Scientific writing

Dr Roderick MacKenzie
e-mail: roderick.mackenzie@nottingham.ac.uk

Lecture aim

- I want to give you a brief tour of **how to write scientific* text** and **how scientific* publishing works.**
- Think of this as a crash course in scientific writing.
- This is derived from my own experiences, so it's useful advice and tips not just some theory.

*For scientific read Engineering, Biological, Medical etc..

Lecture aim

- By the end of the lecture I want you to understand that:

Scientific writing/publishing is **very different to other forms of writing/publishing.**

THE Sun

£50,000 BINGO Lucky numbers are on Page 18

hursday, March 13, 1986 18p TODAY'S TV IS ON PAGE 14

FREDDIE STARR ATE MY HAMSTER

Comic put a live pet in sandwich, says beauty

SELLERS GIRL IS

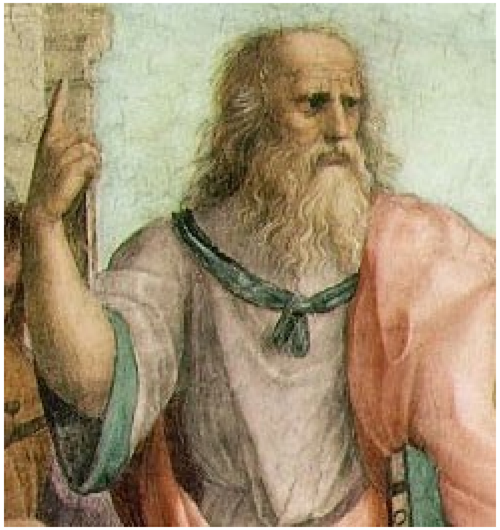
Lecture outline

- The process of knowledge dissemination
- What's the point of references
- Clarity of writing
- Figures and graphs
- How to write a scientific paper
- How to write a scientific report
- How to write a thesis
- How do do a literature review

Lecture outline

- **The process of knowledge dissemination**
- What’s the point of references
- Clarity of writing
- Figures and graphs
- How to write a scientific paper
- How to write a scientific report
- How to write a thesis
- How do do a literature review

How do you get your good idea out to the world?



Idea/New exciting data

- This is the problem we need to solve.

How do you get your good idea out to the world?

- Facebook
- Whasapp
- E-mail
- Youtube
- Periscope
- A random blog

How do you get your good idea out to the world?

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- These are pretty good ways to decimate inform about dancing kittens and south Korean pop music.

- However, the problem with them is that nobody checks if what you are saying is correct.
- It is therefore not taken seriously.

So how do Scientists and Engineers decimate information?

Step 1: Performing the experiment

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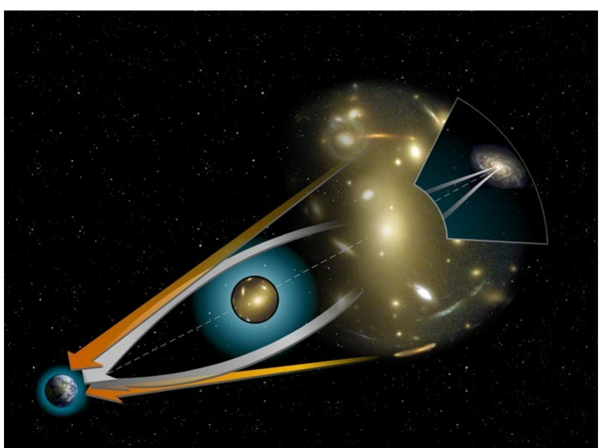
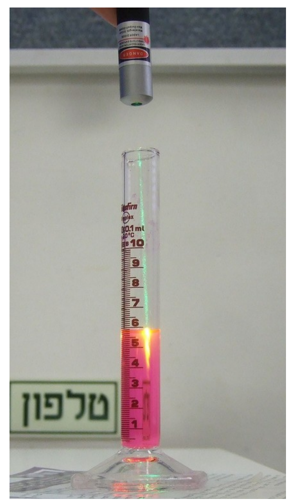
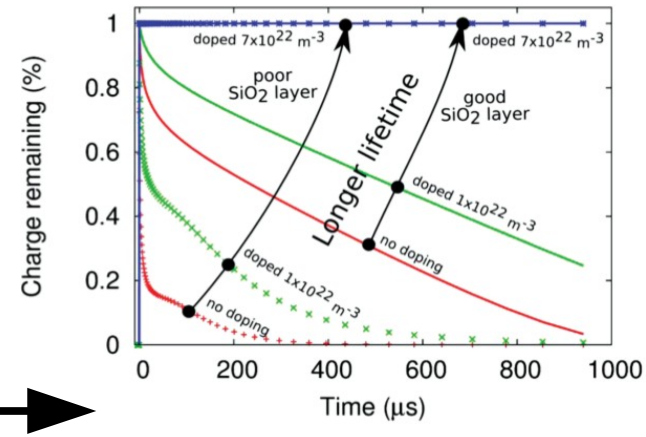
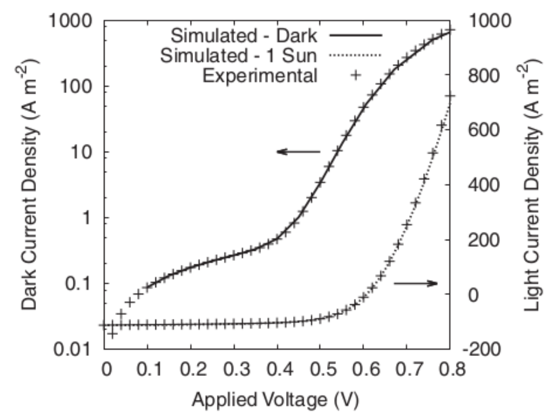
- The first step is to gather data and understand the results:



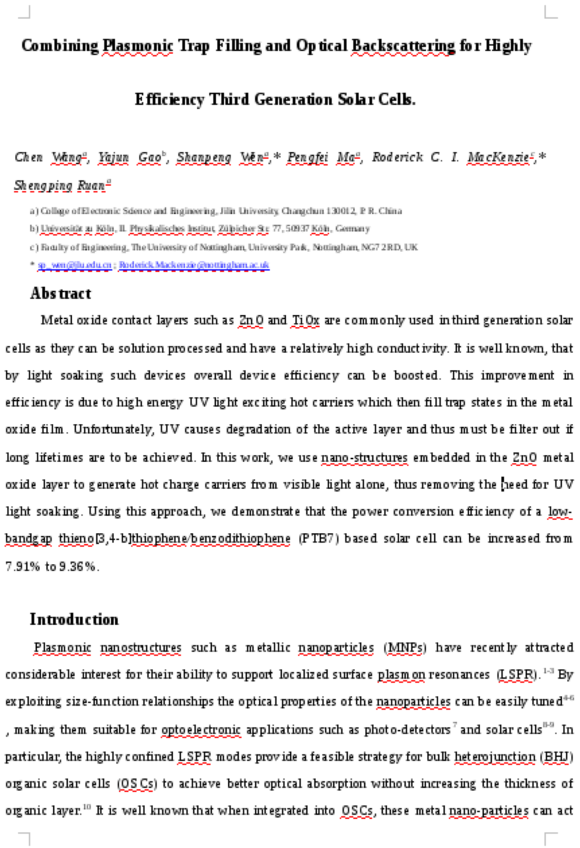






Step 2: Generating a paper...

- Once you have your data or new theory you write it up in draft paper (which we will talk about later).



Combining Plasmonic Trap Filling and Optical Backscattering for Highly Efficiency Third Generation Solar Cells.

Chen Wang[a], Yajun Gao[b], Shanpeng Wen[a], Pengfei Ma[a], Roderick C. I. MacKenzie[c],* Shengping Ruan[a]*

a) College of Electronic Science and Engineering, Jilin University, Changchun 130012, P. R. China
b) Universität zu Köln, II. Physikalisches Institut, Zülpicher Str. 77, 50937 Köln, Germany
c) Faculty of Engineering, The University of Nottingham, University Park, Nottingham, NG7 2RD, UK
* sp_wen@jlu.edu.cn ; Roderick.Mackenzie@nottingham.ac.uk

Abstract

Metal oxide contact layers such as ZnO and TiOx are commonly used in third generation solar cells as they can be solution processed and have a relatively high conductivity. It is well known, that by light soaking such devices overall device efficiency can be boosted. This improvement in efficiency is due to high energy UV light exciting hot carriers which then fill trap states in the metal oxide film. Unfortunately, UV causes degradation of the active layer and thus must be filter out if long lifetimes are to be achieved. In this work, we use nano-structures embedded in the ZnO metal oxide layer to generate hot charge carriers from visible light alone, thus removing the need for UV light soaking. Using this approach, we demonstrate that the power conversion efficiency of a low-bandgap thieno[3,4-b]thiophene/benzodithiophene (PTB7) based solar cell can be increased from 7.91% to 9.36%.

Introduction

Plasmonic nanostructures such as metallic nanoparticles (MNPs) have recently attracted considerable interest for their ability to support localized surface plasmon resonances (LSPR).[1-3] By exploiting size-function relationships the optical properties of the nanoparticles can be easily tuned[4-6], making them suitable for optoelectronic applications such as photo-detectors[7] and solar cells[8-9]. In particular, the highly confined LSPR modes provide a feasible strategy for bulk heterojunction (BHJ) organic solar cells (OSCs) to achieve better optical absorption without increasing the thickness of organic layer.[10] It is well known that when integrated into OSCs, these metal nano-particles can act

- Generally speaking this is a normal MS Word (Libre office) document, which is double spaced so people can write on it.

