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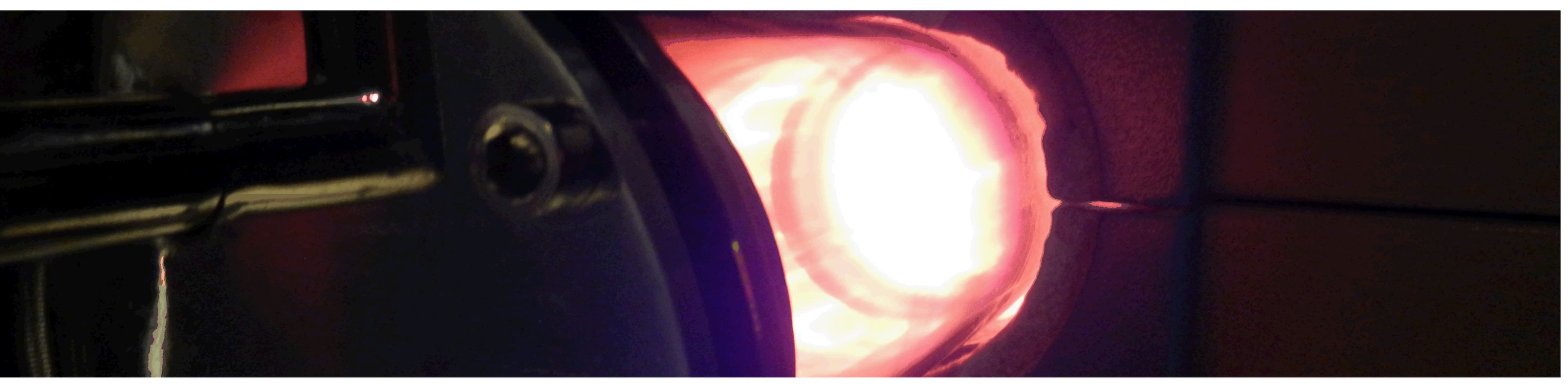

