Enhancing Stiffness and Damping in Graphene Oxide Films

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INTRODUCTION

Graphene oxide (GO) is a nanomaterial that can be used in various aerospace and automotive applications that require high damping and stiffness materials to combat cyclic loading conditions and fatigue. Already mechanically superior to metal matrix composites and other viscoelastic materials, GO also has the potential to be fine-tuned in its synthesis process to also exhibit exceptional damping properties.

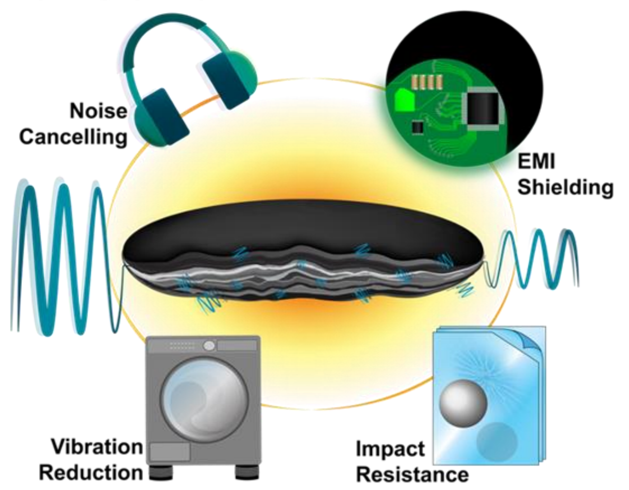

Fig. 1 The material properties of graphene oxide allow for a diverse range of potential applications

OBJECTIVE

"Fine-tuning" encompasses processing various GO samples under different ionic strengths and solvent flux. Increasing ionic strength and solvent flux in a GO dispersion reduces electrostatic repulsion, according to DLVO Theory, and accelerates nucleation rate leading to the agglomeration of GO sheets.

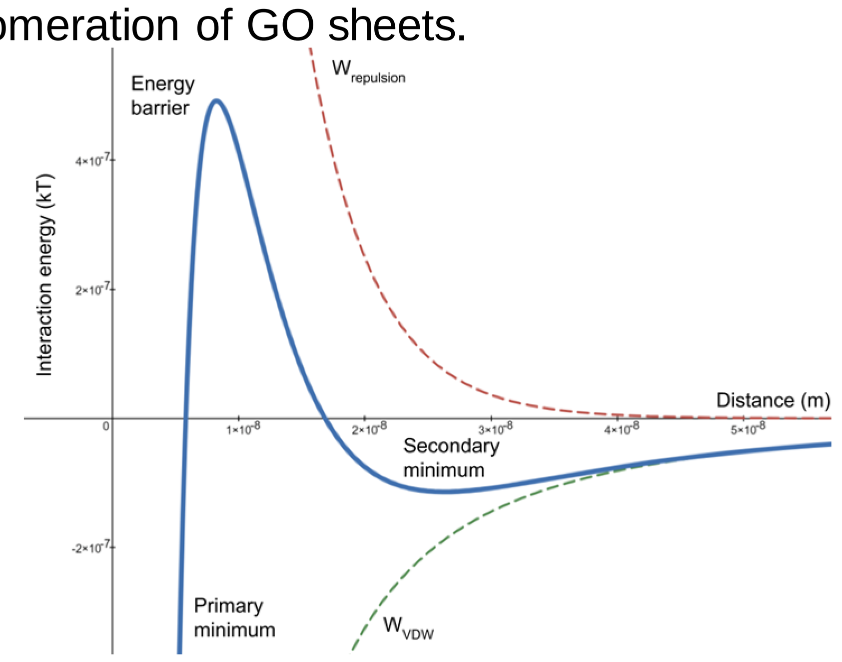

Fig. 2 DLVO graph with Hamaker constant, counterion number density, and zeta potential assumptions as a function of critical coagulation concentration (CCC)

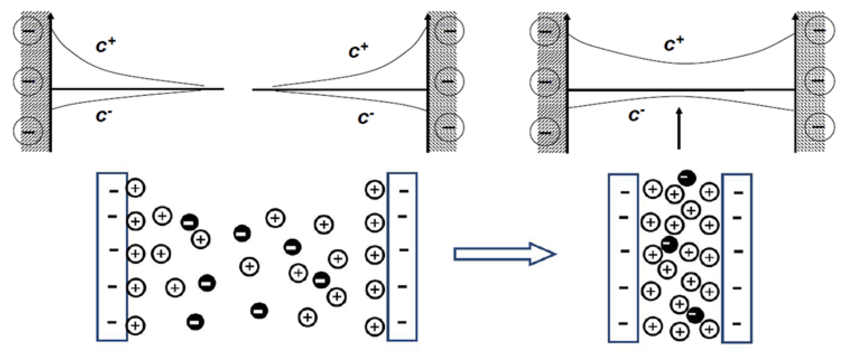

Fig. 3 Electrostatic repulsion [3] between two GO sheets showing how lower counter-ion concentration constitutes less ion screening and agglomeration/flocculation