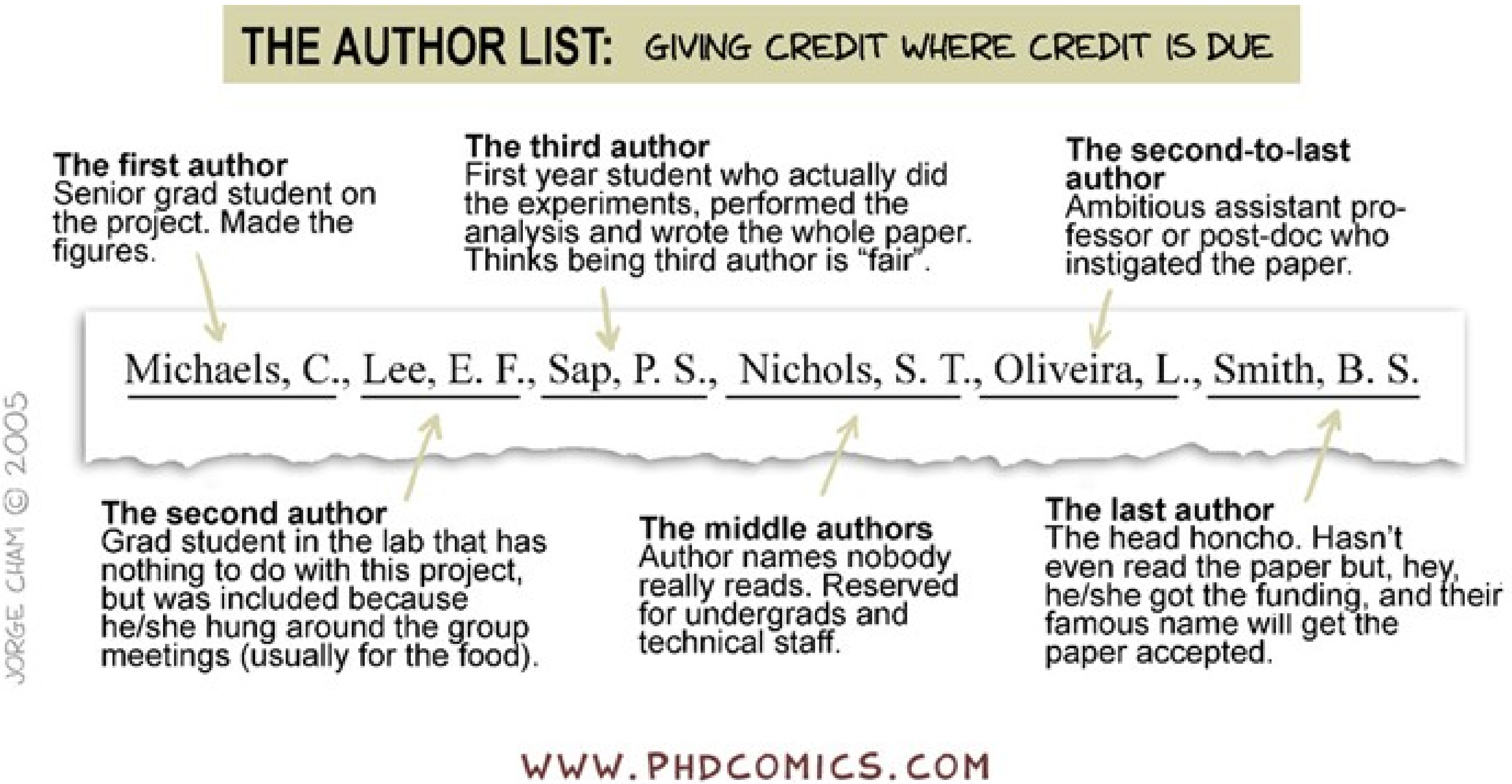
Author order and what it means..

Chen Wang[a], Yajun Gao[b], Shanpeng Wen[a], Pengfei Ma[a], Roderick C. I. MacKenzie[c],* Shengping Ruan[a]*

- 1st: The person who did the work*
- 2nd: The person who helped in the lab.
- Other people who helped a bit
- Second last: Co supervisor or someone fairly important but did not get the money for the experiment.
- Last: The person who funded the work*

- *These are the most important places to have your name, and you can **upset people a lot** by insisting you name has to be in a set position!

Author order and what it means..



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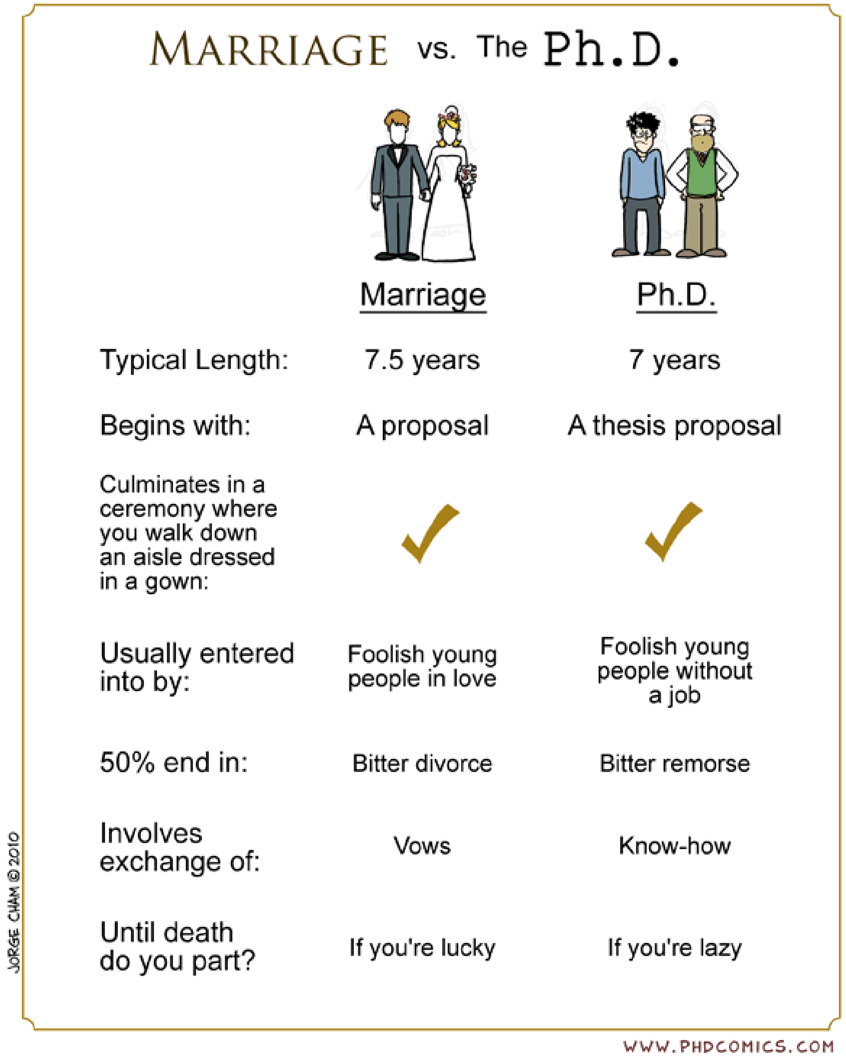


Corresponding author

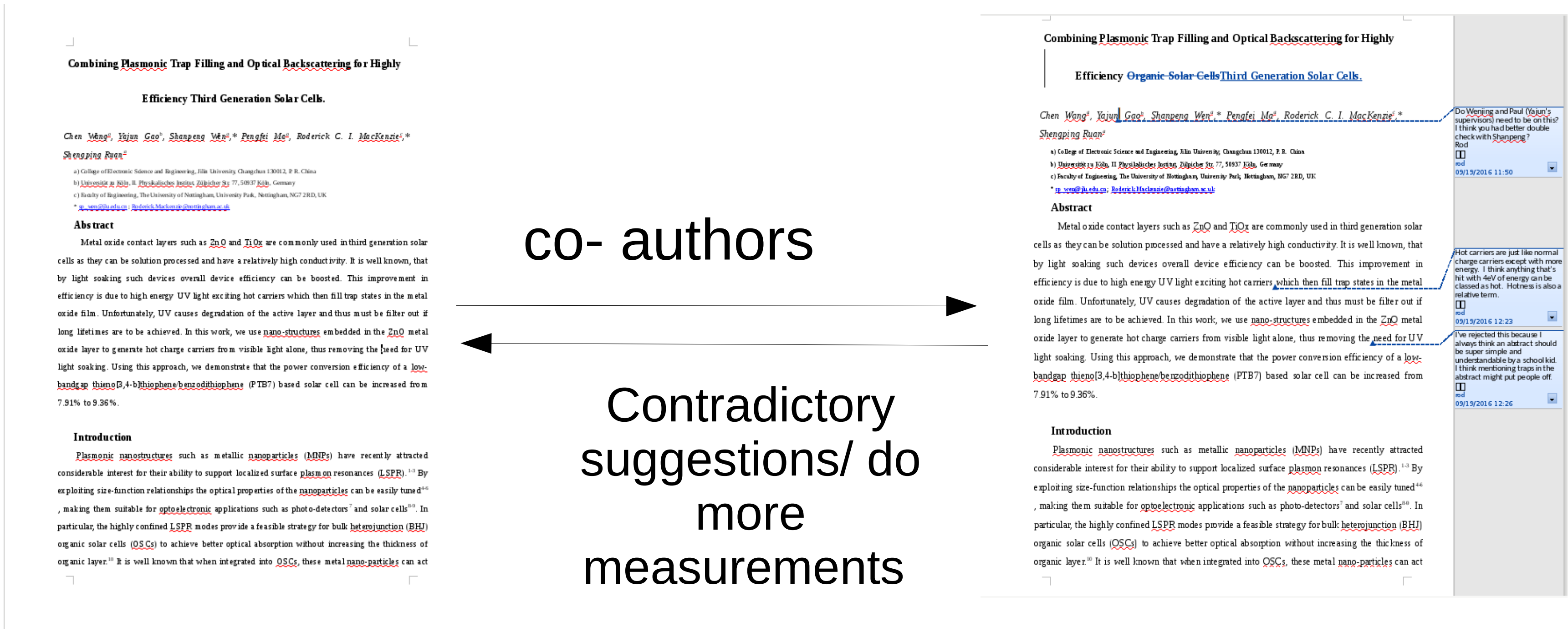
- If you look at this list, you can see a star above some names.

Yajun Gao, Roderick C. I. MacKenzie, Yang Liu, Bin Xu, Paul H. M. van Loosdrecht,* and Wenjing Tian**

- These are the **corresponding authors**
- These are the people **you can e-mail** if you have questions about the paper – they may even respond to e-mails about their work (if the questions are intelligent/polite).
- In UK academic culture people generally, **don’t care who is corresponding author**. And it’s often the person who just has the job of writing letters to the editor.
- In other academic cultures, corresponding author matters and even the order of the corresponding authors matters (China).

Now send your paper to the co-authors for comment.

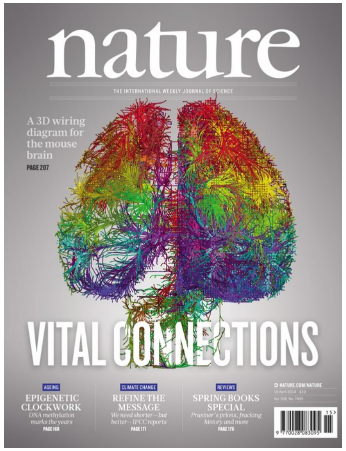
- Be patient with them but firm.
- They are very busy people.



- They will then send you back changes and suggestions to the paper using track changes.
- Your paper can go **back and forth quite a few times**.

