How to read a scientific article

(that you think is too complicated)

Created by Steve Van Tuyl, Adapted by Beth Newborg and your 0012 Writing Instructors

The paper…

CHEMISTRY OF MATERIALS
Article

Chem. Mater. **2010**, *22*, 4153–4157 4153
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Systematic Post-assembly Modification of Graphene Oxide Paper with Primary Alkylamines

Sasha Stankovich,[†,‡] Dmitriy A. Dikin,[†] Owen C. Compton,[‡] Geoffrey H. B. Dommett,[‡] Rodney S. Ruoff,*[,†,§] and SonBinh T. Nguyen*[,‡]

[†]*Department of Mechanical Engineering and* [‡]*Department of Chemistry and The International Institute for Nanotechnology, Northwestern University, 2145 Sheridan Road, Evanston, Illinois 60208-3133.* [§]*Current address: Department of Mechanical Engineering and the Texas Materials Institute, The University of Texas at Austin, 1 University Station, C2200, Austin, TX 78712-0292*

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Graphene oxide paper can be systematically modified with alkylamines in both solution- and vapor-phase, with the latter process being significantly slower. After removal of physisorbed amine, the increases in gallery spacing, physical thickness, and mass of amine-modified papers can be directly correlated to the length of the intercalated alkyl chain. While the tensile strength of the modified papers slightly decreases with increasing amine lengths, their "effective graphene oxide moduli" were essentially unchanged, suggesting that graphene oxide is the sole contributor to the stiffness of amine-modified papers.

Introduction

The bottom-up assembly of nanosized building blocks offers a versatile route to the fabrication of a variety of functional macrostructures that are inaccessible via conventional top-down synthetic techniques, especially in the case of hybrid and nanocomposite materials. In particular, flexible paper- or foil-like assemblies have been formed from exfoliated lamellar clays,[1] carbon nanotubes,[2] stacks of expanded graphite platelets,[3] platelets of graphene oxide,[4] and platelets of reduced graphene oxide,[5] to afford materials that exhibit excellent mechanical, electronic, and, in some cases, optical properties. We have recently reported the preparation of graphene oxide paper,[4] also by pressure-assisted assembly of aqueous suspensions of graphene oxide platelets,[6] which are produced by the exfoliation of graphite oxide (GO). Flow-directed filtration of water-dispersed graphene oxide induces self-assembly of individual platelets into a stacked ...red structure with near-parallel platelet arr...

(epoxy, hydroxyl, carbonyl, and carboxyl) on their basal planes and edges,[7−10] this paper should be modifiable via covalent reaction, allowing for the preparation of functionalized graphene oxide papers. Alternatively, assembled graphene oxide paper could also be reduced to graphene paper by several methods.[11]

In spite of the rich chemistry available through its oxygen-containing funtionalities,[7] systematic studies of structure-property relationships in modified graphene oxide papers have been largely overlooked, with previous work focusing only on improving upon their already excellent mechanical properties.[6,12] This i... prising because chemical derivat... oxide can also significa... ties of these pl... macrosco... exa...

Source: Chemistry of Materials. 2010. Volume 22. Pages 4153-4157.

But we don’t yet understand *all* the science in a paper that we think might be useful—we’re still first-year students!

- Don’t simply pass up a paper that that has areas that appear impossibly technical/unclear to you. There could well be information that is important to your FYEC paper and that you actually *do* or *will be able to* understand.
- Do your best—concentrate; look up unfamiliar terms; try to follow the science/engineering as best you can; keep in mind the applications and evaluation in the paper that might align with your FYEC paper!

How can we *start* to understand an "advanced" scientific paper; how can we see if it might be useful to *us*

1. Read the abstract (concentrate; look things up)
2. Read the beginning and end of the introduction (concentrate; look things up)
3. Look at the figures and tables including the captions (to spark/enhance understanding of key concepts/specifics)
4. Read the conclusions or last several paragraphs of the paper (to better understand the key points and their relevance to *your* FYEC paper)

Fear Not! We can figure this out
(more or less)

Scientific papers can look dense and intimidating when you encounter them in your first year, but here are strategies that will help you make best use of this type of article/paper

- Become familiar with structure and components of a scientific paper
- Starting out, spend time on particular components of the paper—Abstract; Charts/Graphs/"Visuals"; Conclusion
- Don't stay "stuck"
- Keep using/applying what you've learned

Become familiar with structure and components of a scientific paper

Many scientific papers follow the general structure outlined below. Some fields of research follow slightly different structures – keep an eye on the papers in your field and you'll start to see the patterns, even if the papers don't have exactly these sections.

