Graphene Processing for Tunable Metasurfaces

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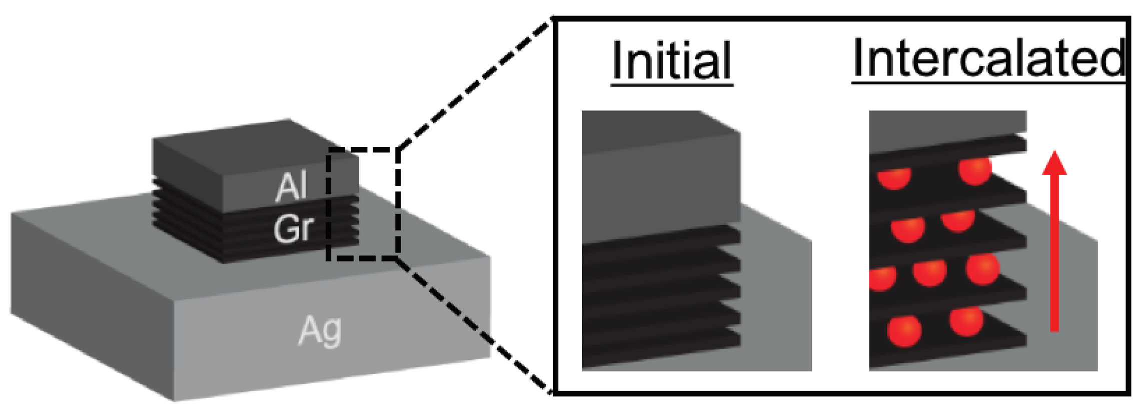
Abstract

Metamaterials enable optical properties that cannot be found in nature. Through the use of graphene intercalation, we seek to create a tunable perfect absorber metamaterial that can be used for low power visible displays. A design for this metasurface has been developed; however, the graphene processing and characterization for the design have not been fully explored. Here, we study exfoliation techniques and etch rates of graphene for fabrication of the metasurface.