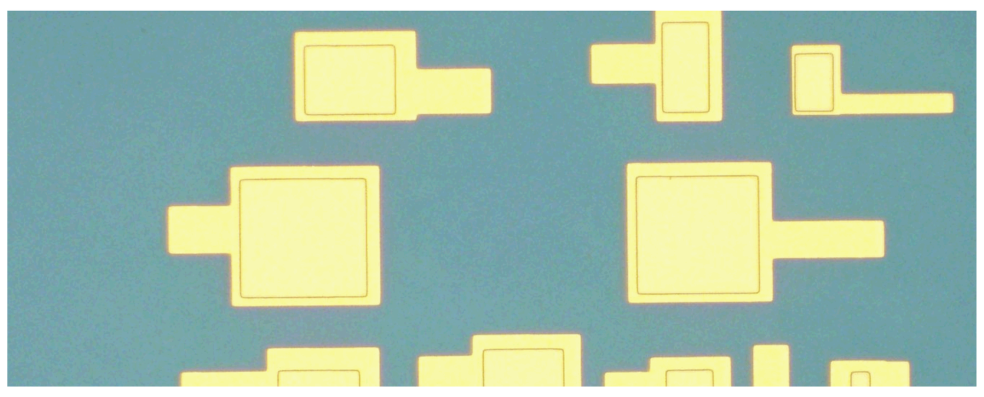

Optical Visibility of Passivated Graphene Films

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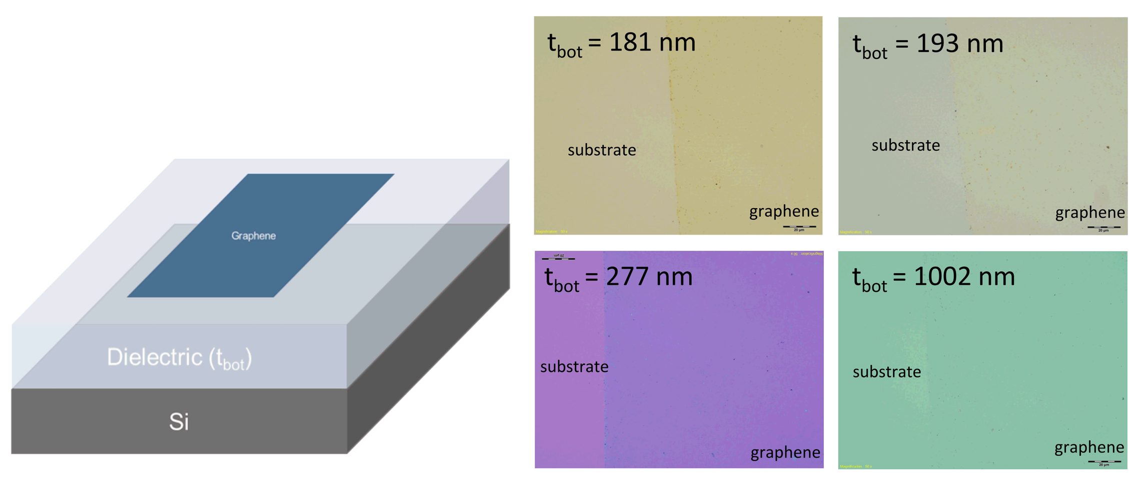
Abstract

Graphene is affected by direct exposure to the atmosphere, resulting in variability of its properties. Thus, any serious application will require a passivation layer over the graphene in order to eliminate any film variability. The visibility of graphene buried in dielectric is still important for characterization and failure analysis purposes. Here an optical contrast model of passivated graphene films is developed to determine it visibility against the bare substrate. Graphene is then synthesized by chemical vapor deposition (CVD) and is buried in varying top and bottom thickness of SiO_2. This allows a path forward to characterize graphene films and devices after they have been fabricated.

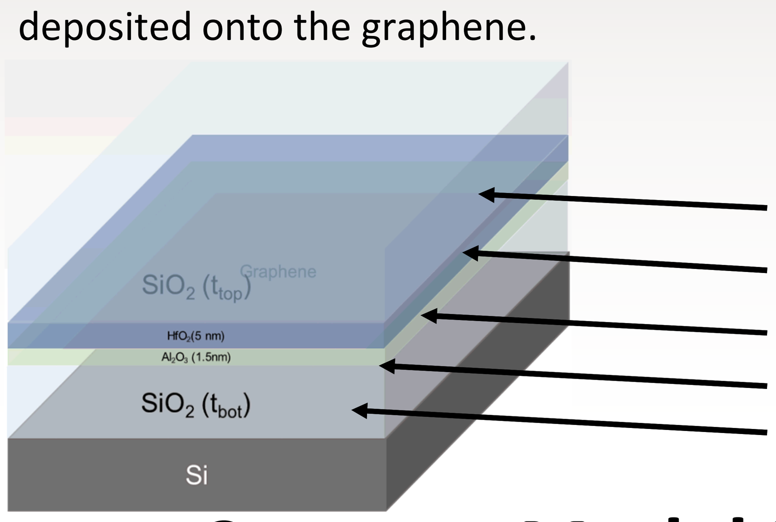
Optical Contrast of Graphene



Graphene only absorbs 2.3% of light, thus is practically transparent. However, when placed on a dielectric, its contrast against the dielectric varies significantly. The contrast of exposed graphene on top of various dielectrics has been studied extensively but the same is not true for dielectrically encapsulated graphene. Here we aim to study the visibility of graphene when sandwiched between two dielectrics and show that the top dielectric layer can be tailored to vary the graphene visibility.