Once you are happy with your paper you select a journal to send it to.

- Journals are judged to some extent by their impact factor:
  - Nature 38.138 (Science journal)
  - Cell 28.710 (Science journal)
  - Journal of Physical Chemistry A 2.8 (Engineering)
  - Physical Review B 3.7 (Engineering)
  - IEEE Journal of Quantum Electronics 1.8 (Engineering)



- Ideally you want to put your paper **somewhere where** it will be **read** by **people** in your field.

The cover letter

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- With the paper you usually need to write a cover letter

College of Electronic Science and Engineering
Jilin University
Changchun 130012
P. R. China
e-mail: sp_wen@jlu.edu.cn

12th September 2016

Dear Editors,

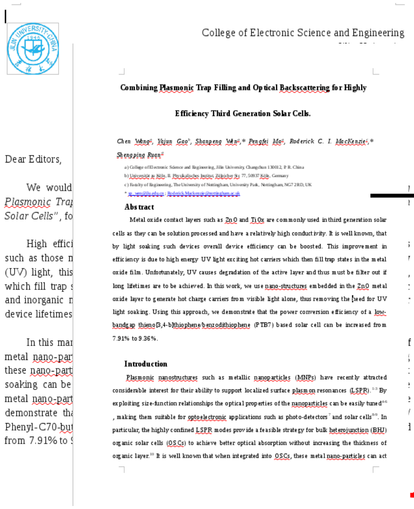
We would very grateful if you could consider the attached manuscript "*Combining Plasmonic Trap Filling and Optical Backscattering for High Efficiency Third Generation Solar Cells*", for publication in Energy and Environmental Science.

High efficiency third generation solar cell, often use transparent metal oxide contacts such as those made form TiOx. It is common to light soak these layers using high energy (UV) light, this significantly increases device efficiency by generating hot charge carriers, which fill trap stats in the oxide layer. However, UV is well known to degrade both organic and inorganic materials, and thus this process is not compatible with the search for longer device lifetimes.

In this manuscript, we demonstrate the general result, that by tuning the shortest side of metal nano-particles to generate hot charge carriers from visible light, then by embedding these nano-particles in the metal oxide contact layer of a solar cell; the benefits of UV light soaking can be gained from visible light alone. We then tune the longest dimension of the metal nano-particles to promote light trapping in the device. Using this general strategy, we demonstrate that a state-of-the-art low-bandgap thieno[3,4-b]thiophene/ benzodithiophene/ Phenyl-C70-butyric acid methyl ester (PTB7:PCBM) cell, can have it's efficiency boosted from 7.91% to 9.36%.

- The cover letter should tell the editor why he should publish your paper.
- Why his readers will be interested in it.
- And why your paper will get cited and thus increase his journals impact factor.

Send the paper/letter to the journal



1 month

Wait for the editor to read the paper

Reject (**Some journals reject 70% of papers at this stage**)

1 month

Editor sends the paper to the reviewers

1 month

3 reviewers make recommendations

Reject?

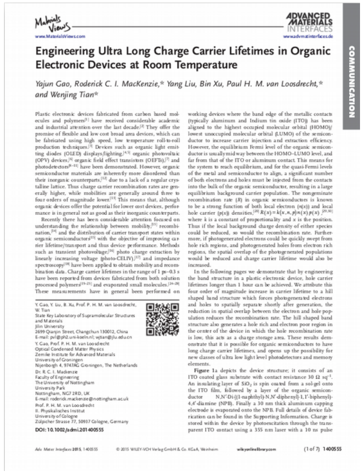
6 month

You change the paper according to the reviewers recommendations.

1 month

Accept?

Type setting and final paper published on line.



Overall acceptance rate for Nature: 7%

Typical is about 50%

Send the paper/letter to the journal

- This process takes about **a year+ from start to finish.**
- Key to this process is **peer review,** where three experts in the field will assess your paper on quality and novelty.
- It is not like a newspaper where you can publish any old rubbish


THE Sun 30p

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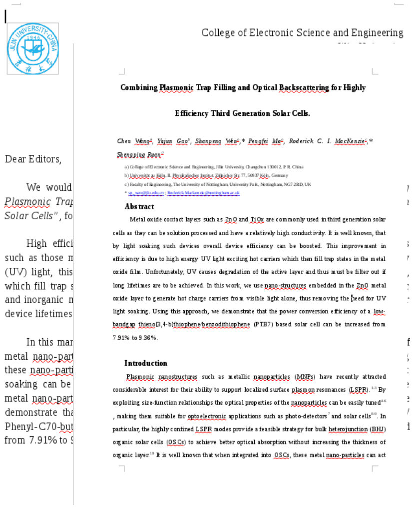
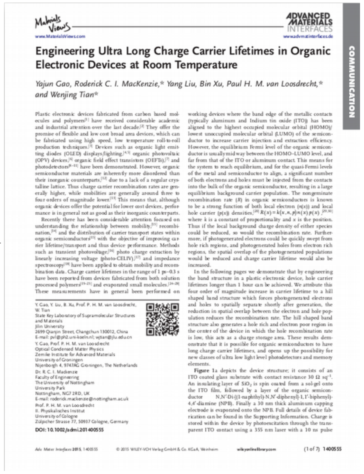

College of Electronic Science and Engineering

Dear Editors,

Combining Plasmonic Trap Filling and Optical Backscattering for Highly Efficiency Third Generation Solar Cells.

Abstract

Introduction


ADVANCED MATERIALS INTERFACES

COMMUNICATION

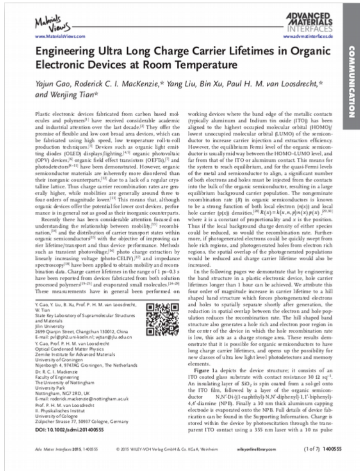
Engineering Ultra Long Charge Carrier Lifetimes in Organic Electronic Devices at Room Temperature

Yajun Gao, Roderick C. I. MacKenzie,* Yang Liu, Bin Xu, Paul H. M. van Loosdrecht,* and Wenjing Tian*

- Because of this process a paper published in a reputable journal probably contains reasonable science.
- Editors/reviewers do this for free so be nice to them!

Final words on papers

- They are a **very raw form of knowledge** and represent the **latest thinking in a field**.
- Information in papers may later be found out to be **wrong or indeed contradict other** ideas which were published later.
- So, you should always be critical of things written in papers and judge for your self if they are correct.



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COMMUNICATION

Engineering Ultra Long Charge Carrier Lifetimes in Organic Electronic Devices at Room Temperature

Yajun Gao, Roderick C. I. MacKenzie, Yang Liu, Bin Xu, Paul H. M. van Loosdrecht,* and Wenjing Tian**

Plastic electronic devices fabricated from carbon based molecules and polymers[1] have received considerable academic and industrial attention over the last decade.[2] They offer the promise of flexible and low cost broad area devices, which can be fabricated using high speed, low temperature roll-to-roll production techniques.[3] Devices such as organic light emitting diodes (OLED) displays/lighting,[4,5] organic photovoltaic (OPV) devices,[6] organic field effect transistors (OEFTs),[7] and photodetectors[8–11] have been demonstrated. However, organic semiconductor materials are inherently more disordered than their inorganic counterparts,[12] due to a lack of a regular crystalline lattice. Thus charge carrier recombination rates are generally higher, while mobilities are generally around three to four orders of magnitude lower.[13] This means that, although organic devices offer the potential for lower cost devices, performance is in general not as good as their inorganic counterparts.

Recently there has been considerable attention focused on understanding the relationship between mobility,[13] recombination,[14] and the distribution of carrier transport states within organic semiconductors[15] with the objective of improving carrier lifetime/transport and thus device performance. Methods such as transient photovoltage,[16] photo charge extraction by linearly increasing voltage (photo-CELIV),[17] and impedance spectroscopy[18] have been applied to obtain mobility and recombination data. Charge carrier lifetimes in the range of 1 ps–0.3 s have been reported from devices fabricated from both solution processed polymers[19–23] and evaporated small molecules.[24–28] These measurements have in general been performed on working devices where the band edge of the metallic contacts (typically aluminum and Indium tin oxide (ITO)) has been aligned to the highest occupied molecular orbital (HOMO)/lowest unoccupied molecular orbital (LUMO) of the semiconductor to increase carrier injection and extraction efficiency. However, the equilibrium Fermi level of the organic semiconductor is usually midway between the HOMO–LUMO level, and far from that of the ITO or aluminum contact. This means for the system to reach equilibrium, and for the quasi-Fermi levels of the metal and semiconductor to align, a significant number of both electrons and holes must be injected from the contacts into the bulk of the organic semiconductor, resulting in a large equilibrium background carrier population. The nongeminate recombination rate (R) in organic semiconductors is known to be a strong function of both local electron ($n(x)$) and local hole carrier ($p(x)$) densities,[28] $R(x) = k(x,n,p)n(x)p(x)$,[29,30] where k is a constant of proportionality and x is the position. Thus if the local background charge density of either species could be reduced, so would the recombination rate. Furthermore, if photogenerated electrons could be quickly swept from hole rich regions, and photogenerated holes from electron rich regions, the spatial overlap of the photogenerated populations would be reduced and charge carrier lifetime would also be increased.

In the following pages we demonstrate that by engineering the band structure in a plastic electronic device, hole carrier lifetimes longer than 1 hour can be achieved. We attribute this four order of magnitude increase in carrier lifetime to a hill shaped band structure which forces photogenerated electrons and holes to spatially separate shortly after generation, the reduction in spatial overlap between the electron and hole population reduces the recombination rate. The hill shaped band structure also generates a hole rich and electron poor region in the center of the device in which the hole recombination rate is low, this acts as a charge storage area. These results demonstrate that it is possible for organic semiconductors to have long charge carrier lifetimes, and opens up the possibility for new classes of ultra low light level photodetectors and memory elements.

