Formulation of a Graphene Based Ink for Inkjet Printing Wearable Electronics

Hayden Qualls
Advisor: Yijing Stehle
Mechanical Engineering, Union College, Schenectady NY

Background

Printable electronics and sensors are a new field of study that show great promise for wearable electronics. Graphene is a promising new material in the world of printable electronics because of its mechanical stiffness, strength and elasticity, very high electrical and thermal conductivity, transparency and impermeability [1].

Objectives

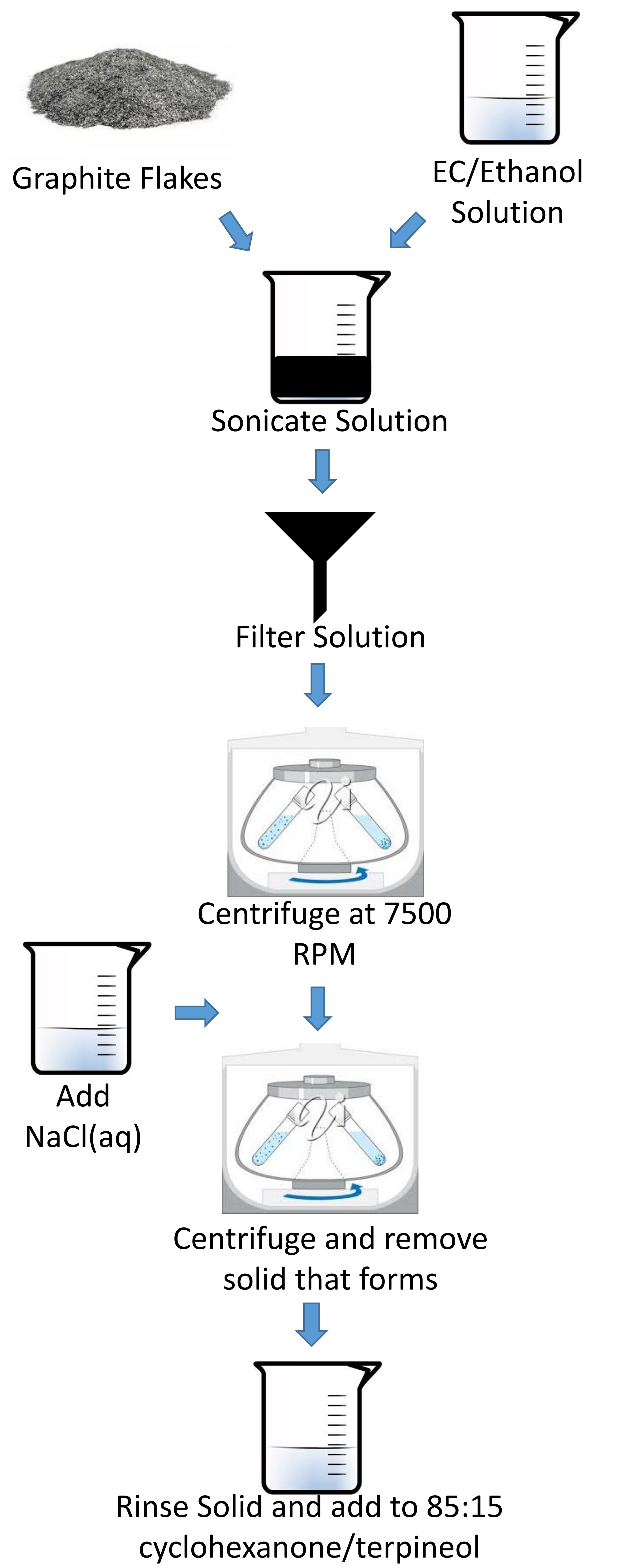
This project is focused on the formulation and property testing of a graphene-based ink. The formulation process was based on the methods of Secor et. al. [2] and Parvez et. al. [3].