FABRICATION

Centrifuge

- Centrifuged vials of 1 mg/mL (0.1% weight concentration) diluted crude GO to separate the multilayer graphitic flakes at 500G's for 5 minutes

Pressure Filter

- Filter-pressed supernatant in 60 psi pressurized container to separate GO from water/counterions using magnetic stir bar and magnetic stirrer (~8 hours/100 mL)
- Tried ceramic paper, glass wool, woven glass fiber

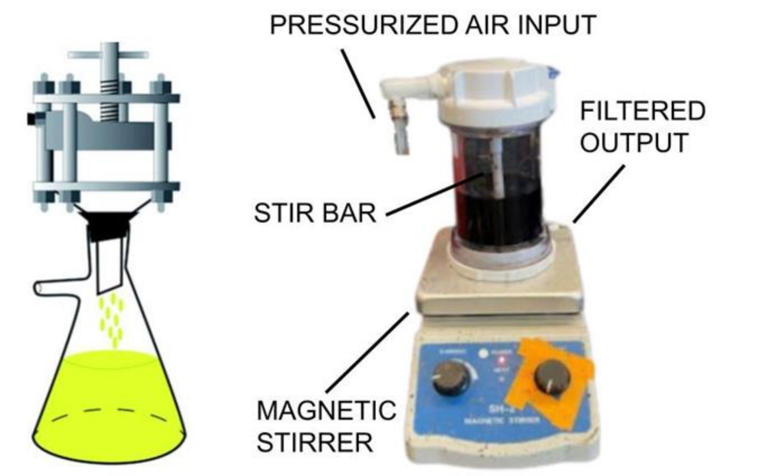

Fig. 4 Ideal filter press system [2] (left) and laboratory rendition (right)

Fig. 5 Bath sonication (left) that is used to re-disperse filter cake (right)

Titration and pH measurement

- Neutralization of redispersed GO at 2 wt% neutralized with 0.02M NaOH in deionized water
- Deprotonation of the buffering hydroxyl (OH) groups driven by higher pH

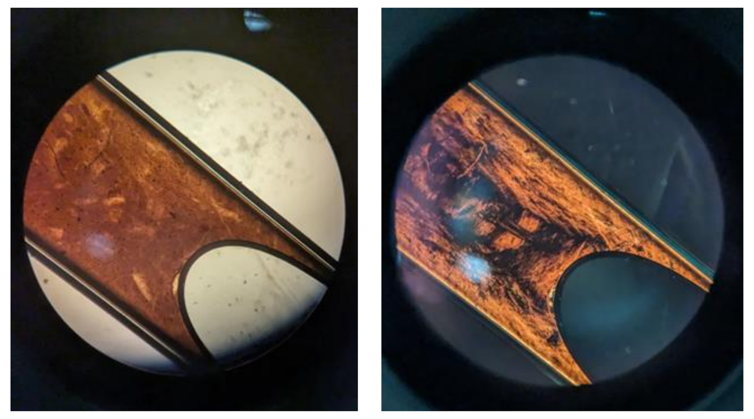

Fig. 6 Deprotonated GO sample demonstrating Poiseuille flow visualized via polarized optical microscopy with parallel polarization (left) and cross polarization (right)

Drying

- Used 1 mm SAP Sphere hydrogel beads to remove water and concentrate GO dispersion
- Conducted shear induced alignment via doctor blading to transition from liquid crystal to dry film