- **Title/Authors** – This is the basic information for the article, pretty self-explanatory
- **Abstract** – A general run-down of all of the contents of the paper; your Full Proposal will eventually be morphing into *your* abstract!
- **Introduction** – The "why" of the research project – putting this research in the context of the greater research community
- **Methods** – How did the researchers do what they did? Why did they do it that way?
- **Results** – This is what happened when they did the research and what they think it means.
- **Discussion** – This is how the results fit into the corpus of other research of this sort. This is also where the authors talk about why what happened (Results) is important (or not).
- **Conclusions** – Usually provides an overview of the research. Also provides the reader with the answer to the "so what"/ "who cares?" questions – why are the research and findings important?

Starting out, spend time on particular components of the paper:

Read the Abstract

Systematic Post-assembly Modification of Graphene Oxide Paper with Primary Alkylamines

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1

Graphene oxide paper can be systematically modified with alkylamines in both solution- and vapor-phase, with the latter process being significantly slower. After removal of physisorbed amine, the increases in gallery spacing, physical thickness, and mass of amine-modified papers can be directly correlated to the length of the intercalated alkyl chain. While the tensile strength of the modified papers slightly decreases with increasing amine lengths, their "effective graphene oxide moduli" were essentially unchanged, suggesting that graphene oxide is the sole contributor to the stiffness of amine-modified papers.

2

3

The abstract will basically tell you everything important about the paper. In this case, the paper indicates that the researchers:

1) modified graphene oxide paper with something called alkylamines
2) found that variability in the products depended on something called the alkyl chain (including a reduction in paper strength)
3) found that "effective graphene oxide moduli" were unchanged

…but wait! We don't know what those terms mean!

Read the Abstract

But we don't understand a lot of the terms in the Abstract!

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- Look up the terms that are unfamiliar to you!
- Use basic sources such as dictionaries and Wikipedia to get a sense of what the complex terms in the paper mean. Of course, you are "going beyond" these basic sources, but such sources are useful for initially clarifying unfamiliar words, terms, concepts.
- Look around in the paper, itself, for those particular terms– context and further explanation within the paper might help you out
- For example:

Read the Abstract

But we don't understand a lot of the terms in the Abstract!

Look them up!

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"Looked up" terms:

- **Graphene oxide paper** – "…a composite material fabricated from graphene oxide… The material has exceptional stiffness and strength, due to the intrinsic strength of the two-dimensional graphene backbone and to its interwoven layer structure which distributes loads… graphene oxide paper is an electrical insulator; however, it may be possible to tune this property, making the paper a conductor or semiconductor, without sacrificing its mechanical properties." (from Wikipedia)
- **Gallery spacing** – Refers to the spacing between layers of graphene. Figured this out by doing a quick search for "spacing" in the paper and deducing the meaning by context.
- **Alkylamine** – this is an amine (ammonia derivative) with an alkyl group attached. Figured this out by looking in the dictionary! A quick search for "alkylamine" in the paper shows that the authors have previous information suggesting that alylamines will be useful for this type of work (see the first paragraph of Results and Discussion)
- **Moduli** – refers to the "stiffness" of the material. Figured this out by doing a quick search for "moduli" in the paper and found that the authors are referring to Young's Modulus, which I then looked up in Wikipedia.

Read the Abstract; But we don't understand…; Look them up;

Put the terms together

Systematic Post-assembly Modification of Graphene Oxide Paper with Primary Alkylamines

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2

3

Graphene oxide paper was modified using alkylamines. The length of the alkyl chain (in the alkylamine) is correlated with changes in the structure of the resultant graphene paper – specifically, longer alkyl chains resulted in more distance between graphene sheets and decrease in tensile strength. However, the flexibility of the graphene paper was not affected.