Figure 1a depicts the device structure; it consists of an ITO coated glass substrate with contact resistance 30 Ω sq^{-1}. An insulating layer of SiO_2 is spin coated from a sol-gel onto the ITO film, followed by a layer of the organic semiconductor N,N′-Di-[(1-naphthyl)-N,N′-diphenyl]-1,1′-biphenyl)-4,4′-diamine (NPB). Finally a 30 nm thick aluminum capping electrode is evaporated onto the NPB. Full details of device fabrication can be found in the Supporting Information. Charge is stored within the device by photoexcitation through the transparent ITO contact using a 355 nm laser with a 10 ns pulse

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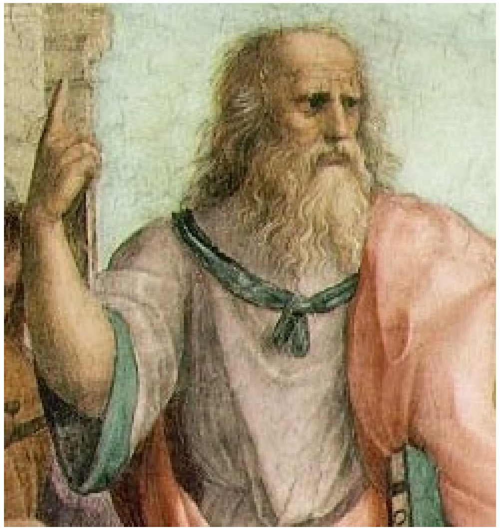
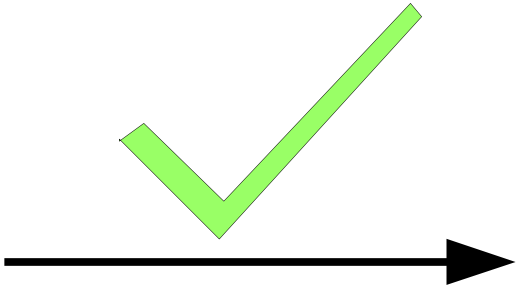
DOI: 10.1002/admi.201400555

The process of knowledge dissemination





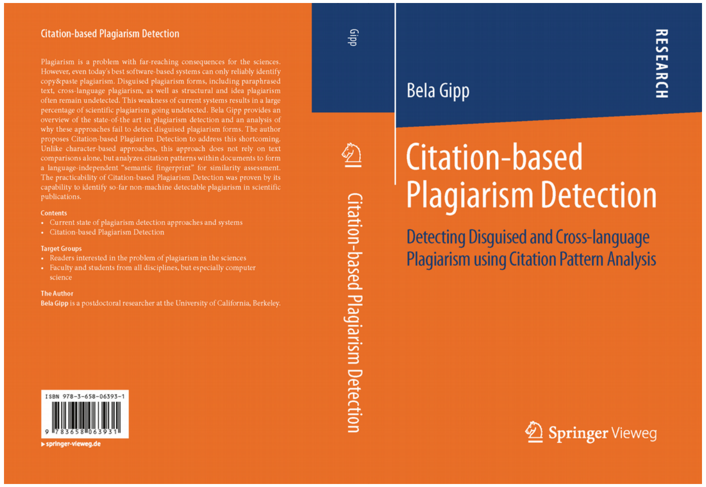
Idea/New exciting data

- But papers are a very raw form of knolage, how is this distilled and refined…..

Refining knowledge..

- After 10 years or so when lots of papers have been published in a given field and there has been a body of knowledge been generated.
- Somebody will write a book on the topic.

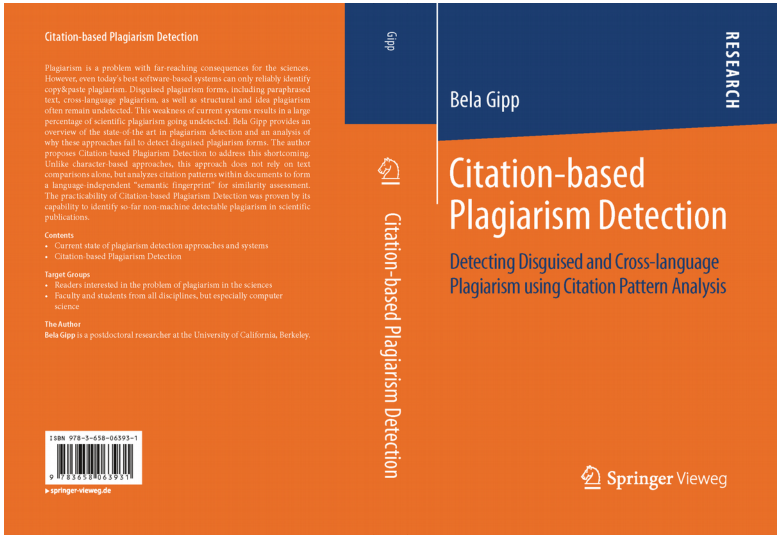
Book



- These first books are generally hard to understand and complex.

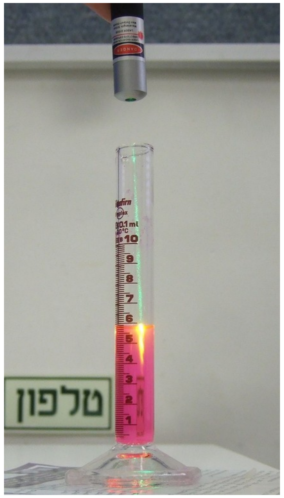
Academic books

- Often the contents of these early academic books, is mainly correct but there can be errors and mistakes in the filed.
- They should also be treated with caution.

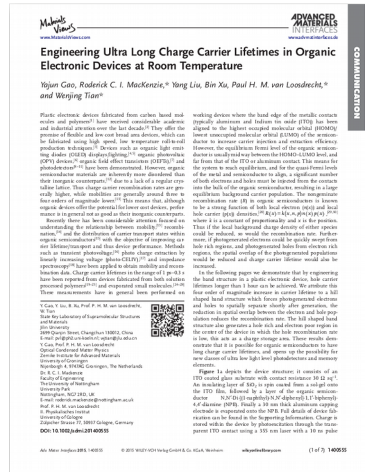


- In general after about 10-15 years there will have been enough books written on a topic and enough papers published that we have a good idea of what is correct/not correct in a field.

Overview of the process, from paper to lecture.



1 year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COMMUNICATION

Engineering Ultra Long Charge Carrier Lifetimes in Organic Electronic Devices at Room Temperature

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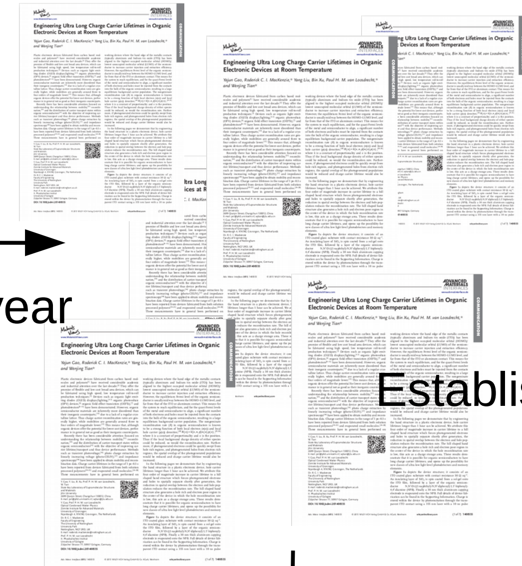
Experiment

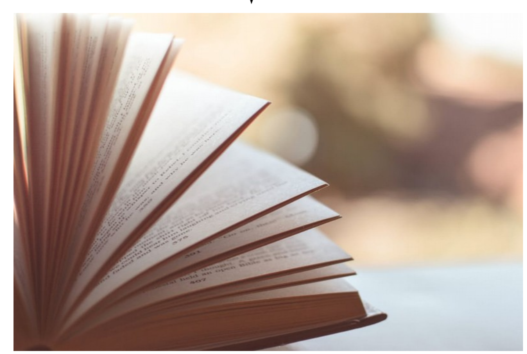
Paper

10 year



Established field

5-10 years



Book

5 years

Lectures

- Time scales can vary, these are just to give you an idea.

Lecture outline

- The process of knowledge dissemination
- **What's the point of references?**
- Clarity of writing
- Good figures and graphs.
- How to write a scientific report
  - Abstract/Method/Discussion/Conclusion
- How to write a scientific paper.
  - Abstract/Introduction/Results/Discussion/Conclusion
- What editors look for in a paper.
- How to write a thesis

References, an example.

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1 Introduction

Organic solar cells have recently shown great promises as a low cost source of low carbon electricity, their efficiencies have rapidly improved from 3% in 2007[1] to over 10% today.[2] There has been much work done on optimizing all aspects of organic photovoltaic devices (OPVs) including; development of narrow bandgap polymers to improve light absorption;[3] developing better contacts[4,5] to replace expensive Indium Tin Oxide;[6,7] and development of faster production technologies to reduce the fabrication cost.[8–10] However the cost per Watt of energy produced with an organic solar cell is still not competitive to silicon[2,11] and for OPV devices to become commercially viable, improvements still need to be made in both efficiency and cost.

In the following pages we demonstrate how a significant

Grounding everything you say to the literature.

1 Introduction

Organic solar cells have recently shown great promises as a low cost source of low carbon electricity, their efficiencies have rapidly improved from 3% in 2007[1] to over 10% today.[2] There has been much work done on optimizing all aspects of organic photovoltaic devices (OPVs) including; development of narrow bandgap polymers to improve light absorption;[3] developing better contacts[4,5] to replace expensive Indium Tin Oxide;[6,7] and development of faster production technologies to reduce the fabrication cost.[8–10] However the cost per Watt of energy produced with an organic solar cell is still not competitive to silicon[2,11] and for OPV devices to become commercially viable, improvements still need to be made in both efficiency and cost.

In the following pages we demonstrate how a significant

- Can you see that every time I say something is true, I put a reference to back it up.
- If people don't believe what I am saying, then they can go and find the references to convince them selves.

- If they disagree with me, they not only have to disagree with me but also the author of the other paper.
- They also provide a jumping in point for people who are new to the subject.

References

- Generally in science/engineering you are not allowed to make statements without a reference backing them up.
- For example you can not write,
  - "**I think solar energy** is the fastest growing form of energy"
- because that is what they do in the sun ->

- You must back it up with a reference.

  Solar energy is the fastest growing form of energy[1]

Web references?

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- **Web references are bad**, this is because your written work will be read by other long after you are dead.
- This means that in **200 years,** someone needs to be able to find the reference you are citing.

ON THE MOVEMENT OF SMALL PARTICLES SUSPENDED IN STATIONARY LIQUIDS REQUIRED BY THE MOLECULAR-KINETIC THEORY OF HEAT

by A. Einstein

[*Annalen der Physik* 17 (1905): 549-560]

$$F = -\frac{R}{N} T \lg \int e^{-\frac{EN}{RT}} dp_1 \ldots dp_\ell = -\frac{RT}{N} \lg B.$$

Let us now imagine a liquid enclosed in the volume V; let the partial volume V^* of V contain n dissociated molecules or suspended bodies, which are retained in the volume V^* by a semipermeable wall; this will affect the integration limits of the integral B entering the expressions for S and F. Let the total volume of the dissolved molecules or suspended bodies

[1]In this section it is assumed that the reader is familiar with the author's papers on the foundations of thermodynamics (cf. *Ann. d. Phys.* 9 (1902): 417 and 11 (1903): 120). Knowledge of the papers cited and of this section of the present paper is not essential for the understanding of the present paper's results.