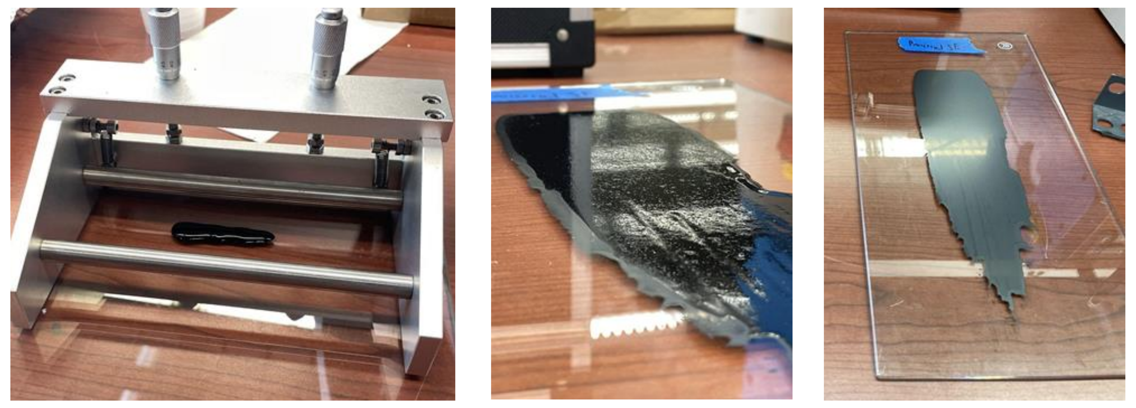

Fig. 7 Doctor blading setup with micropipetted GO on glass substrate (left); doctor blader is adjusted to 200 micron wet film thickness using knobs and slid across substrate (middle); dry film after 4 hours (right)

RESULTS

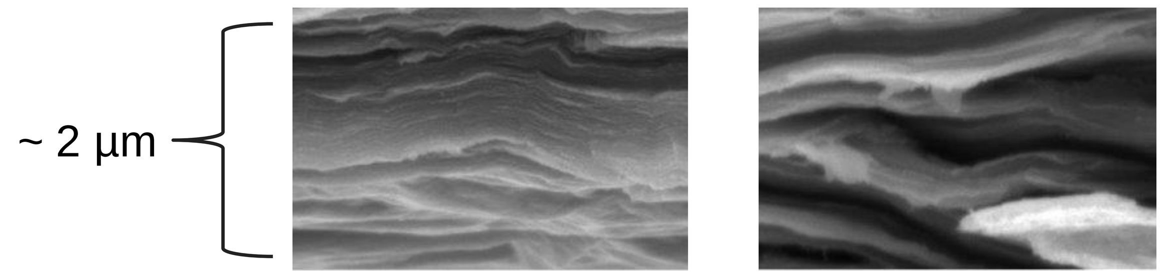

Fig. 8 Scanning electron microscopy (SEM) imagery of small GO layers (left) and larger GO layers (right) at ~2 µm scale

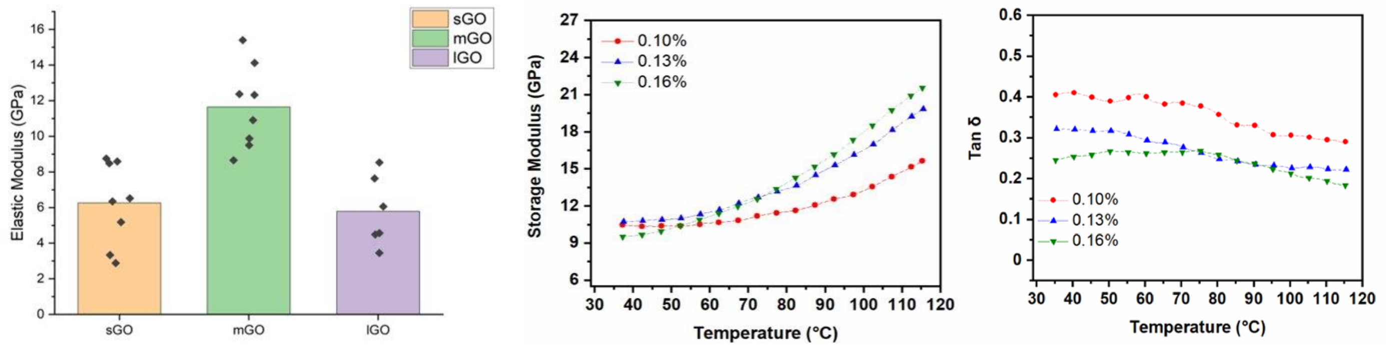

Fig. 9 Previous dynamic mechanical analysis (DMA) results of elastic modulus, storage modulus, and tan δ (damping factor) as a function of temperature between GO layers of different sizes

CONCLUSIONS

Fabrication and Testing

- Experimental centrifugation parameters optimize removal of large GO flakes compared to diminishing return in multiple rounds
- Compressed air in parallel flow and filter-cake agitation is more effective as opposed to orthogonal flow in "dead-end" filtration
- Optimized layer size-oriented fabrication methods yield high-stiffness GO films
- Increase temperature (solvent flux) → non-uniform drying → introduction of internal stress → reduced interlayer interaction

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