Midshipman Research Course: SP495/496/503/504 [Choose appropriate one]

Midshipman Name: W. T. Door **Alpha #: XXXXX**
Major: Physics/Astrophysics/Applied Physics [Choose] **Company:** XX

1. Title of Proposed Project

Orientational Control of Graphene and Giant Enhancement in Dielectric Anisotropy in a Liquid Crystal

2. Faculty Mentor: Associate Professor Rajratan Basu

3. Summary of Proposed Project

a. Problem to be addressed:

I will investigate the dielectric, electro-optical and mechanical properties of liquid crystal (LC)-graphene composite systems, pursuing the exploration of current themes of self-assembly and ordering of monolayer graphene flakes in LC platforms. To accomplish the proposed goals, I will utilize a wide variety of experimental tools, including (but not limited to) electro-optic and dielectric techniques available in the Soft Matter and Nanomaterials Lab.

b. Background Information:

When nanomaterials are dispersed in an LC, they self-organize themselves minimizing the free energy of the composite system, as well as share their intrinsic properties with the LC molecules through surface interactions, exhibiting novel phenomena, such as a non-volatile electromechanical memory effect, chiral-transmission, and a faster nematic switching — recently observed by Prof. Basu.

When Graphene (GP) flakes are doped in an LC cell, they align in 'sheet' structures that run parallel to each other. Our goal is to examine how the addition of monolayer GP flakes affects the dielectric anisotropy within the liquid crystals thus producing faster response times from an electro-optical perspective.

Last semester I worked with Prof. Basu in experimenting with monolayer + multilayer GP flakes in the LC and found that the electro-optic effects the LC +GP produced were much faster than the pure LC. We published our results in **Journal of Applied Physics** 117, 074301 (2015).

I will continue this project, exploring the separate effects for the monolayer and the multilayer graphene flakes on the LC's dielectric, elastic and electro-optic properties.