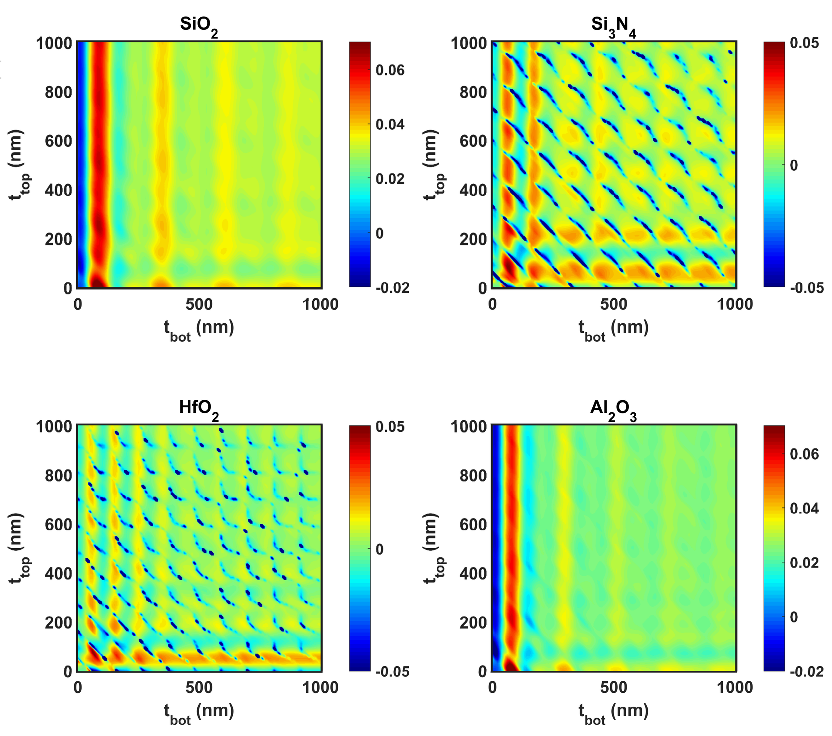
Experimental Passivation

Depositing a dielectric onto graphene directly is challenging. The dielectrics will tend to not grow on the graphene or will Furthermore, some of the deposition processes can be detrimental to the graphene film. For instance, in the case of depositing a dielectric through plasma enhance chemical vapor deposition (PECVD), the environment in the chamber may damage or destroy the graphene through ion bombardment or chemical etching before the dielectric can be deposited onto the graphene.