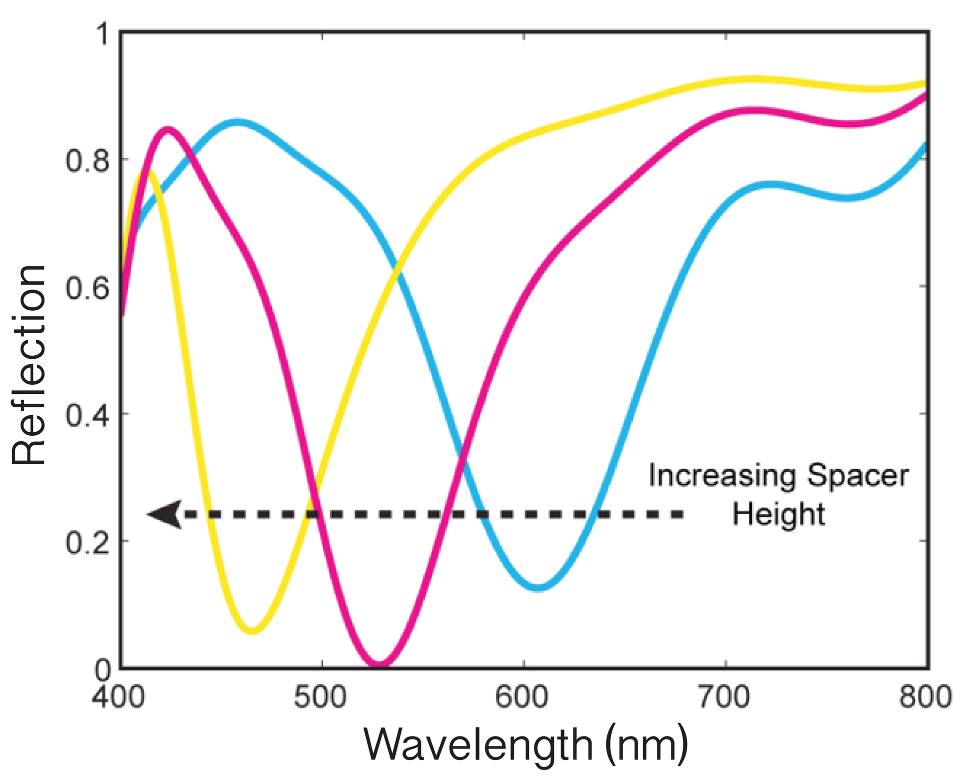
Metamaterial Modeling

Metallic Metamaterial

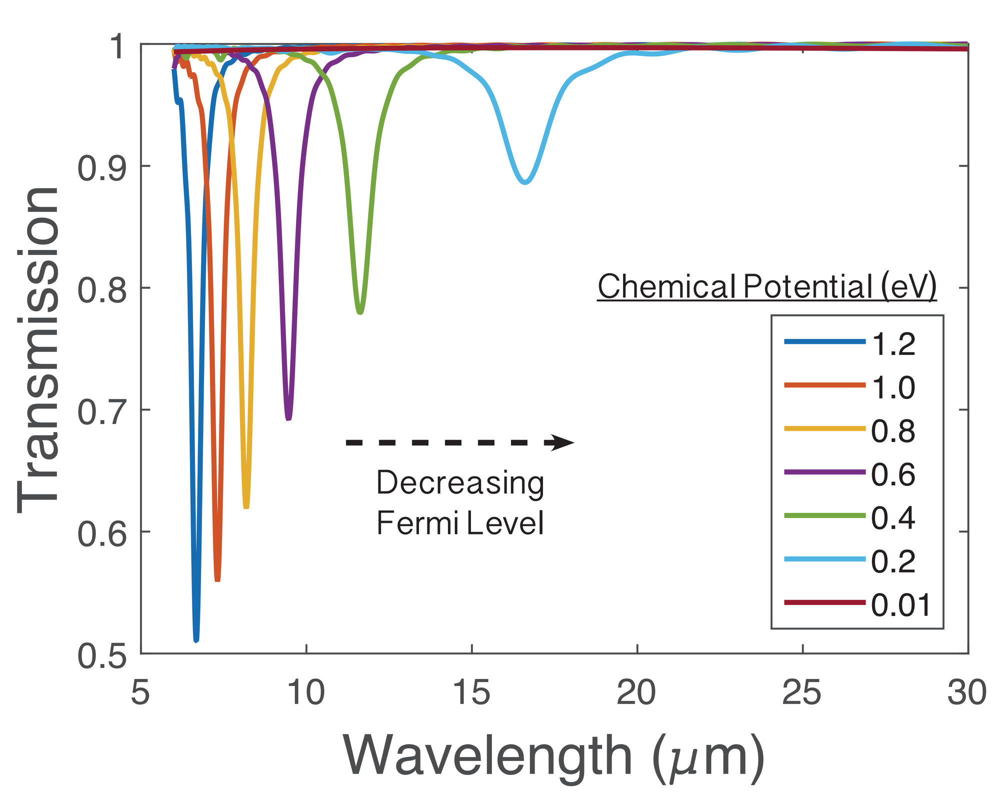


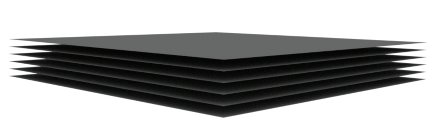
Schematic of unit cell with intercalation of sodium ions.

Simulated reflection curves for metamaterial unit cell. As intercalation occurs, the spacer height increases making the color change.



Non-metallic Metamaterial





Schematic of 6 graphene sheet unit cell used for simulation.

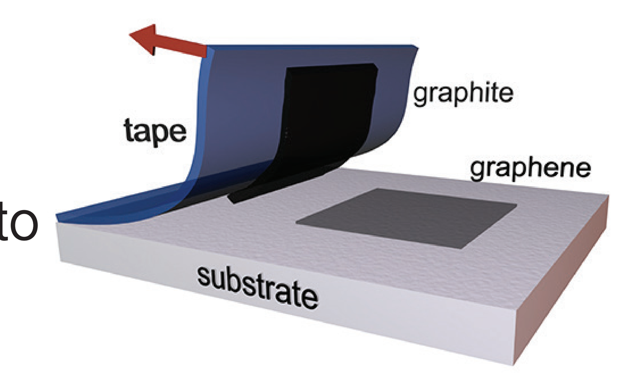
Simulated transmission for 6 graphene sheets at decreasing fermi levels.