A sample of the final ink that was created and tested

References

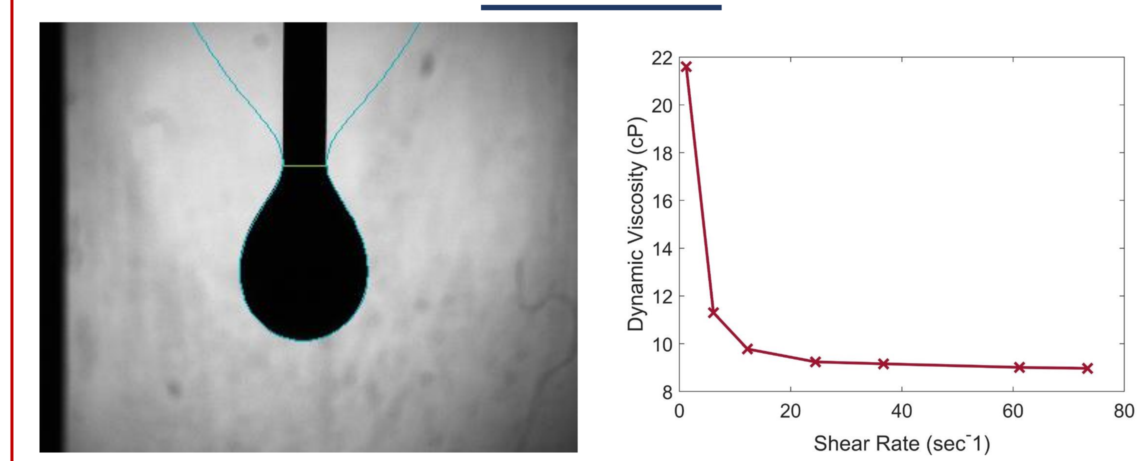
[1] Novoselov, K. et. al., (2012), "A roadmap for graphene," Nature, 490.
[2] Parvez, K. et. al., (2019), "Water-based and inkjet printable inks made by electrochemically exfoliated graphene," Carbon, 149.
[3] Secor, E. B. et. al., (2013), "Inkjet Printing of High Conductivity, Flexible Graphene Patterns," The Journal of Physical Chemistry Letters, 4(8).