How should I set out my references?

- There are lots of different forms of referencing, which should I use?:

(1) Emmott, C. J.; Urbina, A.; Nelson, J. Effects of Annealing and Degradation on Regioregular Polythiophene-Based Bulk Heterojunction Organic Photovoltaic Devices. *Sol. Energy Mater. Sol. Cells* **2012**, 97, 14–21.

[1] M. A. Green, K. Emery, Y. Hishikawa, W. Warta, and E. D. Dunlop, Prog. Photovolt: Res. Appl. **20**, 12 (2012).

14. Cabanillas-Gonzalez, J., Grancini, G. & Lanzani, G. Pump-probe spectroscopy in organic semiconductors: monitoring fundamental processes of relevance in optoelectronics. *Adv. Mater.* **23**, 5468–5485 (2011).

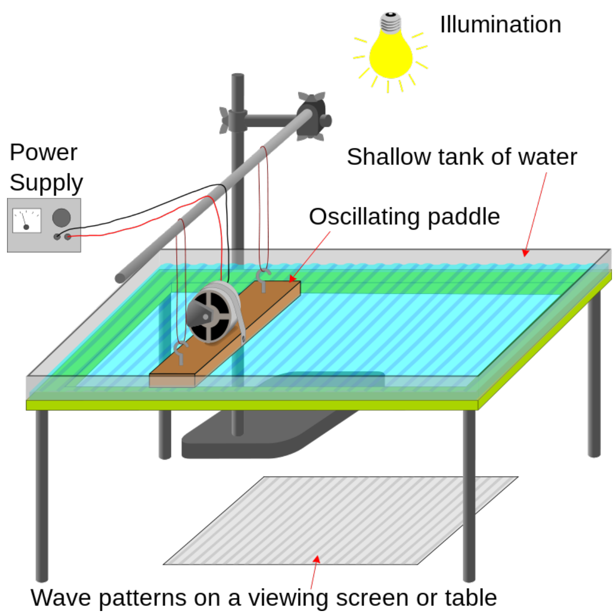
- It does not matter at all, but do stick to one style!
- I suggest you use a reference manager, to do the hard work for you (See H14ERP).

Lecture outline

- The process of knowledge dissemination
- What's the point of references
- **Clarity of writing**
- Good figures and graphs.
- How to write a scientific report
  - Abstract/Method/Discussion/Conclusion
- How to write a scientific paper.
  - Abstract/Introduction/Results/Discussion/Conclusion
- What editors look for in a paper.
- How to write a thesis

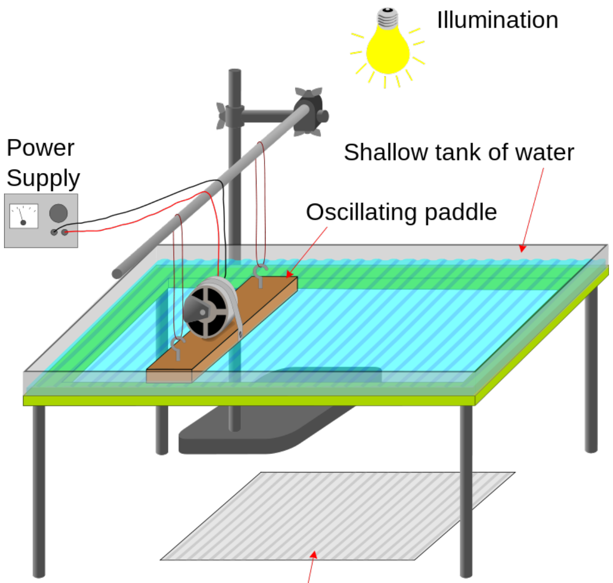
How to write scientific English

- Scientific English should use **short sharp** sentences which say **exactly** what you want to with the very **minimum** of **words**.
- An example of a bad sentence would be:



"To do the experiment we all got together in the lab on Tuesday and measured the waves in the wave tank many times."

A better example would be



Using a ripple tank (with an oscillator running at 10 Hz), the interference pattern was projected onto the desk (see diagram). We then used a ruler to measure the peak-to-peak distance which was found to be 1.5 cm.

- Notice every part of this sentence tells me new information, it is sharp, short and accurate.

Deadwood phrases

a majority of -- most

a sufficient amount of -- enough

according to our data -- we find

accordingly -- therefore, so

after the conclusion of -- after

along the lines of -- like

as is the case -- as is true

ascertain the location of -- find

at such time as -- when

at the present time -- now

at this point in time -- now

give consideration to -- consider, examine

give indication of -- show, indicate, suggest

happen(s) to be -- am/is/are

has been proved to be -- is

if conditions are such that -- if

in a number of -- several, many

in all cases -- always

in case -- if

in close proximity to -- near

in excess of -- more than

in the vicinity of -- near

in this case -- here

in view of the fact that -- because, since

is capable of -- can

is found to be -- is

is in a position to -- can

it has been found that -- (nothing)

it has long been known that -- (nothing)

it is a fact that -- (nothing)

it is evident that -- (nothing)

http://www.pnl.gov/ag/usage/deadwood.html

Deadwood phrases

prior to -- before

provided that -- if

put an end to -- end

reach a conclusion -- conclude

serves the function of being -- is

subsequent to -- after

the question as to -- whether

there can be little doubt that -- probably

utilize or utilization -- use

with reference to -- about

with the exception that -- except that

future predictions -- predictions

general rule -- rule

green colored -- green

increase in increments -- increase

initial prototype (model) -- prototype

joint cooperation -- cooperation

major breakthrough -- breakthrough

modern science of today -- modern science

most optimum -- optimum

necessary requirement -- requirement

Your go!

- Describe this experiment in as few words as possible.
- Then discuss this with your partner.
- We will read these out a bit later.

https://www.youtube.com/watch?v=p4Mq1B1-XOw

Scientific writing in English.

- Finally, in English, when you write Science and Engineering documents.
- Don’t try to show the reader how clever you are by using long words, or fancy language, just keep every sentence to the very minimum.
- Try to **avoid acronyms** (**TLAs!**) they just make stuff much harder to understand.
- Always, try to write as if you are trying to explain what you are doing to a **clever child.**

Lecture outline

- The process of knowledge dissemination
- What’s the point of references
- Clarity of writing
- **Figures and graphs**
- How to write a scientific report
  - Abstract/Method/Discussion/Conclusion
- How to write a scientific paper.
  - Abstract/Introduction/Results/Discussion/Conclusion
- What editors look for in a paper.
- How to write a thesis

Good figures and graphs

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- What's this about?

Tom (named "Jasper" in his debut appearance) is a grey and white domestic shorthair cat. ("Tom" is a generic name for a male cat.) He is usually but not always, portrayed as living a comfortable, or even pampered life, while Jerry (named "Jinx" in his debut appearance) is a small, brown, house mouse who always lives in close proximity to Tom. Despite being very energetic, determined and much larger, Tom is no match for Jerry's wits. Jerry also possesses surprising strength for his size, approximately the equivalent of Tom's, lifting items such as anvils with relative ease and withstanding considerable impacts. Although cats typically chase mice to consume them, it is quite rare for Tom to actually try to consume Jerry. Most of his attempts are just to torment or humiliate Jerry, sometimes in revenge, and sometimes to obtain a reward from a human for catching Jerry. By the final "fade-out" of each cartoon, Jerry usually emerges triumphant, while Tom is shown as the loser.

However, other results may be reached. On rare occasions, Tom triumphs, usually when Jerry becomes the aggressor or when he pushes Tom a little too far. In *The Million Dollar Cat* Jerry learns that Tom will lose his newly acquired wealth if he harms any animal, "including a mouse;" he then torments Tom a little too much until he retaliates. In *Timid Tabby* Tom's look-alike cousin pushes Jerry over the edge. Occasionally and usually ironically, they both lose, usually when Jerry's final trap or attack on Tom backfires or Jerry overlooks something. In Chuck Jones' *Filet Meow*, Jerry orders a shark from the pet store to scare Tom away from eating a goldfish, but finds himself entirely intimidated as well. Finally, they occasionally end up being friends, although within this set of stories, there is often a last minute event that ruins the truce. One story that has friendly ending is *Snowbody Loves Me*.

Good figures and graphs

- Don’t know and it’ looks quite boring...

Good figures and graphs

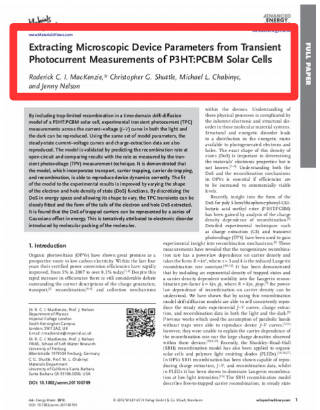
- What's this about?
- What's happening?

Good figures and graphs

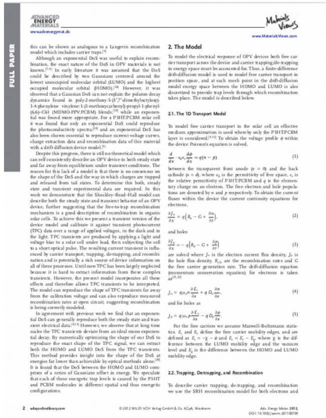
- What’s this about?
- What’s happening?

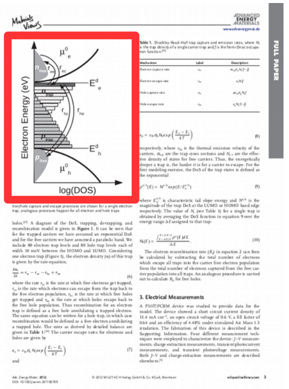
- All we need to understand what is going on is good pictures/figures and a little bit of text or figure captions.

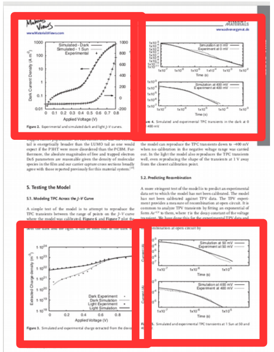
Think of a paper or a report as a cartoon.
Can you understand it by looking at the figures alone.