WOW! Now you understand! Keep going; more strategies ahead

Read the Introduction, especially the beginning and end of the introduction

Beginning

Potentially less- relevant-to-your-paper And *really* confusing middle

End

Introduction

The bottom-up assembly of nanosized building blocks offers a versatile route to the fabrication of a variety of functional macrostructures that are inaccessible via conventional top-down synthetic techniques, especially in the case of hybrid and nanocomposite materials. In particular, flexible paper- or foil-like assemblies have been formed from exfoliated lamellar clays,[1] carbon nanotubes,[2] stacks of expanded graphite platelets,[3] platelets of graphene oxide,[4] and platelets of reduced graphene oxide,[5] to afford materials that exhibit excellent mechanical, electronic, and, in some cases, optical properties. We have recently reported the preparation of graphene oxide paper,[4] also by pressure-assisted assembly of aqueous suspensions of graphene oxide platelets,[6] which are produced by the exfoliation of graphite oxide (GO). Flow-directed filtration of water-dispersed graphene oxide induces self-assembly of individual platelets into a stacked, layered structure with near-parallel platelet arrangement, yielding a self-supporting, mechanically strong paper upon drying. Since the assembled graphene oxide platelets retain all their oxygen-containing functional groups

Herein, we report a systematic study on the intercalation of primary alkylamines in both solution and vapor phase into graphene oxide paper. The modified materials exhibit a direct relation between the intercalated alkyl chain length and gallery spacing, physical thickness, sample mass, and tensile strength. Surprisingly, in spite of the large interlayer spacings produced by intercalation of amines, the Young's moduli of the modified papers remained constant.

The **beginning** and the **end** of the Introduction are most likely to give us background into why the research was conducted (beginning) and either an introduction of the goals of the research or a complete overview of the research including results (end).

There is a lot of complicated stuff in the middle of the introduction that is probably confusing and does not seem very relevant to grasping key terms and concepts; don't "get stuck" there; go to the end of the intro.

Read the beginning and end of the introduction; don't get stuck!

Introduction

Beginning:

The bottom-up assembly of nanosized building blocks offers a versatile route to the fabrication of a variety of functional macrostructures that are inaccessible via conventional top-down synthetic techniques, especially in the case of hybrid and nanocomposite materials.

Nanotech fabrication show promise not seen in 'top-down' assembly methods

Beginning:

In particular, flexible paper- or foil-like assemblies have been formed from exfoliated lamellar clays,[1] carbon nanotubes,[2] stacks of expanded graphite platelets,[3] platelets of graphene oxide,[4] and platelets of reduced graphene oxide,[5] to afford materials that exhibit excellent mechanical, electronic, and, in some cases, optical properties.

Nano-paper is especially significant (e.g. graphene oxide) for mechanical, electrical, and optical applications

We have recently reported the preparation of graphene oxide paper,[4] also by pressure-assisted assembly of aqueous suspensions of graphene oxide platelets,[6] which are produced by the exfoliation of graphite oxide (GO). Flow-directed filtration of water-dispersed graphene oxide induces self-assembly of individual platelets into a stacked, layered structure with near-parallel platelet arrangement, yielding a self-supporting, mechanically strong paper upon drying. Since the assembled graphene oxide platelets retain all their oxygen-containing functional groups

The beginning of some potentially very complicated stuff—does it seem relevant to your paper? If not (at least at first), move on. But don't forget the info is there in this paper—as you understand things better, it *might* be useful, and you can spend time trying to understand the terminology, etc.

End:

Herein, we report a systematic study on the intercalation of primary alkylamines in both solution and vapor phase into graphene oxide paper. The modified materials exhibit a direct relation between the intercalated alkyl chain length and gallery spacing, physical thickness, sample mass, and tensile strength. Surprisingly, in spite of the large interlayer spacings produced by intercalation of amines, the Young's moduli of the modified papers remained constant.

Handy!! A **concise overview** of the research project presented in this paper, using slightly different language from the abstract! Is it still relevant to your paper? Keep going

Read the beginning and end of the introduction; don't get stuck!

