# Semiconductor THz antennas for Sensing and Energy Harvesting Applications

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## ❖ Introduction

Multicrystalline Silicon (mc-Si) has been widely used in the fabrication of solar cells due its reasonable performance and low cost that came from the high contamination by transition metals such as iron, which are presented during the module fabrication [1]. At certain point, the high impurities will degrade the performance of solar cell by exhibiting high resistivity preventing the material to be a valid solution for this application. In this work, we will attempt to exploit the drawbacks heavily doped (contaminated) mc-Si by iron to design low-cost feasible nano-antennas for various applications.

## ❖ Aim

When the concentration of iron goes high (i.e around 1020 cm-3), the resistivity will be in the order of 0.001 Ω.cm will results in a conductivity of 105 S/m. This conductivity leads to a reasonable antenna resonance at THz frequencies. Several antenna configurations will be presented in this work based on the new conductivity of the heavily doped mc-Si.

## ❖ Simulation Method

- COMSOL Multiphysics based on Finite Element Method (FEM) is used to simulate the THz antennas [2].
- The electric field is concentrated inside the gap of the nano-antenna, where a MIM diode can be embedded to rectify the captured signal.
- High solar energy is expected at frequencies (12 THz – 75 THz) [3].

## ❖ Reference

[1] Oras Al-Ani, et al, *Solid State Phenomena*, Vol. 242, pp. 96-101, 2016.
[2] COMSOL Multiphysics 3.4, COMSOL Inc. (http://www.comsol.com).
[3] M. Gallo, et al. *Energy*, vol. 39, no. 1, pp. 27–32, 2012.

## ❖ Dipole THz antenna

Silica glass substrate with εr=2.09 has been employed on all antennas. The dielectric properties of gold, which is used by COMSOL, is obtained by fitting the experimental data into the Drude model.

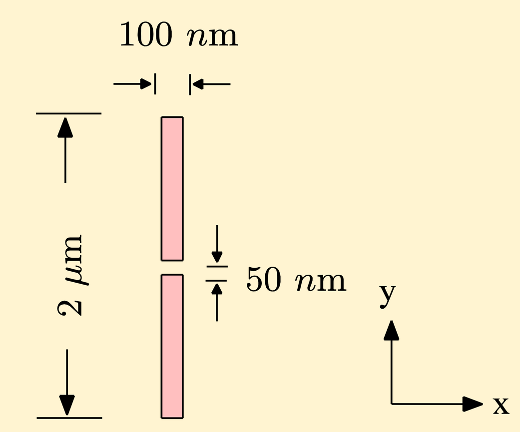



Fig. 1. Configuration of the THz dipole antenna.

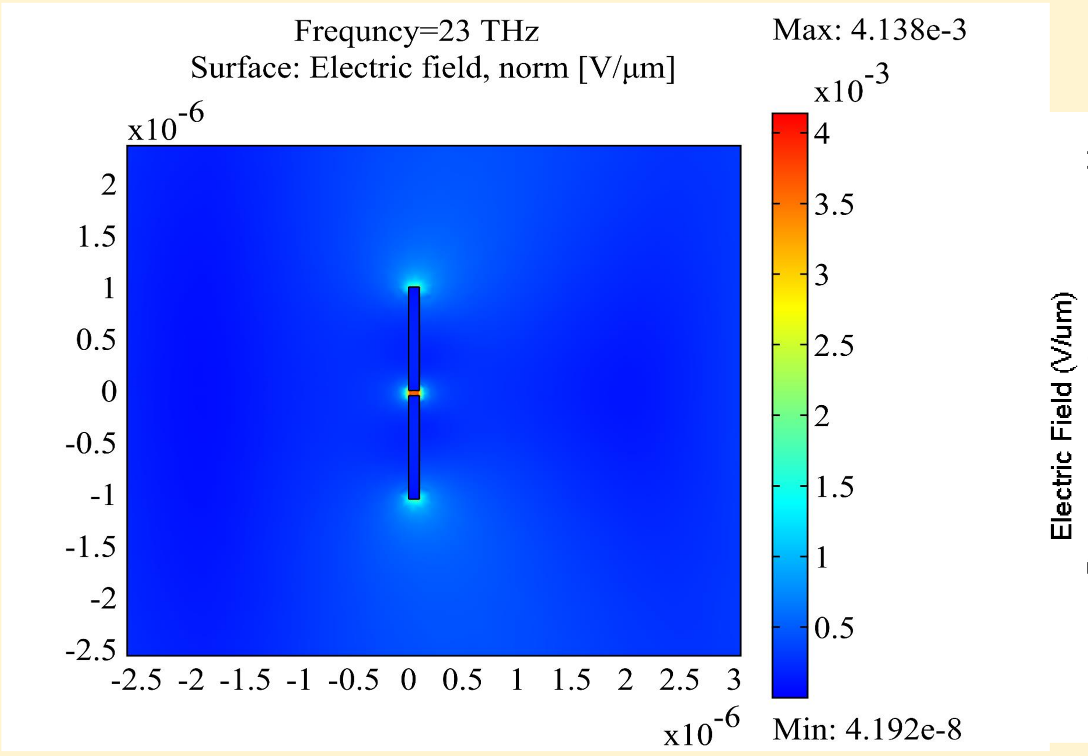



Fig.2 Electric field concentration in the gap of dipole antenna.