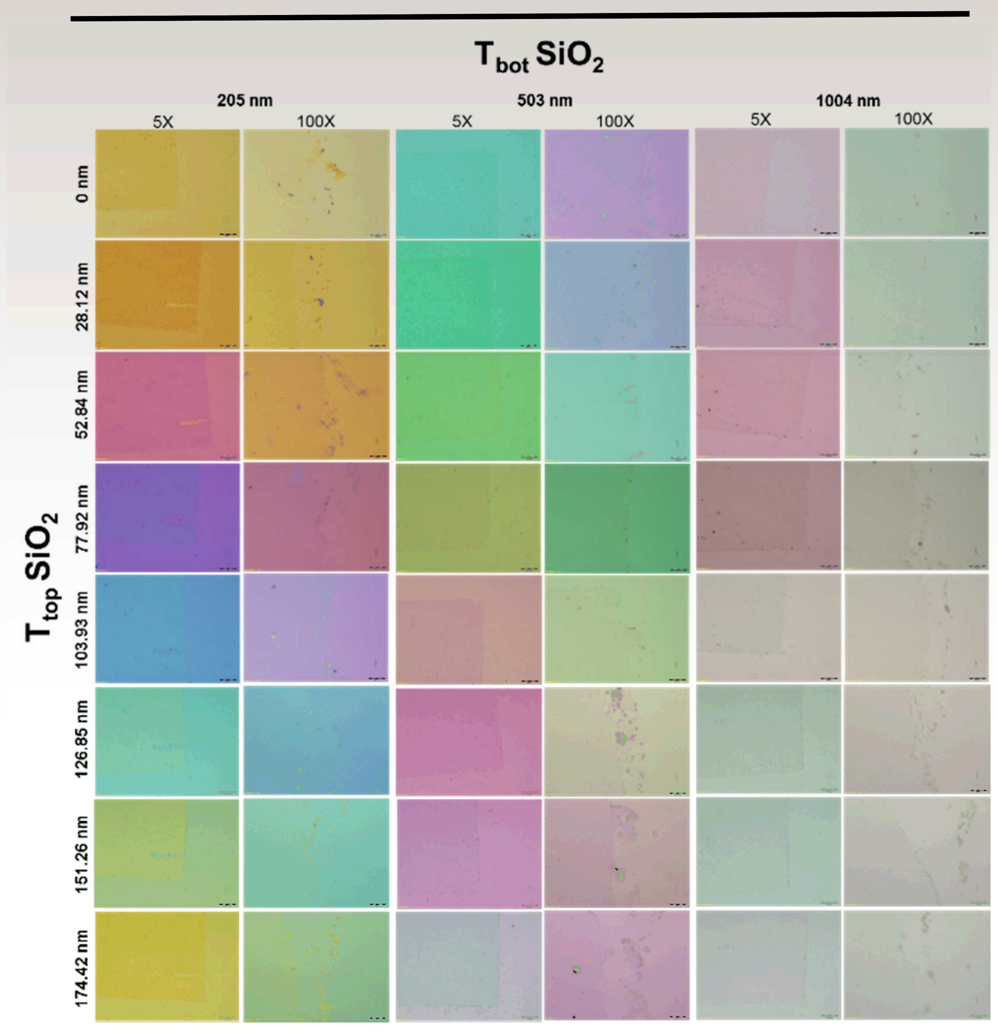


Contrast Model Results

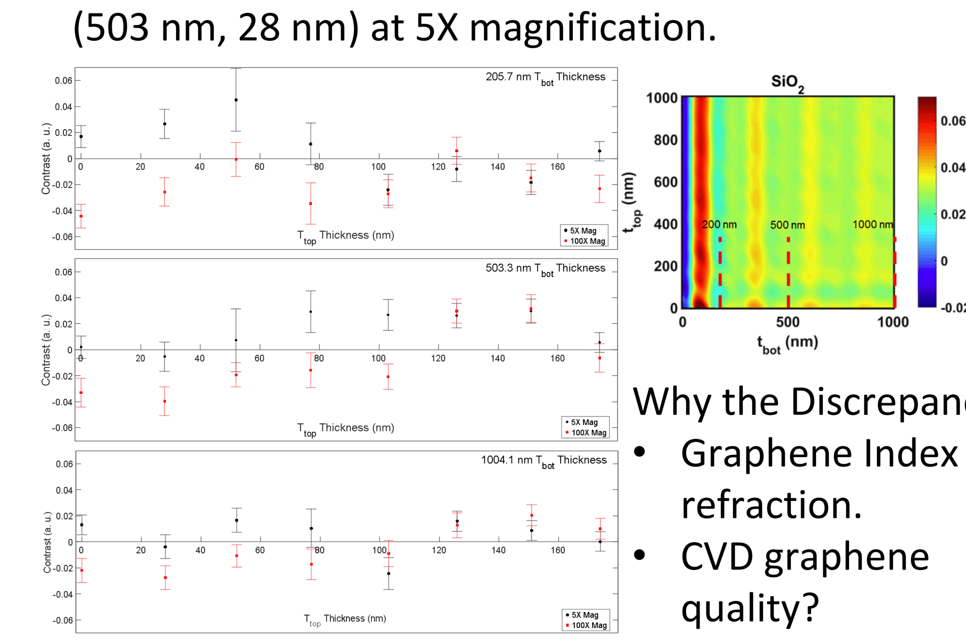
The contrast map for SiO_2 is in good agreement with what has previously been recorded in literature. For SiO_2 and Al_2O_3 the parameter to control contrast appears to be t_{bot}. In the cases of Si_3N_4 and HfO_2 however, the contrast maps show a much more interesting pattern. It can be seen that the contrast can be varied between dramatically with either t_{bot} or t_{top}.