Introduction

Beginning: The bottom-up assembly of nanosized building blocks offers a versatile route to the fabrication of a variety of functional macrostructures that are inaccessible via conventional top-down synthetic techniques, especially in the case of hybrid and nanocomposite materials. In particular, flexible paper- or foil-like assemblies have been formed from exfoliated lamellar clays,[1] carbon nanotubes,[2] stacks of expanded graphite platelets,[3] platelets of graphene oxide,[4] and platelets of reduced graphene oxide,[5] to afford materials that exhibit excellent mechanical, electronic, and, in some cases, optical properties. We have recently reported the preparation of graphene oxide paper,[4] also by pressure-assisted assembly of aqueous suspensions of graphene oxide platelets,[6] which are produced by the exfoliation of graphite oxide (GO). Flow-directed filtration of water-dispersed graphene oxide induces self-assembly of individual platelets into a stacked, layered structure with near-parallel platelet arrangement, yielding a self-supporting, mechanically strong paper upon drying. Since the assembled graphene oxide platelets retain all their oxygen-containing functional groups

Beginning:

Now we have a really good idea of what the paper is about based on the Abstract and the last paragraph of the Introduction.

AND we have a good idea of why this research is important based on the first part of the Introduction.

End: Herein, we report a systematic study on the intercalation of primary alkylamines in both solution and vapor phase into graphene oxide paper. The modified materials exhibit a direct relation between the intercalated alkyl chain length and gallery spacing, physical thickness, sample mass, and tensile strength. Surprisingly, in spite of the large interlayer spacings produced by intercalation of amines, the Young's moduli of the modified papers remained constant.

This scientific paper you are now making sense of still seems useful/relevant to your team's FYEC paper? Keep going

Look over the figures and tables, including the captions; use/apply what you're learning!

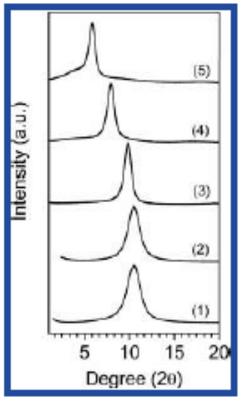


Figure 1. (1 and 2) XRD patterns of graphene oxide paper before (1) and after (2) soaking in methanol for 24 h. (3–5) Solution-phase modified graphene oxide papers treated with butylamine (3), octylamine (4), and dodecylamine (5) after soaking in methanol for 24 h.

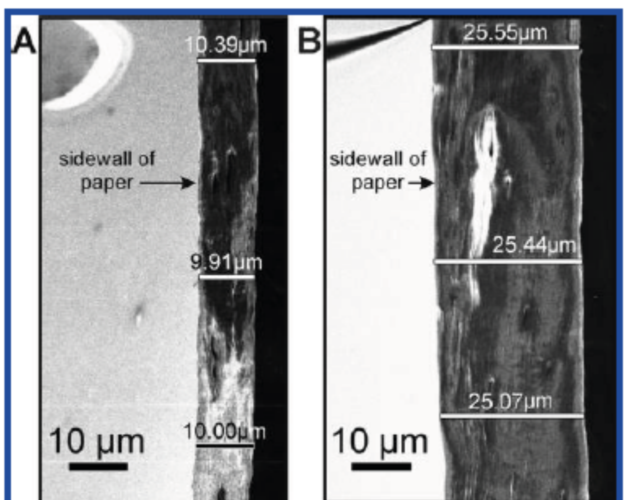


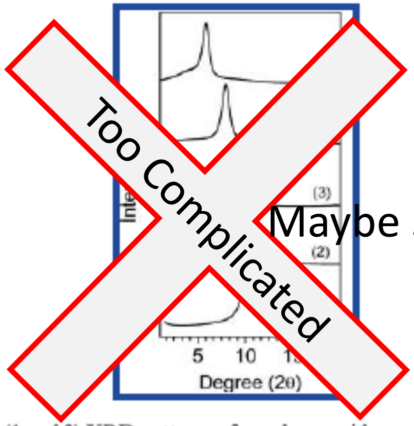
Figure 3. SEM images of the fracture surface of a ~10 μm-thick graphene oxide paper sample before (A) and after (B) solution-phase treatment with dodecylamine.

Based on what you know so far, it might be useful to check check out what the figures and tables show. Figures and tables are often "visual" clarifications or summaries of crucial information—as such, they can help you understand key information in the paper.

Continue to look up unfamiliar terms; ~~but also don't hesitate to move on to the next item~~. continue to apply *what you've already learned* via the Abstract and Introduction and via other research you have been doing.

Look over the figures and tables, including the captions; use/apply what you're learning; don't "get stuck "

Too Complicated



Maybe save for later, if needed

Figure 1. (1 and 2) XRD patterns of graphene oxide paper before (1) and after (2) soaking in methanol for 24 h. (3–5) Solution-phase modified graphene oxide papers treated with butylamine (3), octylamine (4), and dodecylamine (5) after soaking in methanol for 24 h.