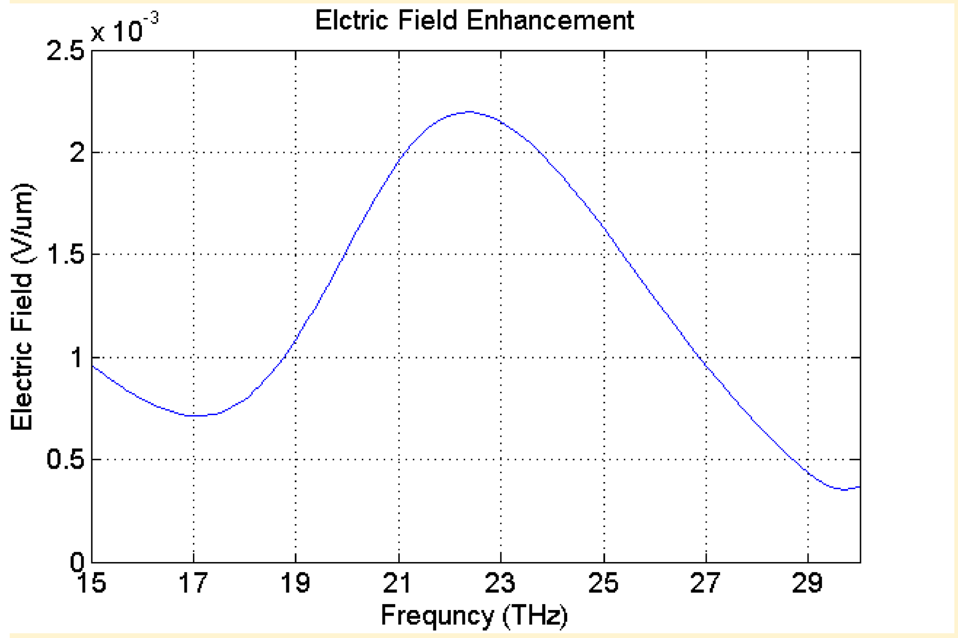



Fig. 3. Electric field along the gap of the dipole nanoantenna versus the wavelength.

## ❖ Bowtie THz antenna

The simulations were performed by launching a plane wave at normal incidence with an electric field magnitude of (1V/m) and polarized along the antenna axis, and the electric field across the feed gap of the antennas has been calculated.

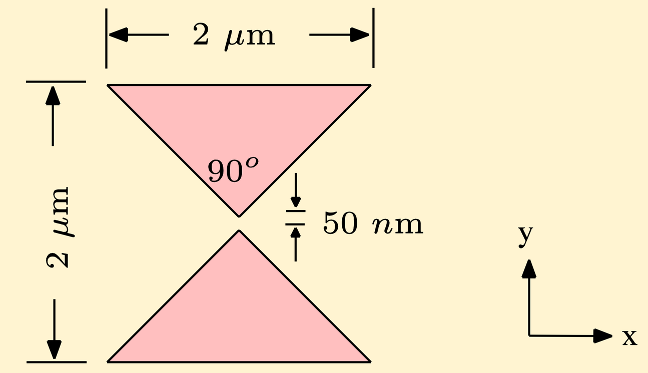



Fig. 4. Configuration of the THz bowtie antenna.