Extracting Microscopic Device Parameters from Transient Photocurrent Measurements of P3HT:PCBM Solar Cells

Roderick C. I. MacKenzie, Christopher G. Shuttle, Michael L. Chabinyc, and Jenny Nelson







Good figures and graphs

- And let's face it what you write will be pretty dull so people are not going to read the text anyway :)

- Communicate through pictures

Always assume this!

- Examples of good and bad graphs/figures...

Examples of wonderful figures.

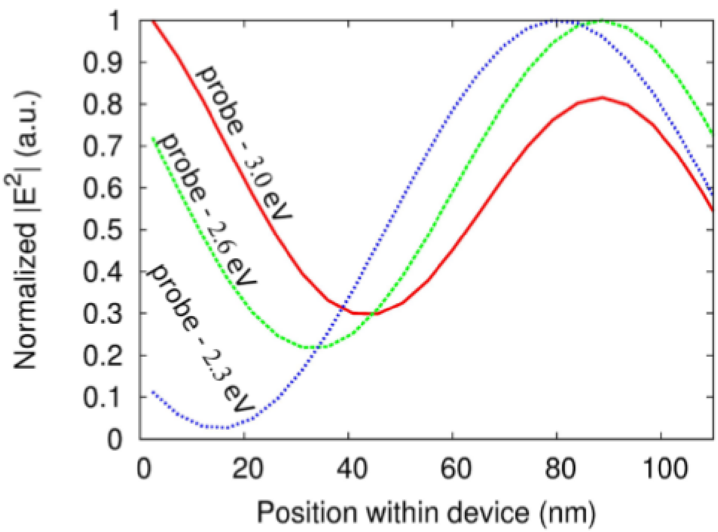


FIG. 8. (Color online) Normalized modal profiles of the probe light for photon energies of 2.3 (blue), 2.6 (green), and 3.0 eV (red). It can be seen that as photon energy is increased the photon density on the left-hand side of the device increases. Thus at low photon energies the EA measurement will only be sensitive to band bending on the right-hand side of the device, while at higher photon energies, the EA measurement will be able to measure average band bending over the whole device.

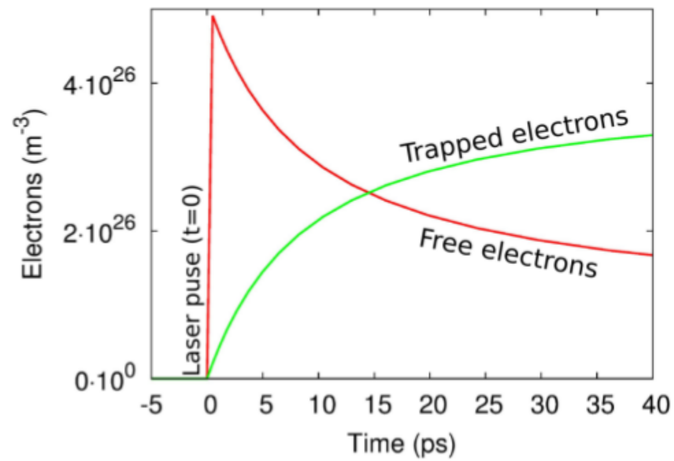


FIG. 9. (Color online) The average carrier density corresponding to free (hot) and trapped (cool) electrons during the measurement. Initially all photogenerated carriers are free but as they cool they become trapped. It can be seen that during the first 10 ps there are more free carriers than trapped carriers; this is the reason for the initial fast separation of the charge packets. It can be seen that past 10 ps most carriers are trapped and thus do not move; this is the reason for the second slow phase to the charge separation transient. At long times the number of trapped carriers decreases; this is due to recombination.

Is this a good or a bad figure?

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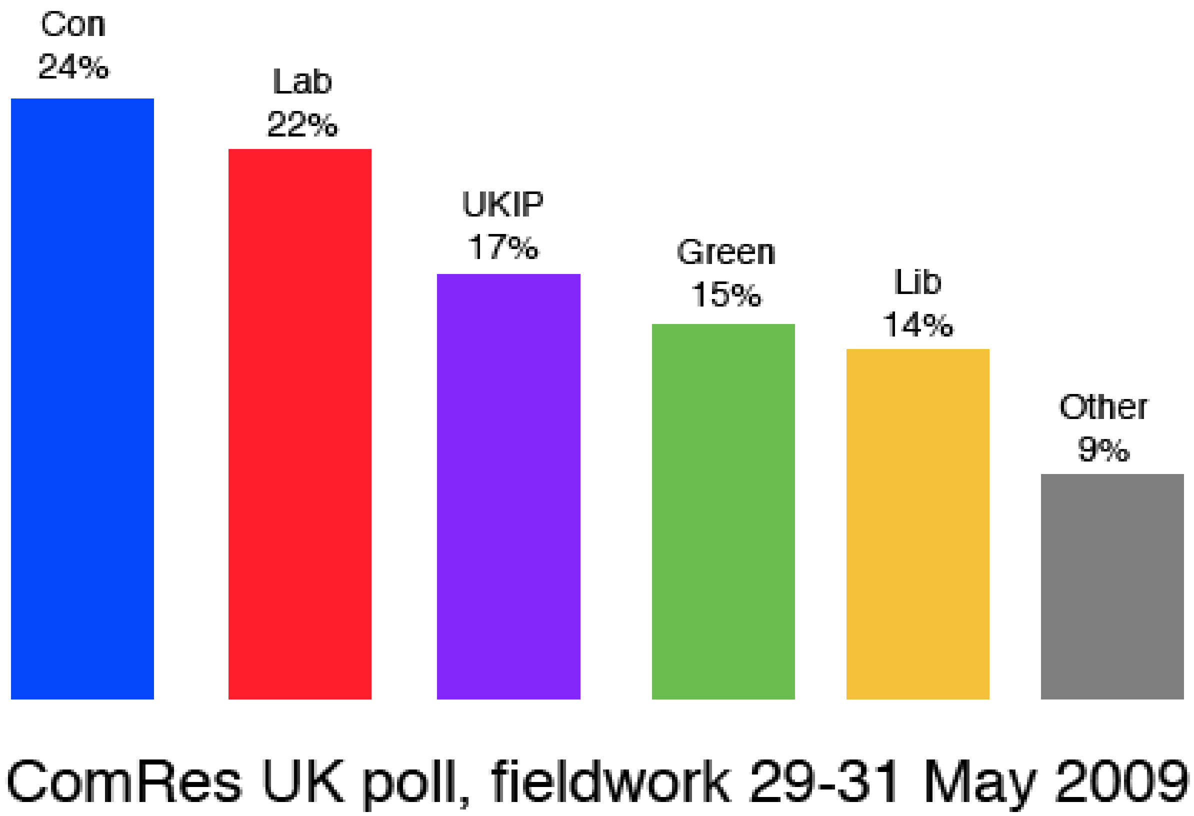
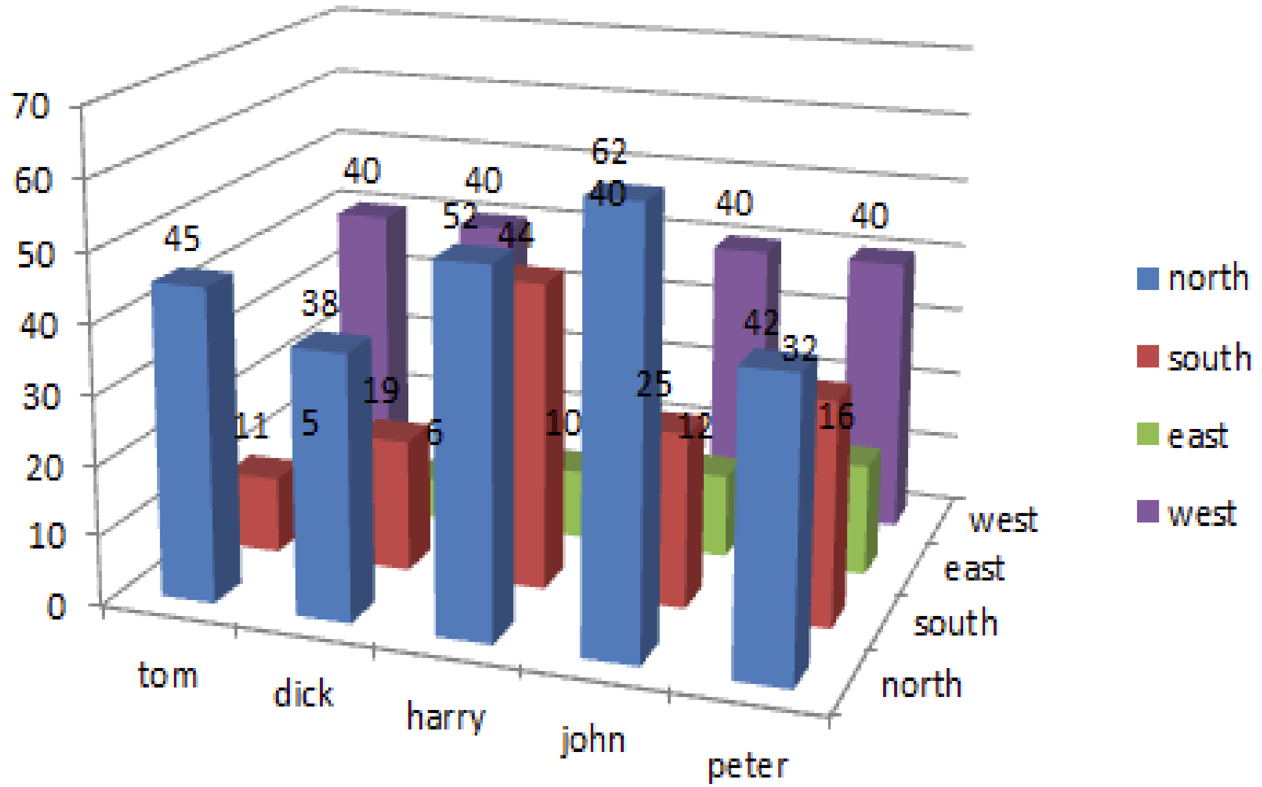
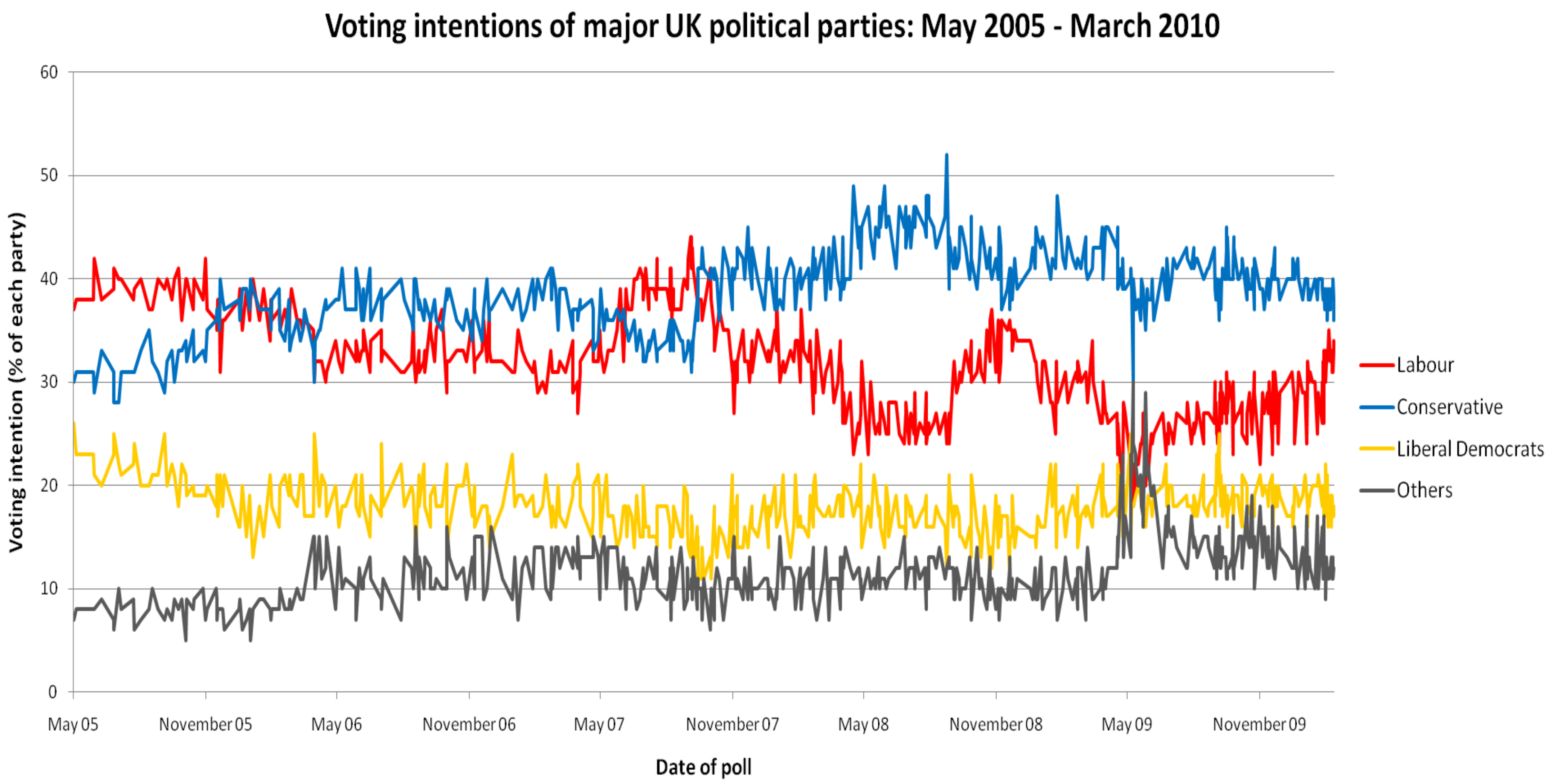