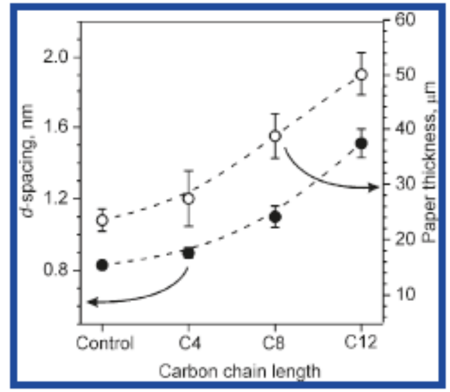


Figure 2. Plot of gallery spacing (*d*-spacing) (●) and average thickness of graphene oxide paper samples (○) versus the intercalated amine's alkyl chain length. All data were collected after samples were soaked in methanol for 24 h. The dashed lines are included as visual guides.

This figure shows how the alkyl chain length affects gallery spacing (remember that from the Abstract?). Now you can understand the process even better.

Oooh! Pictures of graphene oxide of different thicknesses!

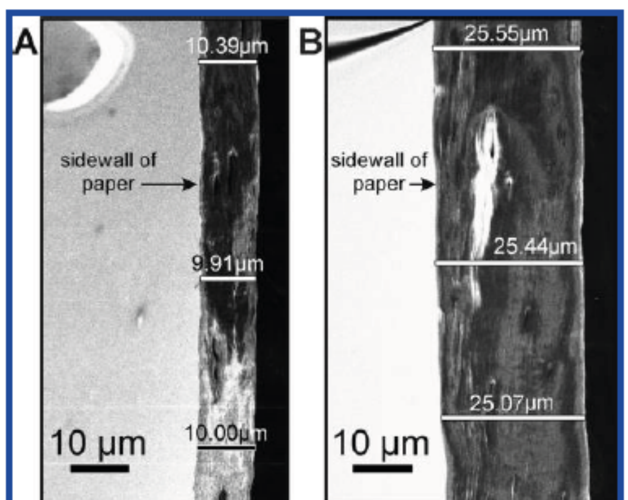


Figure 3. SEM images of the fracture surface of a ~10 *μ*m-thick graphene oxide paper sample before (A) and after (B) solution-phase treatment with dodecylamine.

Look over the figures and tables, *including the captions;* use/apply what you're learning; don't "get stuck " (**but don't be intimidated—you have new knowledge to apply**!)

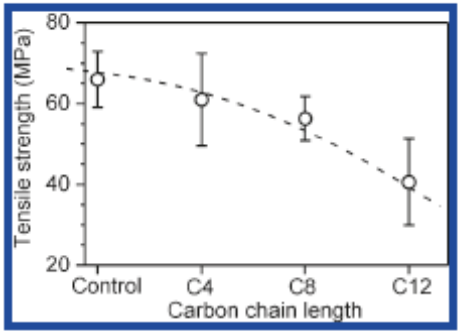


Figure 4. Tensile strength calculated using the physical cross section of the sample along the fracture edge. Values are plotted against carbon number (alkyl chain length) of the intercalated amine. The dashed line is included only as a visual guide.

Ah, yes, a reduction in tensile strength (y-axis) with increase in alkyl chain length (x-axis) – as mentioned in the Abstract

Kind of complicated, but we figured it out!

Modulus (x-axis; flexibility) and alkyl chain length. No change in modulus with increase in alkyl chain length except at C12 (long) alkyl chain lengths…

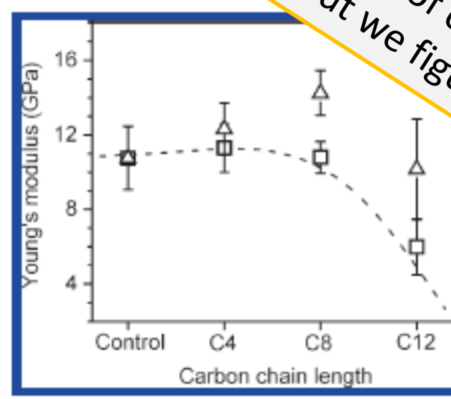


Figure 5. Modulus values (*E*) determined by linear fitting of the stress–strain dependence in the "elastic" regime. Values denoted with □ are calculated using the physical cross section and are Young's modulus values. Values denoted with △ are calculated using the thickness of an unmodified control sample and represent "effective graphene oxide modulus". The dashed line is included only as a visual guide.