Results



When the substrate appears pinkish the graphene contrast is high and is easy to visualize such as the case of (t_{bot}, t_{top}) equal to (205 nm, 52 nm), (503 nm, 103 nm), (503 nm, 126 nm) at 5X magnification. On the other hand, when the substrate appears to be green the graphene contrast against the substrate is low and is difficult to spot as in (205 nm, 126 nm), (503 nm, 0 nm) and (503 nm, 28 nm) at 5X magnification.



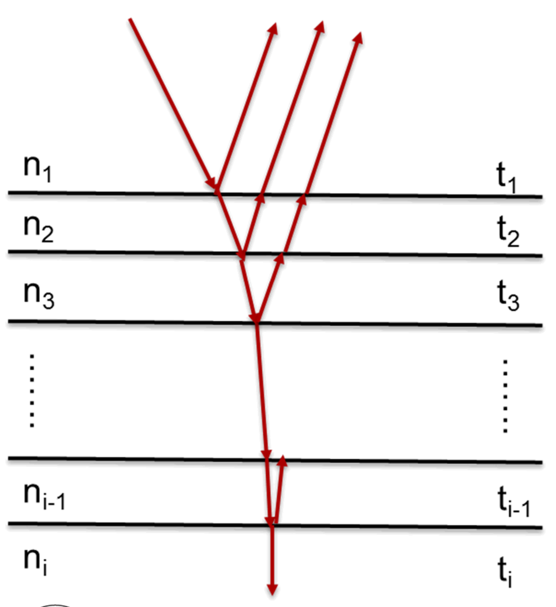
Why the Discrepancy?

- Graphene Index of refraction.
- CVD graphene quality?

Optical Model and Reflection Spectra Measurement

Using a transfer matrix method the reflected light through various stacks of solids can be calculated. The reflection spectra (R) can be calculated as shown below. The important parameters are the material thicknesses and index of refection as well as the lights angle of incident and wavelength.

General



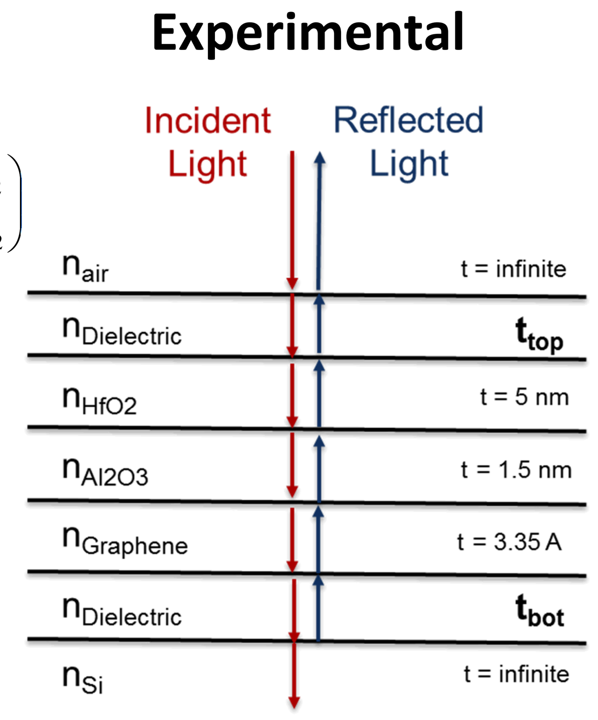
$$S = H_{1,2}L_2H_{2,3}L_3 \ldots L_{n-1}H_{n-1,n} = \begin{pmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{pmatrix}$$