Formulation

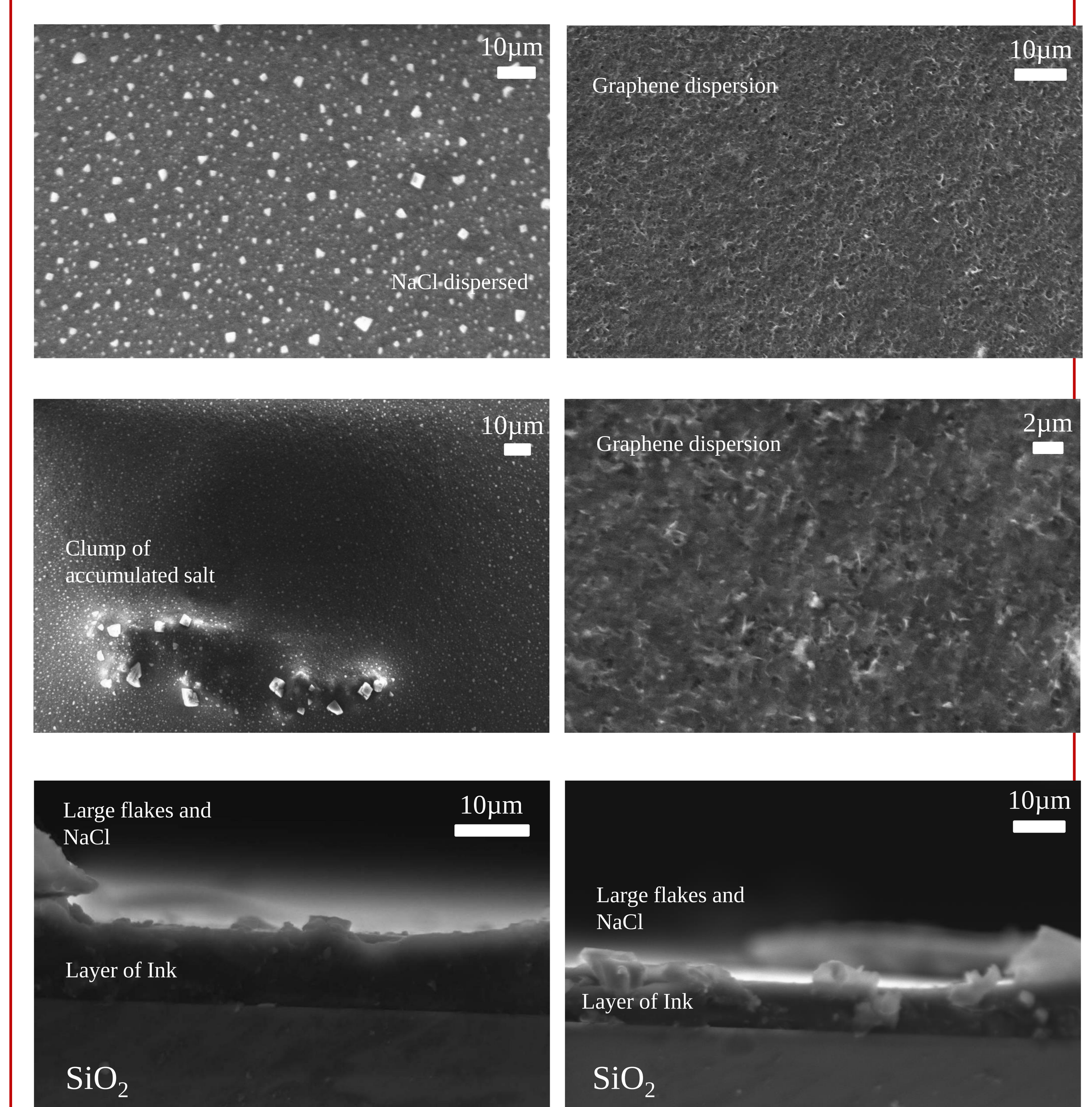


Step by step methodology for the formulation of the ink being tested and analyzed

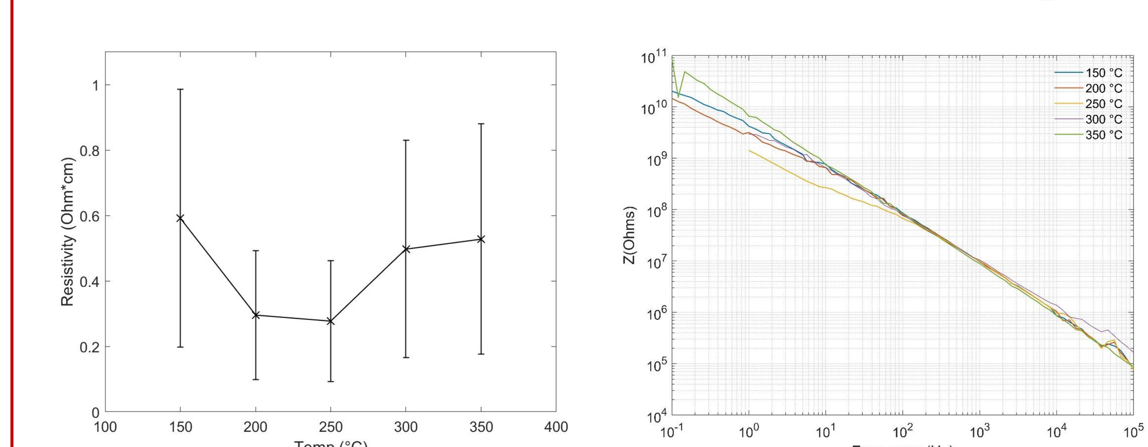
Results



Liquid ink characterization. Left shows the surface tension testing and the right shows dynamic viscosity plotted against shear rate



SEM images of dried samples showing good dispersion with some large flakes and NaCl still in the ink. Bottom two images show cross sections and thickness of two samples



Dried samples were annealed to remove EC. Left shows smallest resistivity reached at 250°C and left shows impedance for all annealed samples

Theoretical Printability

An inverse Ohnesorge number is typically used to determine the stability of the jetting that determines how successful the printing process will be($1<Z<10$ is a generally accepted range although this is not perfect). This dimensionless number is based on the dynamic viscosity, density, and surface tension of the ink as well as the nozzle diameter it will be printed through. Since this is only a theoretical calculation it is calculated at a variety of nozzle diameters.

		Z Value						
		Nozzle Diameter (μm)						
		10	20	30	40	50	60	70
Viscosity (cP)	21.6	0.787567	1.11379	1.36411	1.57513	1.76105	1.92914	2.08371
	11.3	1.505438	2.12901	2.6075	3.01088	3.36626	3.68756	3.98302
	9.78	1.739412	2.4599	3.01275	3.47882	3.88944	4.26067	4.60205
	9.24	1.841066	2.60366	3.18882	3.68213	4.11675	4.50967	4.871
	9.16	1.857146	2.6264	3.21667	3.71429	4.1527	4.54906	4.91355
	9.01	1.888064	2.67013	3.27022	3.77613	4.22184	4.62479	4.99535
	8.97	1.896483	2.68203	3.28481	3.79297	4.24067	4.64542	5.01762

Conclusion

The liquid ink shows good printability with a variety of nozzle sizes. The morphology analysis shows the NaCl and large graphite flakes are still in the final ink which if removed could improve conductivity. Annealing at 250°C for 30 min seems to be the optimal amount to breakdown the ethyl cellulose. Future work will be done to improve conductivity and remove these impurities before creating a humidity sensor using the ink.

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