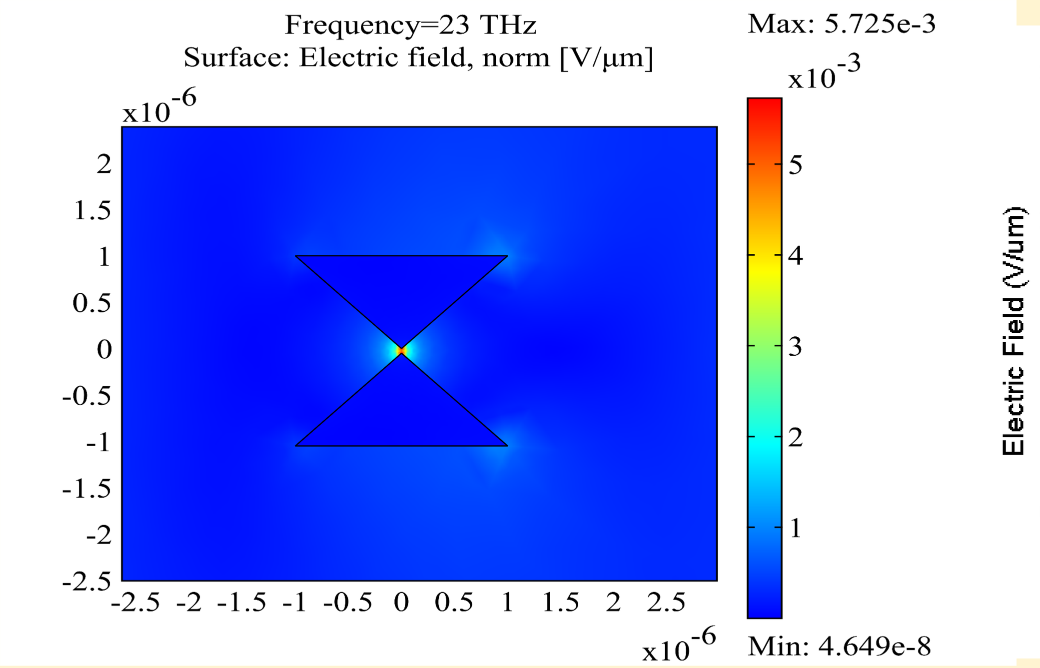



Fig. 5. Electric field concentration in the gap of bowtie antenna.

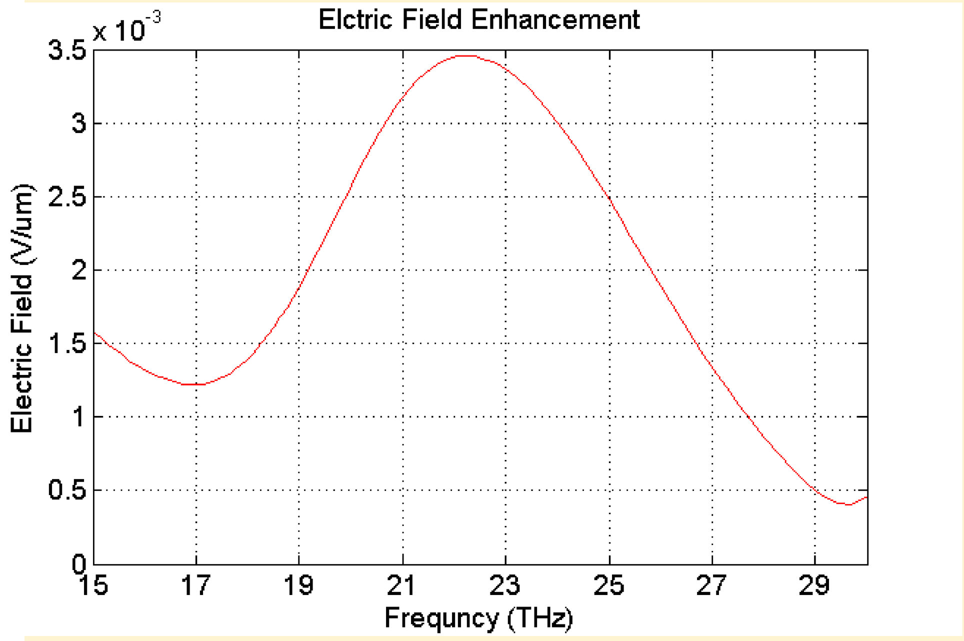



Fig. 6. Electric field along the gap of the bowtie nanoantenna versus the wavelength.

## ❖ Spiral THz antenna

Fig. 7. Configuration of the THz square spiral; antenna.

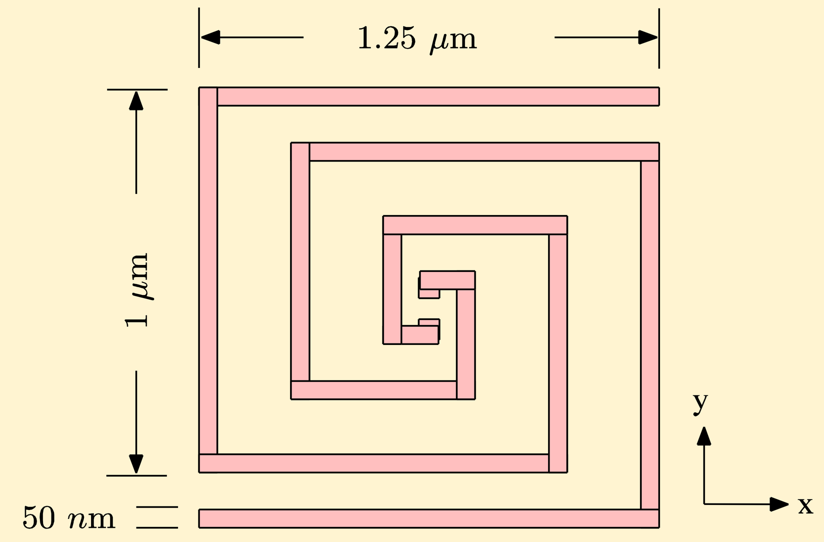



Fig. 8: Electric field concentration in the gap of square spiral antenna.

