the terahertz (1012 Hz) domain. It is expected that patterning the surface of the SI-GaAs with nano-structures increases the light coupling efficiency. Simulation of 800 nm wavelength plane wave incident on the nanostructure patterned SI-GaAs substrate was performed using the COMSOL® Wave Optics Module. Plane wave is considered as a first approximation for incident Gaussian 10 femto-second pulse. A parametric sweep of the height and width of the individual nanostructure was done to find out the optimal structure property which will balance between maximum light coupling and minimum back reflection. The height of the nanostructure was found out to be around 40 nm and width around 400 nm with a period of 100 nm (Figure 2a,b). Moreover, due to the geometrical effects of the nanostructure, the electrostatic field was found to be concentrated at its tips (Figure 3a). The combined effect of the two physical phenomena results in an increased number of photo-excited carriers beneath the nanostructures as well as increase in the photo-excited carrier acceleration towards the electrodes. Since more number of carriers result in more radiation, the overall THz emission power increases. Fabrication of such a nanostructure patterned THz photoconductive emitter was done using electron beam lithography (Figure 3b). Figure 4 shows the practical comparison between the THz emission of the patterned and un-patterned THz emitters. The comparison clearly points out the increased THz emission power of the patterned THz photoconductive emitter as compared to the unpatterned THz photoconductive emitter.

Figures used in the abstract

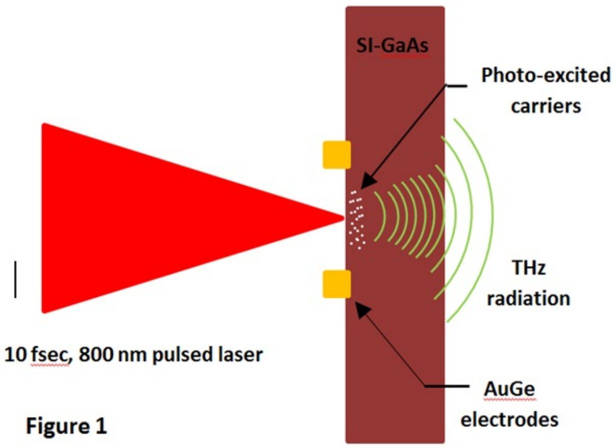

Figure 1: Generation of terahertz radiation from a photoconductive emitter

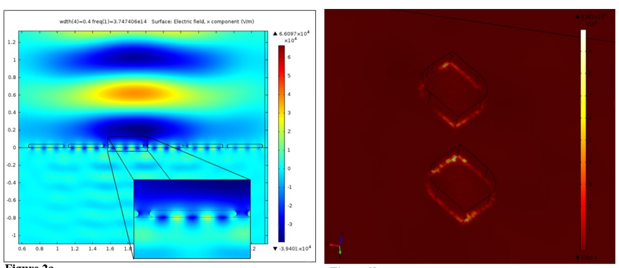

Figure 2a Figure 2b

Figure 2: (2a) 2D simulation of nanostructure pattern to optimize height and width.(2b) 3D simulation of nano-structure. Nano-structures clearly indicate the increased electric field

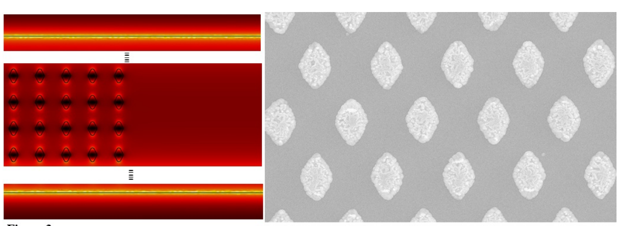

Figure 3a Figure 3b

Figure 3: (3a) Normalized electrostatic field (V/m) enhancement at the tips of the nanostructures. (3b) SEM image of fabricated nanostructure

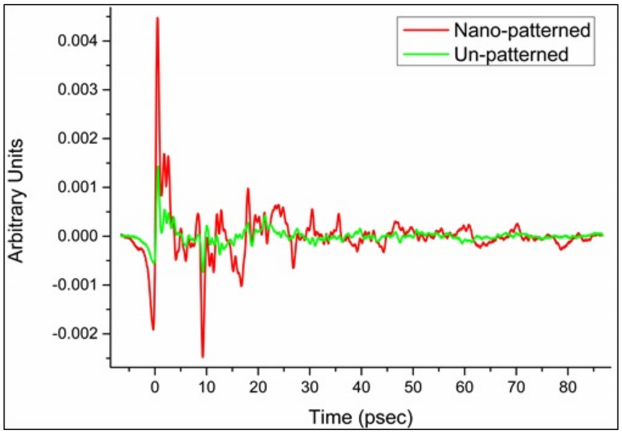

Figure 4: Experimental results of terahertz emission pulse of patterned and unpatterned. A 4 fold increase in the amplitude is observed