Good or a bad?



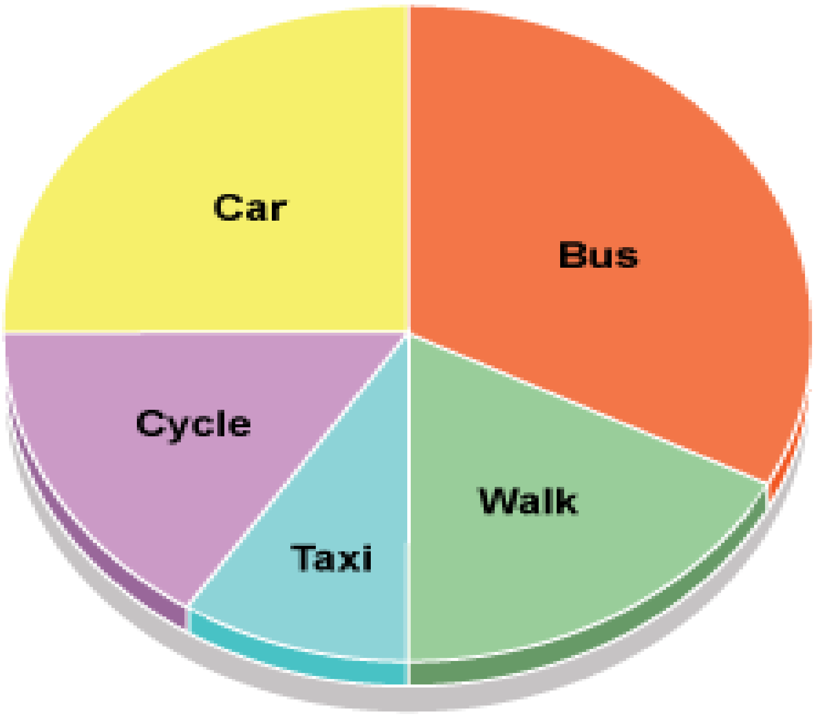
- Remember you are trying to communicate a message to the reader

Good or a bad?



- What has the author done to make the figure more clear?

Good or a bad?



What is missing on this graph?

Good or a bad?

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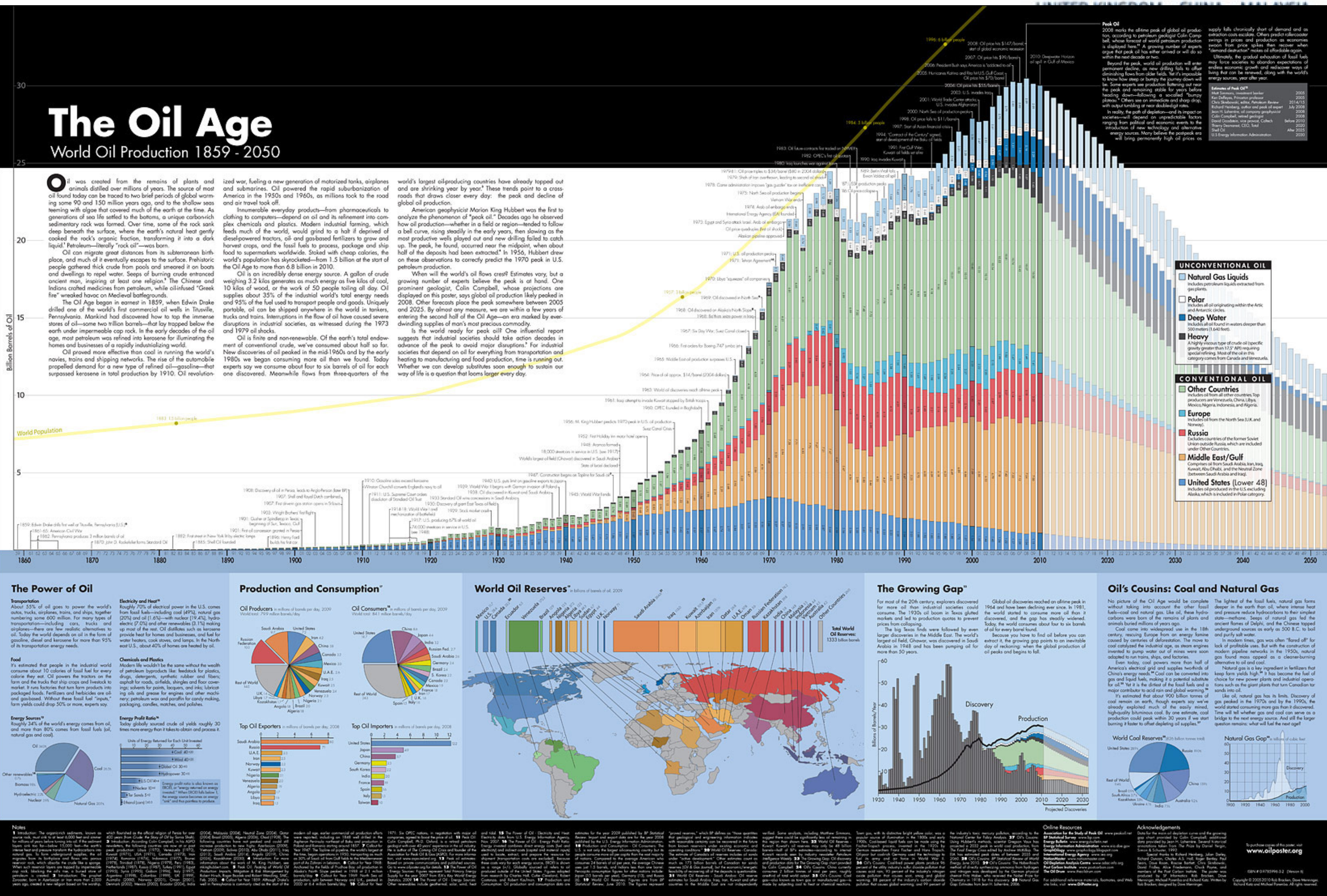
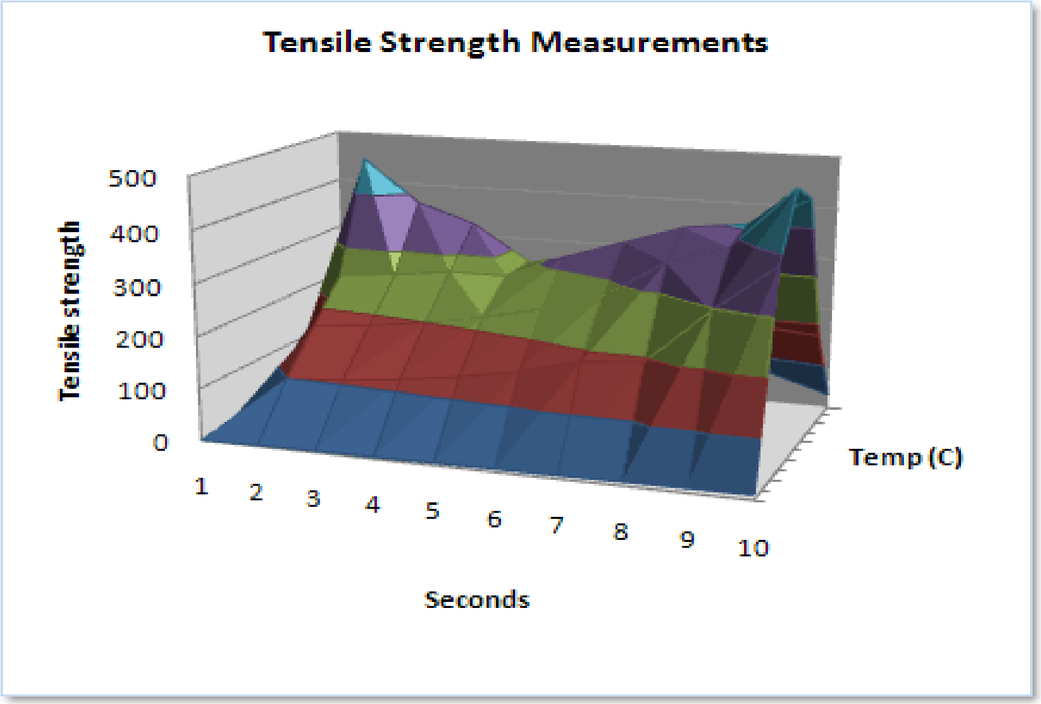


Good or a bad?