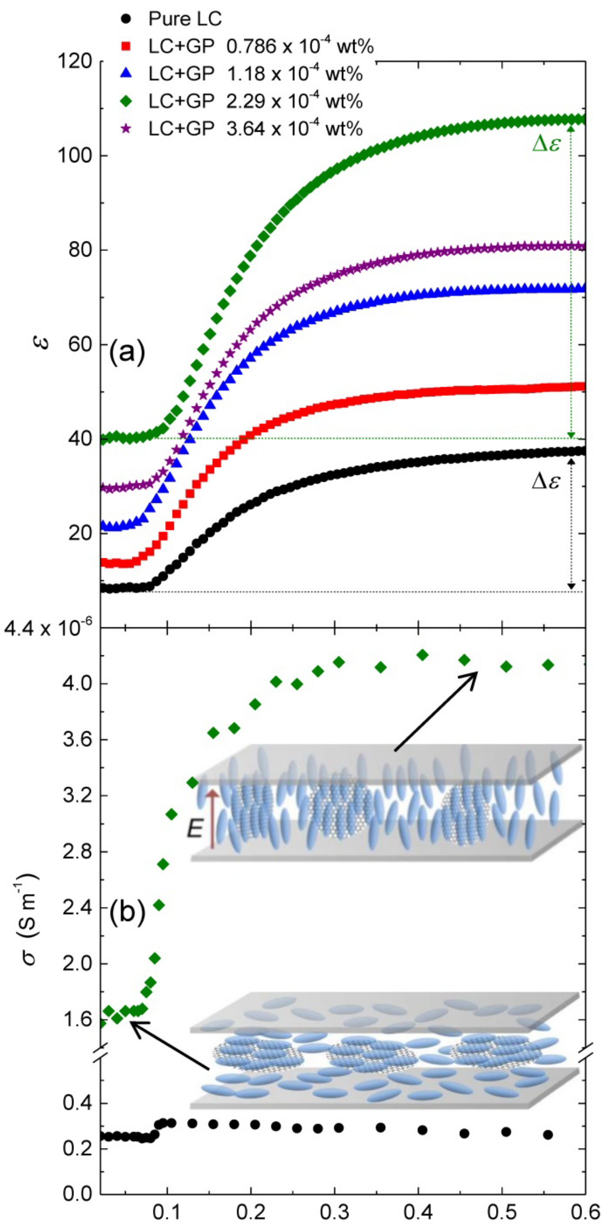

Figure 1: **(a)** Dielectric constant ε as a function of applied rms field $\vec{E}$ (f = 1000 Hz) in the nematic phase (T = 50 ºC) for the pure LC and LC + GP hybrids listed in the legend. This shows a typical Fréedericksz transition and an increase in the dielectric anisotropy $\Delta\varepsilon$ for the LC + GP hybrids. **(b)** Electrical conductance σ as a function of applied rms field $\vec{E}$ (f = 1000 Hz) in the nematic phase (T = 50 ºC) for the pure LC and LC + GP listed in the legend. The reorientation of the graphene flakes with the nematic director is shown in the inset schematics.

b. <u>Describe any preparatory work undertaken by the midshipman research student:</u>

Preparations began in the fall semester of 2014 in the Soft Matter and Nanomaterials Lab. I worked hands-on in the lab, performing experiments on the electro-optic switching phenomenon of the nematic phase and analyzing the experimental data. I spent a good amount of time studying the online resources available for liquid crystals. I continued my work with an SP496 with Prof. Basu the following semester (Spring 2015) and have learned how to operate other software and instruments that are used in the Soft Matter and Nanomaterials Lab.

c. <u>Abstract and Details of the Research Proposal:</u>

Our preliminary studies on dielectric and conductance properties of monolayer GP-doped LC indicate that the flat surface of GP couples to the LC-nematic director and can be oriented in a particular direction by applying an electric field, as shown in Figure 1. With this motivation, we will conduct a systematic investigation on the LC's electro-optic and mechanical properties to study how the liquid crystalline properties are modified by the nano-electromechanical rotation of monolayer GP flakes in the LC.

We will use electro-optic tools to study the field induced switching phenomena of several LC+GP composites. The dielectric and viscoelastic properties of the composites will be characterized using an Automated Liquid Crystal Tester which is attached to a thermal stage.

The scientific impact of this project will be very strong in understanding the basic science behind the interactions of liquid crystals with graphene and the basic soft matter physics about nanoscale LC alignments at the graphene surface.

4. Research Facilities:

a. Primary Facilities and Equipment (type and location) to be used:
Soft Materials and Nanomaterials Lab for Analysis at USNA

b. Available at USNA? Yes.

c. Available nearby? N/A

d. Can be borrowed? N/A

5. Published Material Available:

P. Blake, P. D. Brimicombe, R. R. Nair, T. J. Booth, D. Jiang, F. Schedin, L. A. Ponomarenko, S. V. Morozov, H. F. Gleeson, E. W. Hill, A. K. Geim, and K. S. Novoselov, Nano Lett. **8**, 1704 (2008).

Y. U. Junga, K. W. Parka, S. T. Hura, S. W. Choia, and S. J. Kanga. Liq. Cryst. **41**, 101 (2014).

R. Basu, Applied Physics Letters **105**, 112905 (2014).

A. Malik, A. Choudhary, P. Silotia, A. M. Biradar, V. K. Singh, and N. Kumar, J. Appl. Phys. **108**, 124110 (2010).

6. Requirement for Access to Classified Material: Not Required

7. Access to Special USNA Facilities: N/A

8. Estimate of Costs:

	FY-Fall Semester	FY-Spring Semester
a. Midshipman Travel:	N/A	
b. Midshipman per diem:	N/A	
c. Consumable Supplies:	N/A	
d. Equipment (over $200):	N/A	
e. Equipment (under $200):	N/A	
f. Other contractual services:	N/A	
Total:	$0.00	

[*ANY SOFTWARE NEEDS? HARDWARE?*]

An oral presentation and a well-written report are end-of-course items normally required for passing the course.

Midshipman signature | **Adviser signature**

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