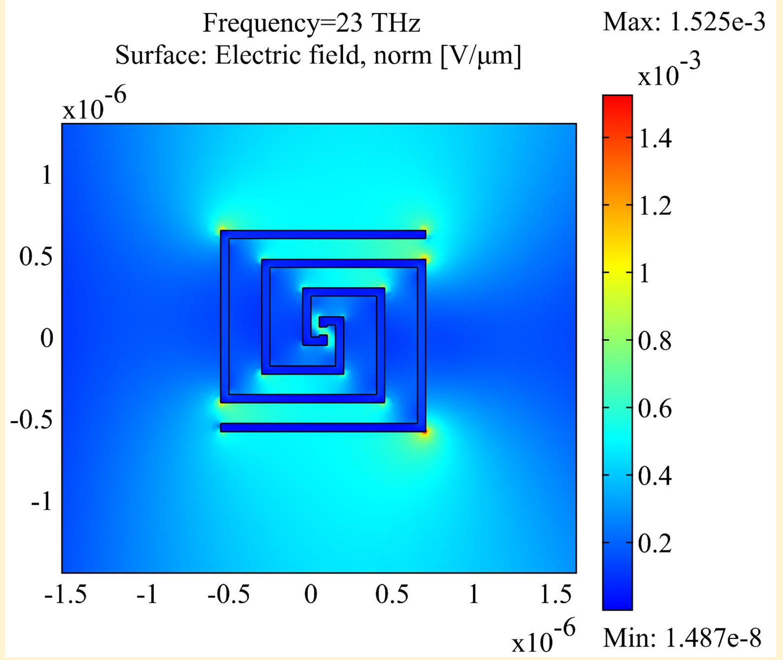
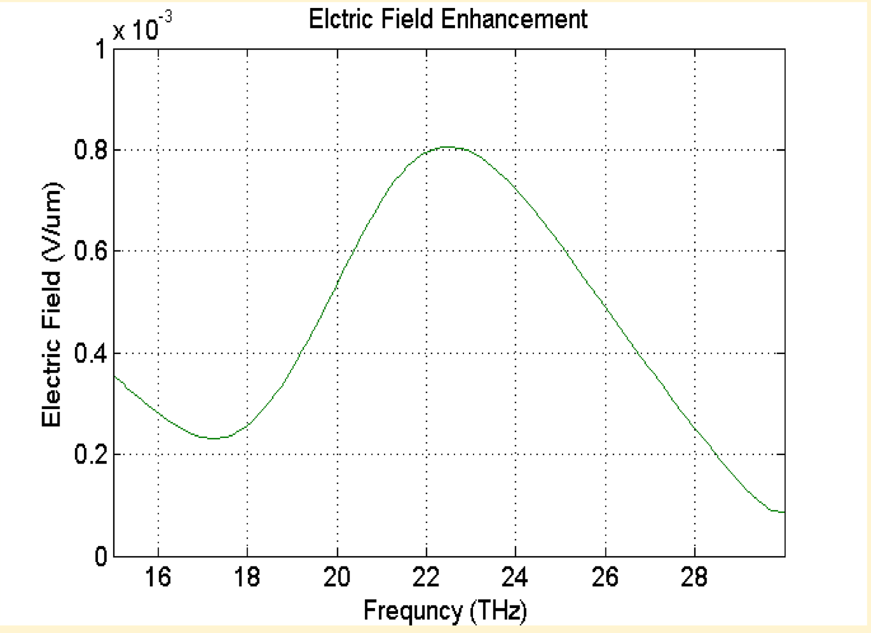



Fig. 9: Electric field along the gap of the square spiral nanoantenna versus the wavelength.




## ❖ Conclusion

In this work, three semiconductor THz antennas, i.e. dipole, bow-tie, and spiral, have been investigated for sensing and energy collection applications exploiting the drawbacks of multicrysalline silicon (i.e high iron impurity). A comparison between their performances has been presented. The results showed that the bowtie THz antenna exhibited the largest captured electric field at resonance, which is also demonstrated the widest bandwidth amongst them. These antennas can be used in harvesting infrared energy from solar radiation or waste heat using nano-rectennas. In addition, nano-rectennas can replace batteries in low-power wearable devices by drawing energy generated from body heat, or ambient radiation. Moreover, these nano-antennas can be used in gas sensing.