Tunable Resonance of Star Shaped Nanostructures

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Abstract

1. Introduction
Auto assembled Ag-ZnO [1] star-shaped nanostructures depicted in figure 1, presents their natural electromagnetic resonance at 60 THz [2]. Since star shaped geometry showed some interesting interactions with electromagnetic field in the optical regime, it is proposed in this work to adapt the geometry to perform some numerical studies assuming a possible subsequent fabrication by the method of nanolithography, a more convenient method to perform superficial nanoantennas which is the main (but not limited to it) application purpose as will be discussed later in this work. By covering the original auto assembled Ag-ZnO structure (fig. 1) with gold (Au), it is possible to change and adjust their electromagnetic field interaction allowing the purpose of having the directional-enhancer electric field nanostructure.

2. Computational Methods
Using the RF Module of the COMSOL Multiphysics® software [3] to solve equation 1, and applying a planar electromagnetic wave, we can find the interaction of electromagnetic field over the structure for different thickness layer of gold.
To perform the simulation, it was constructed a geometry using three different domains, one of them for the star shaped nanostructure, other for covering the nanostructure with air and used as a port to generate the electromagnetic field and applying the scattering boundary condition, and the last one used as a silicon or another material substrate, scattering boundary condition and where the nanostructure is supported or placed (fig 1b).
For each different thickness, must be necessary find their respective frequency of resonance where the capabilities of the COMSOL® software are so helpful allowing to perform complex, large and repetitive amount of calculations and presenting the results in a both, qualitative (3D images representing the behavior of electromagnetic field) and quantitative (data, tables and line graphs without any other postprocessing tools or software). For a particular case of a 50 nm of thickness, figure 2(a) depicts the electromagnetic field intensity response, and figure 2(b) depicts the shape and intensities in their resonance frequency. As geometry is varying, some other unique properties of the COMSOL® software were used: Geometry Import, and LiveLink™ for AutoCAD®.

3. Results

It is possible to have control about the resonance frequency over the star shaped Ag-ZnO nanostructures by covering them with a layer of gold. The resonance frequency is a function of the layer thickness as can be seen in figure 3 and table 1. Figure 5 depicts a linear fited curve from table 1.

4. Conclusions
Adding a layer of gold allows the control of resonance frequency of star shaped Ag-ZnO nanostructures which can be used as THz radiation detection and/or as nanoantennas for TB/s communications which is the next step on this research.

Reference

[1] J. E. Sanchez et al, Electric radiation mapping of silver/zinc oxide nanoantennas by using electron holography, JOURNAL OF APPLIED PHYSICS 117, 034306 (2015).

[2] J. E. Sanchez et al, Resonance properties of Ag-ZnO nanostructures at terahertz frequencies, OPTICS EXPRESS, 23, 025111, (2015).

[3] COMSOL Multiphysics, RF Module manual, (2016).

Figures used in the abstract

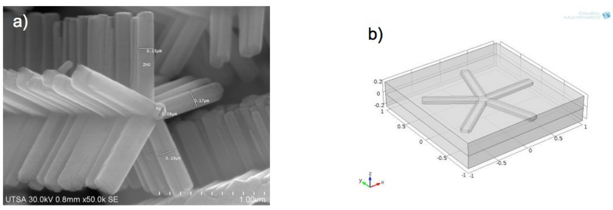

Figure 1: Star shaped nanostructure. a) Actual SEM image. b) COMSOL simplified geometry representation.

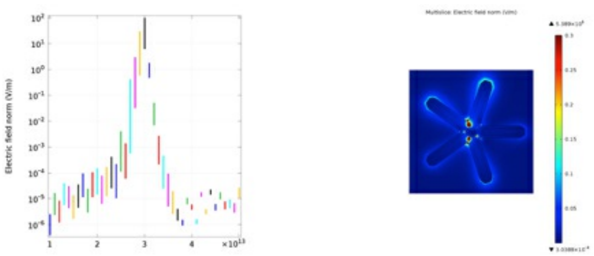

Figure 2: a) Freq. vs. electromagnetic field. b) Simulated electromagnetic field @ resonance freq. (30 THz).

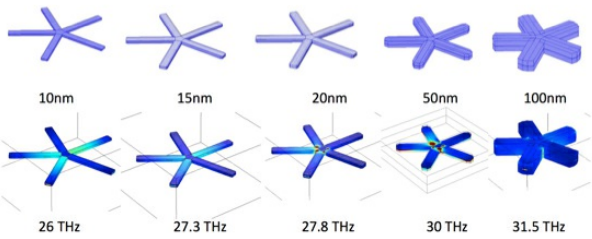

Figure 3: Relation between gold layer thickness and their respective resonant frequency.

Thickness (nm)	Freq. (THz)
10	26
20	27.8
50	30
100	31.5

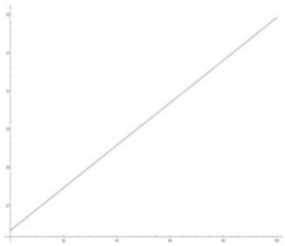

Figure 4: Thickness of gold layer vs. frequency.