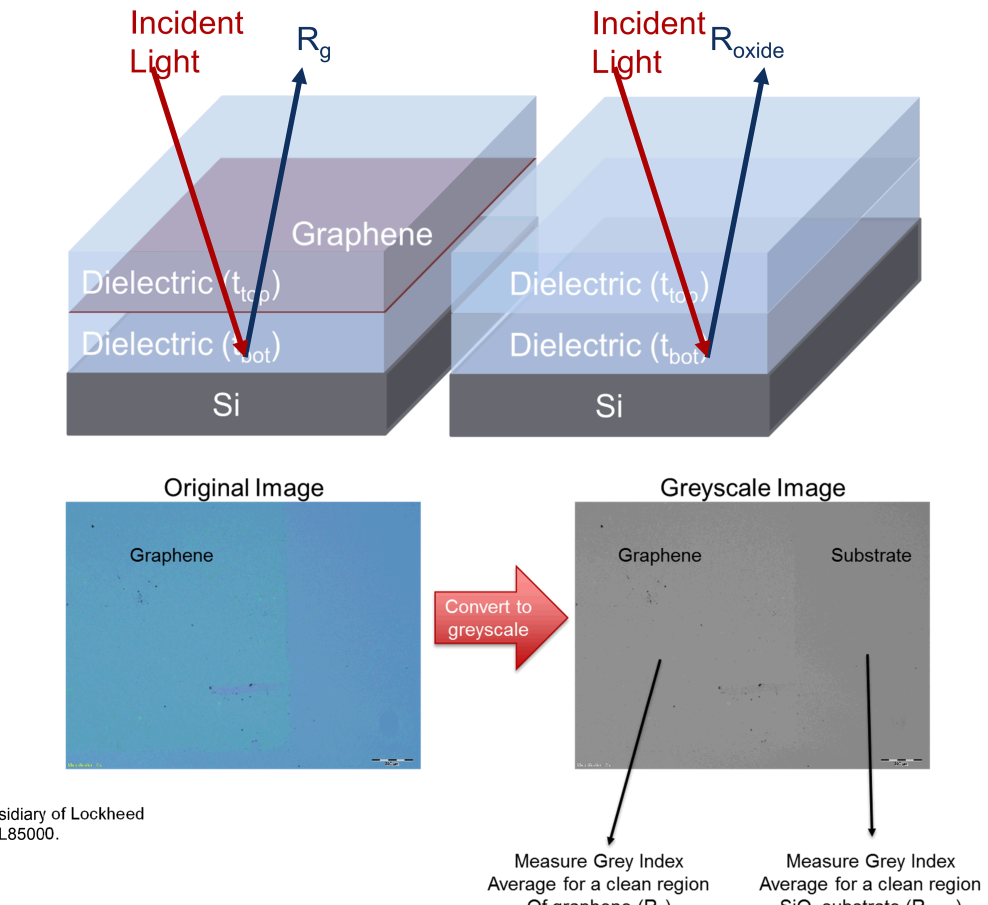
$$R_k = \left| \frac{s_{12}}{s_{22}} \right|^2$$

$$C = \frac{R_{oxide} - R_g}{R_{oxide}}$$

To calculate and experimentally measure the contrast the reflectance of the stack with graphene(R_g) and without graphene (R_{oxide}) need to be calculated. This is done by measuring the contrast separately in the two different regions. Experimentally the contrast is measured using a white light and converting the images to greyscale.

Experimental





Conclusion

We have developed realistic stacking configuration for buried graphene between dielectrics. We theoretically modeled the contrast of graphene using a transfer matrix method consisting of 7 layers for varying thicknesses of SiO_2, Si_3N_4, HfO_2 and Al_2O_3. Passivated graphene stacks were fabricated experimentally for various t_{bot} and t_{top} values and it was shown that the experimental results did not match the model. In future work it may be useful to experimentally build passivated graphene stacks out of the other dielectrics, such as Al_2O_3 or HfO_2, as they reduce the number of necessary layers and simplify the transfer matrix model, possibly resulting in a closer correlation between the experiment and model.

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