4. Read the Conclusions; use/apply what you're learning; look for continuing relevance

You've got the main, relevant-to-your-paper terms/concepts of this scientific paper mostly figured out. Head to the Conclusions section to see if there is any more interesting information that will help *you* understand what *you* are writing about so you can then best clarify your topic/application/example/evaluations *for your readers*

Conclusions

In conclusion, we have demonstrated that post-assembly modification of graphene oxide papers with primary alkylamines can be successfully achieved via solution- or vapor-phase intercalation, with the latter process being significantly slower. After removal of physisorbed amines from the gallery, modified papers systematically exhibit direct correlations between the length of the intercalated alkyl chain and intergallery spacing, physical thickness of the paper, sample mass, and tensile strength. The tensile strength of the amine-modified papers suffers slightly as the length of the amine increases, with longer chains increasing the gallery spacing and making the paper weaker. However, the stiffness of the modified papers remains relatively unaffected, with little change in "effective graphene oxide modulus". These results suggest that graphene oxide paper can be used as an effective storage medium (for charges and chemicals) retaining its good mechanical stiffness in spite of inter-gallery loading.

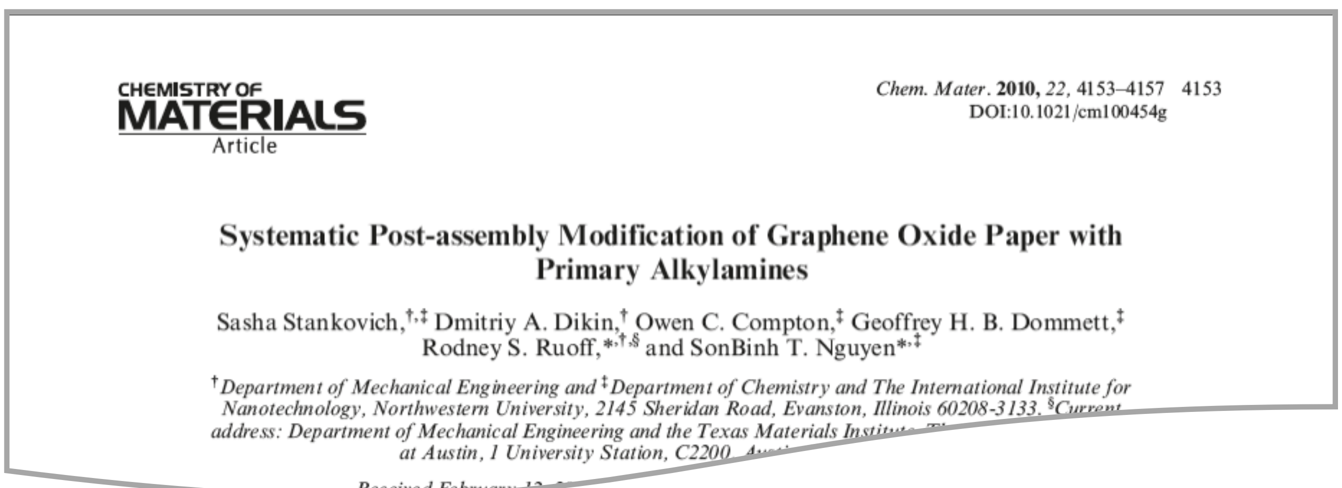
Here, the authors of this scientific paper reiterate what they did. You pretty much understand this stuff, but if you are still a bit confused, reading this will provide clarification.

This is helpful. The authors give an overview of why this research is important: graphene oxide paper can be used to store stuff between layers while retaining most of its physical properties! This clarification with help *you* with *your* evaluations!

Now what?

You've got the gist of the paper, you understand key concepts, and have a sense for why the conceptsof the paper are relevant and important to *your* paper.

You have enough knowledge of key terms to head into the Methods, Results, and/or Discussion sections to see if there is relevant info. in those sections. You might not understand *everything* in those sections, but you can continue to concentrate your efforts on understanding what might be important for your FYEC paper and your readers.



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