Fabrication Procedure

- Use graphene exfoliation to transfer layers of graphene onto aluminum samples
- Etch graphene with argon sputtering to increase the speed of diffusion of sodium ions during intercalation
- Measure the step heights of the graphene flakes using AFM to determine etch rates

Graphene Exfoliation

1. Clean sample.
2. Remove graphene layers from graphite with adhesive tape.
3. Use tape to transfer graphene onto sample.
4. Anneal at 100° C for 2 minutes.
5. Slowly remove adhesive tape leaving behind graphene.



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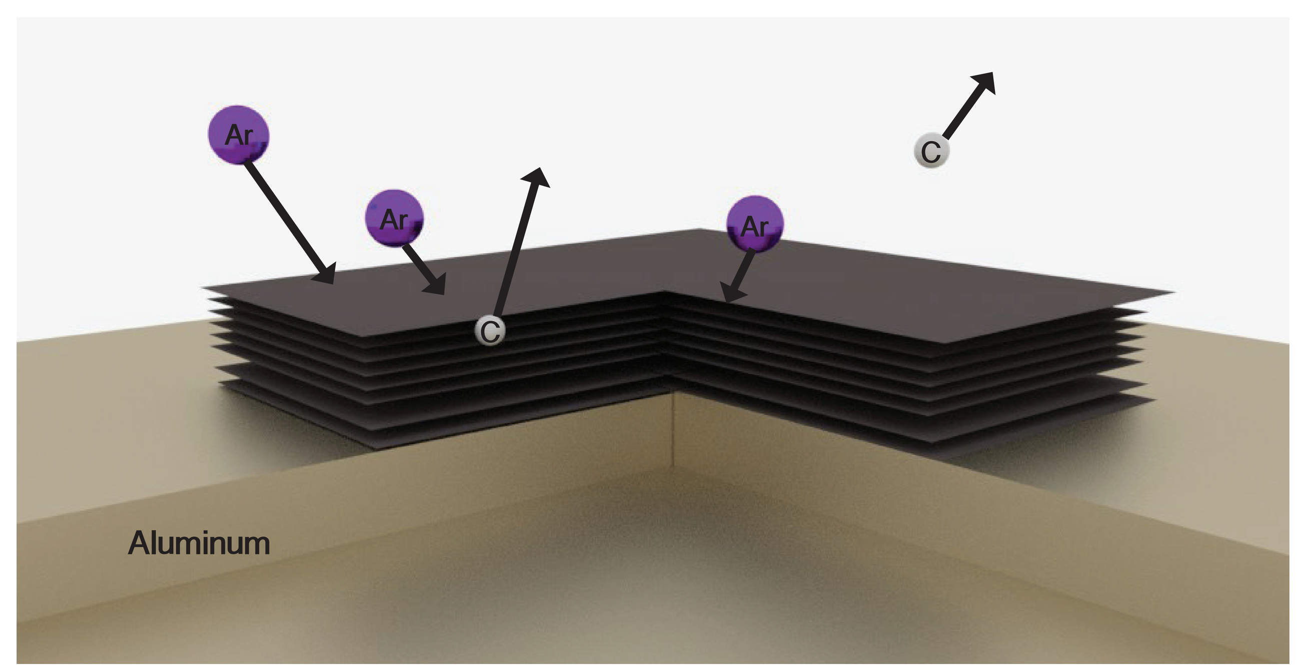
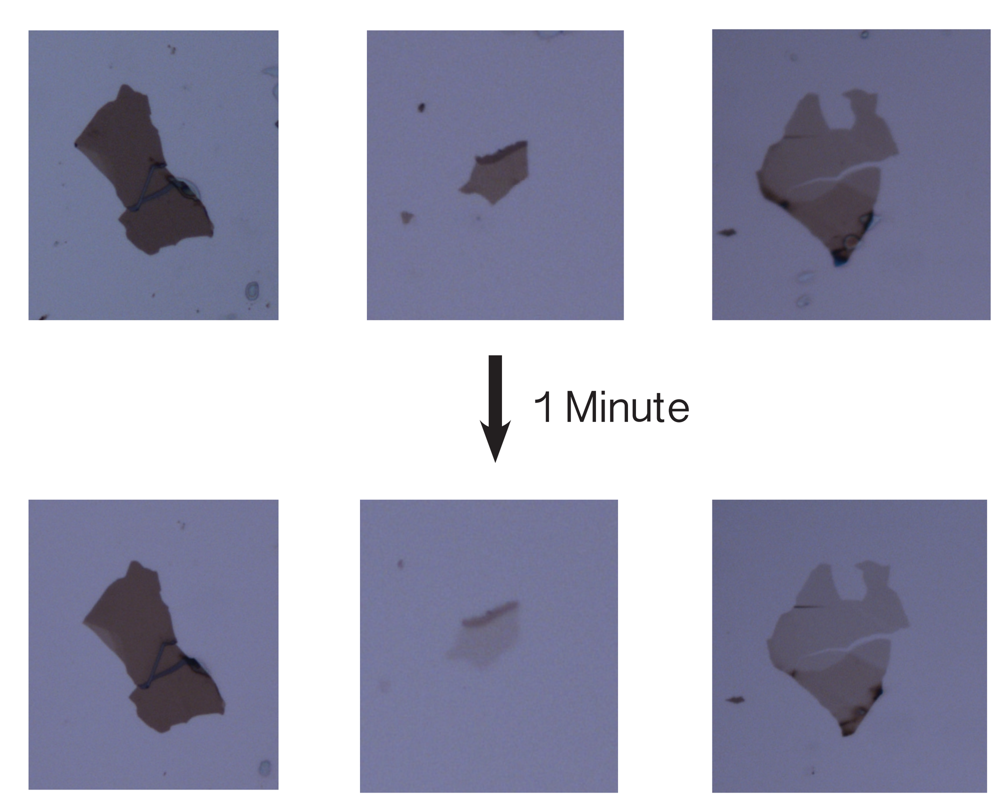
Argon Etching of Graphene



