The Effect of Graphene on Asymmetric Split Ring Resonators

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Overview: Asymmetric Split Ring Resonators (A-SRRs) can be used as a type of metamaterial base unit. They are highly sensitive to red shifts in frequency due to their sharp resonances. In this project the resonant behaviour of A-SRRs in the mid-infrared region was studied using Simulations and the effect of applying a layer of carbon on top of A-SRR arrays was to be studied using Infrared Fourier Transform (FTIR) Spectroscopy.

Background

Metamaterials
- Synthetic materials constructed from arrays of micro and nano-sized structures which act as “artificial atoms”.
- The design of these structures can control how the metamaterials interact with light.
- This allows new electromagnetic phenomena to occur that are not possible with naturally occurring materials. [1]

Asymmetric Split Ring Resonators (A-SRRs)
- A type of “artificial atom” regularly used in the construction of metamaterials.
- Consists of two metal arms of different lengths separated by two gaps.
- The resonant response of A-SRRs makes them ideal for use as biosensors.
- Double Asymmetric Split Ring Resonators (DA-SRRs) are similar to A-SRRs but with two concentric rings.

Graphene
- A form of carbon with a 2D honeycomb structure.
- It’s unique properties make it extremely useful for optoelectronic applications.
- In the Mid-Infrared frequency range graphene has been shown to have a plasmonic, low loss response. [2]

Simulations

Simulations of A-SRRs and DA-SRRs were done using numerical FDTD solver to study the transmission spectra and electric field plots of the structures in the mid-infrared region.

5.6µm Resonance
- The Asymmetry of the structure allows the Trapped Mode to form. This is a resonance that is only weakly bound to free space ad therefore is very low loss. This results in resonances with steep gradients which are extremely useful for sensing. [3]

6.7µm Resonance
- Similar simulations were performed for DA-SRRs which resulted in two extra resonances at 4.3µm and 4.9µm and a 2nd trapped mode at 4.7µm.

Carbon Deposition

Carbon solution was deposited onto the samples by spinning. Measurements of the thickness, taken using the Dektak profiler, resulted in a variation between 250-500nm for most of the sample. Larger clumps could be as thick as several microns. If high uniformity is required another method would give better results, such as Chemical Vapour Deposition.

Conclusion

- The simulations confirmed the presence of the trapped mode and double resonances for this A-SRR geometry
- It has been shown that spinning graphene solution results in a non-uniform layer
- As the (FTIR) Spectrometer has been down for the duration of this project no spectra of fabricated A-SRRs and DA-SRRs were able to be made.

References

Fabrication

(1) Cleaning Samples - The Zinc Selenide substrates were cleaned using Acetone and Isopropyl Alcohol.
(2) Spinning Resist - PMMA 2010 was spun first before baking for 30 minutes. PMMA 2042 was spun on top and the sample was baked for a further 2 hours
(3) Patterning - Electron beam lithography was used to pattern the samples (after an Al charge dissipation layer had been added by evaporation)
(4) Development - The unwanted areas of resist were removed using IPA:MIBK heated to 23˚C.
(5) Deposition of Metals - The Plassys E-beam evaporator was used to deposit 10nm of titanium (as an adhesion layer) and then 100nm of gold.
(6) Lift-off - Warm acetone was used to remove the remaining resist and, with it, the unwanted metal.

An SEM image of a fabricated A-SRR
An SEM image of an Array of DA-SRRs

References