Etching Parameters: RF Power = 19W, ICP Power = 300W, Flow rate = 100 s.c.c.m., Table temperature = 10K, Pressure = 50mTorr

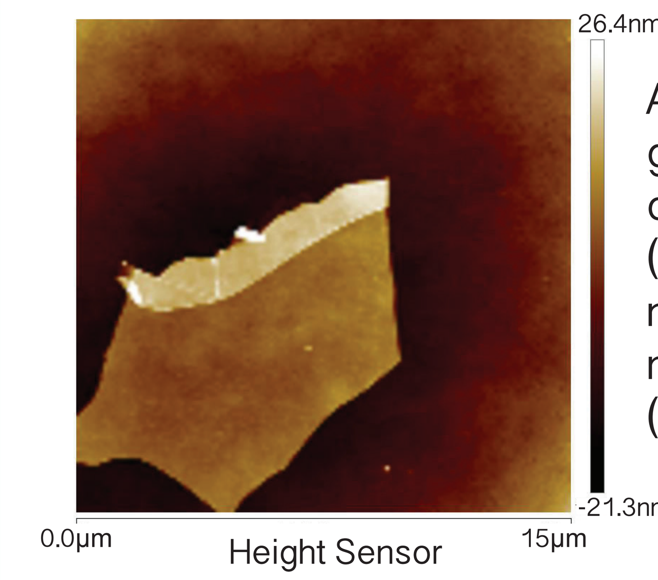
Before Etch



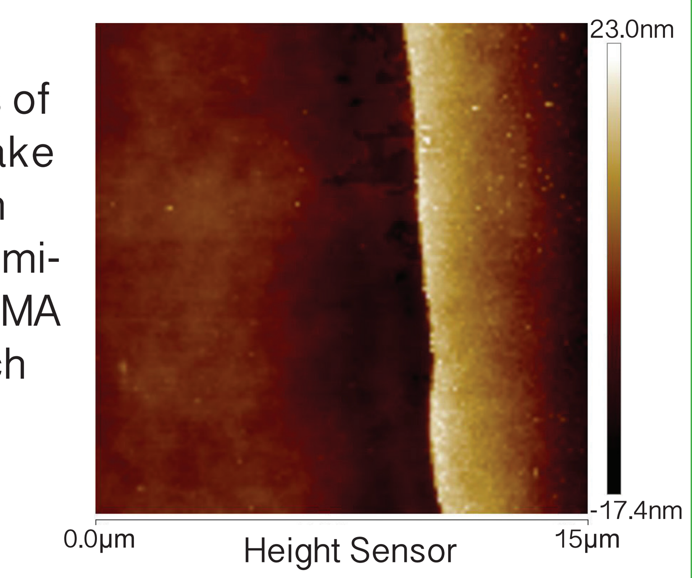
After Etch

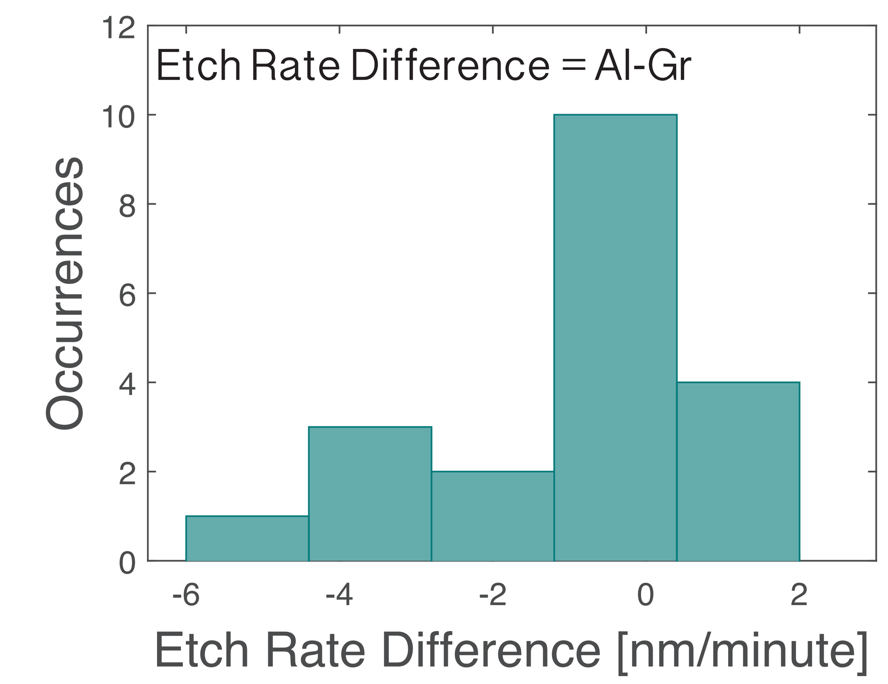
6 nm graphene appear etched in 1 minute

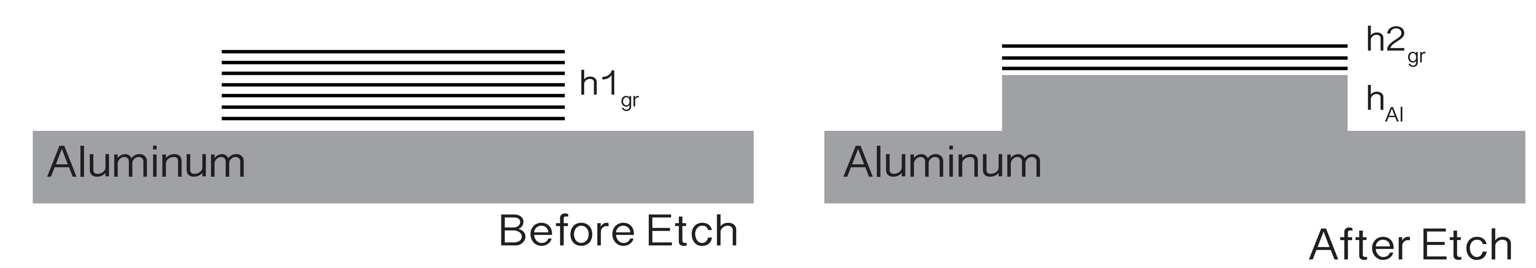
Results



AFM images of graphene flake on aluminum (left) and aluminum with PMMA mask for etch (right).







- Graphene and Aluminum etch at about the same rate
- Etch Rate of Al = 0.8nm/min, however this is only based on one sample and should be verified

Conclusion

By sputter etching samples of aluminum and graphene we find that they both etch at 0.8nm/minute. This meets our expectations because sputter etching is a nonreactive method that will etch the sample if the surface binding energies are less than the kinetic energy of an incoming argon ion [2]. This research will be used in the fabrication of both metallic and non-metallic metasurfaces for low power displays.

Acknowledgements

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References:

[1]Laboratory for Graphene, Institute of Physics Belgrade, Serbia. http://www.graphene.ac.rs/exfoliation.html.
[2]Kudriavtsev, Y., Villegas, A., Godines, A., & Asomoza, R. (2005). Calculation of the surface binding energy for ion sputtered particles. Applied Surface Science, 239(3), 273–278. https://doi.org/http://dx.doi.org/10.1016/j.apsusc.2004.06.014