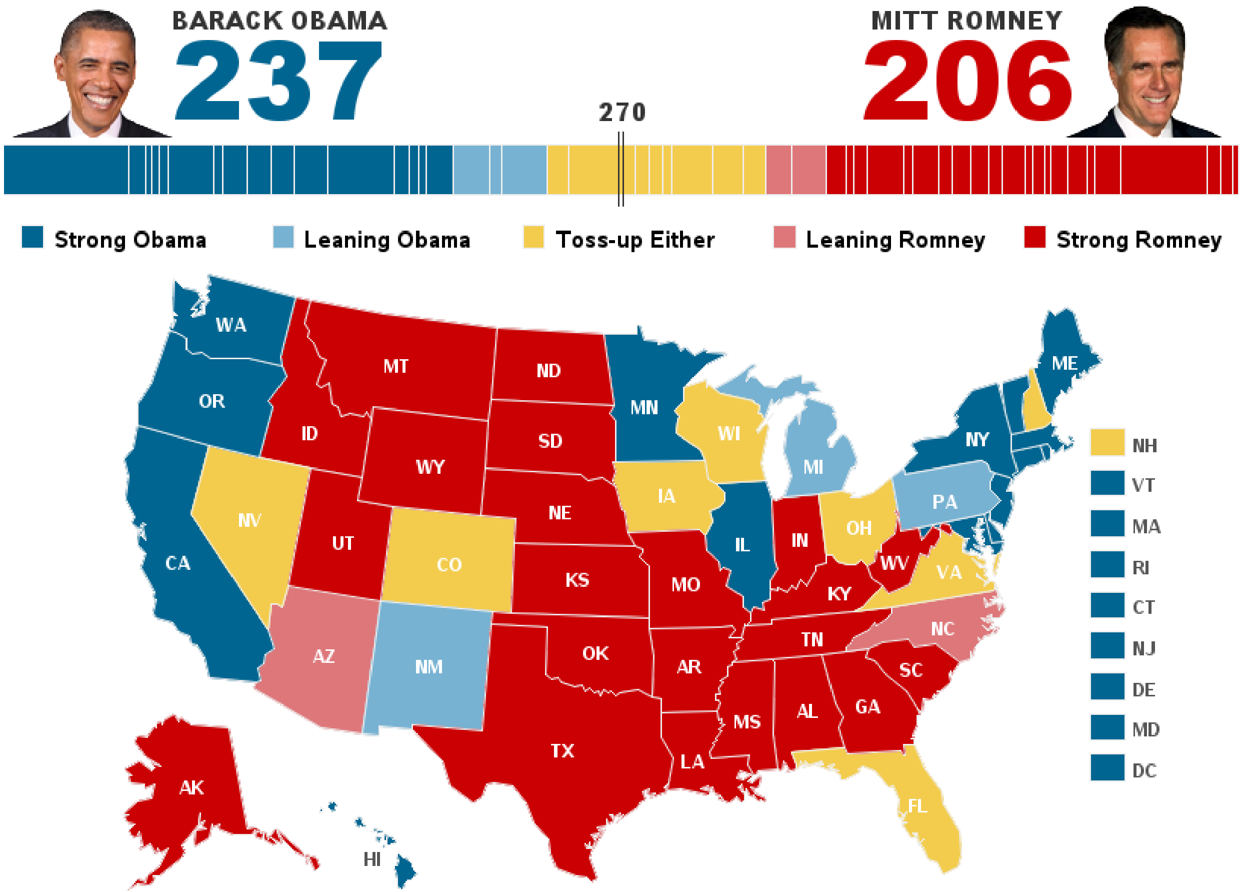
Surface Charts: come in handy if you are to determine the optimum combination between two sets of data.



Electoral Prediction Map

Which candidate will win each state and reach 270 electoral votes first?
Hover your mouse over the states to see the number of electoral votes.

Total number of Electoral College votes: **538**
Total needed to win: **270**



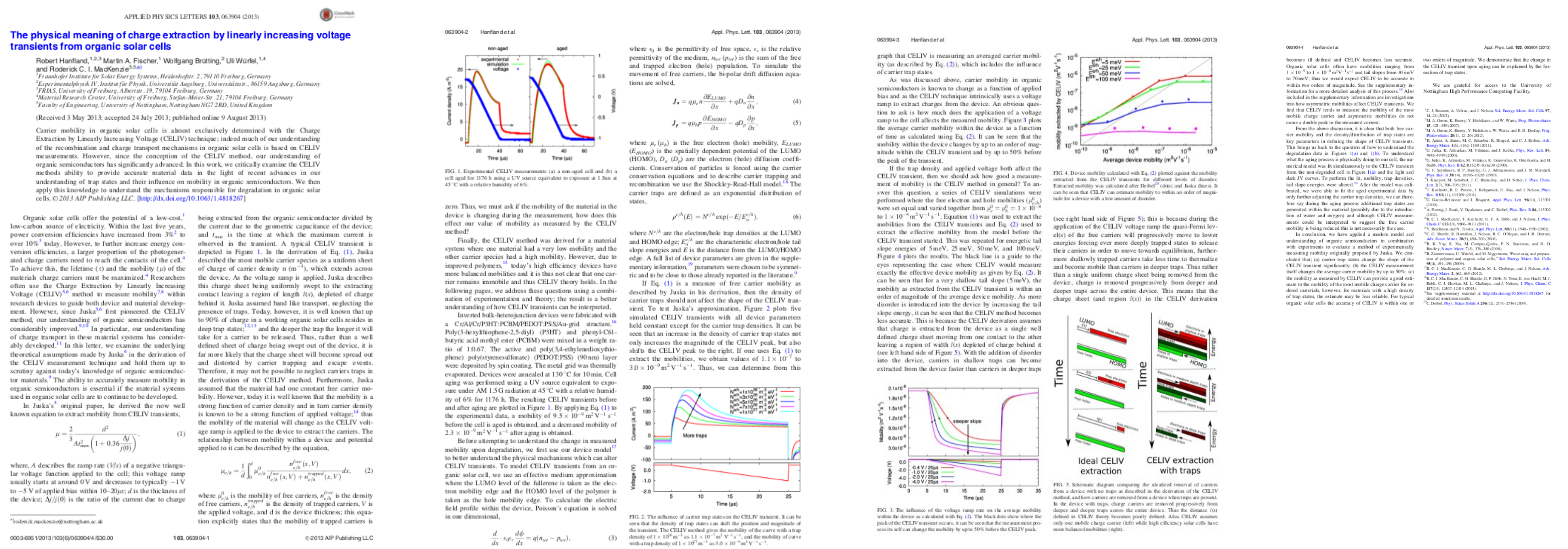
Based on data from CNN.com the morning of November 5, 2012, using SAS/GRAPH software

You should think of every figure as a work of art.

Lecture outline

- The process of knowledge dissemination
- What's the point of references
- Clarity of writing
- Good figures and graphs.
- **How to write a scientific paper.**
- How to write a scientific report
- How to write a thesis.
- How to write a literature review.

Rule 1: Short is good


APPLIED PHYSICS LETTERS 103, 063904 (2013)

The physical meaning of charge extraction by linearly increasing voltage transients from organic solar cells

- People are not that interested in what you have to say, so don’t waste their time by writing too much.
- Always assume they have better things to do than to read your work.
- Keep it short and to the point.

The abstract

The physical meaning of charge extraction by linearly increasing voltage transients from organic solar cells

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[2]*Experimentalphysik IV, Institut für Physik, Universität Augsburg, Universitätsstr., 86159 Augsburg, Germany*
[3]*FRIAS, University of Freiburg, Albertstr. 19, 79104 Freiburg, Germany*
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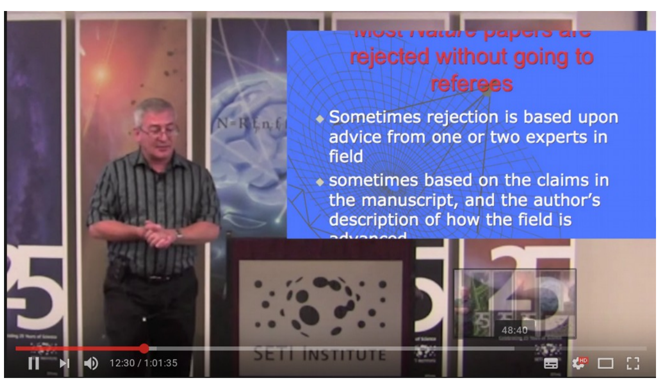
[5]*Faculty of Engineering, University of Nottingham, Nottingham NG7 2RD, United Kingdom*

(Received 3 May 2013; accepted 24 July 2013; published online 9 August 2013)

Carrier mobility in organic solar cells is almost exclusively determined with the Charge Extraction by Linearly Increasing Voltage (CELIV) technique; indeed much of our understanding of the recombination and charge transport mechanisms in organic solar cells is based on CELIV measurements. However, since the conception of the CELIV method, our understanding of organic semiconductors has significantly advanced. In this work, we critically examine the CELIV methods ability to provide accurate material data in the light of recent advances in our understanding of trap states and their influence on mobility in organic semiconductors. We then apply this knowledge to understand the mechanisms responsible for degradation in organic solar cells. *© 2013 AIP Publishing LLC.* [http://dx.doi.org/10.1063/1.4818267]



https://www.youtube.com/watch?v=ys8wHUPd6Vo&t=905s

- Keep the abstract short.
- 200-300 words.
- It should be about the level of a first year undergraduate course so almost anyone can understand what is in the paper.
- It should outline the key findings.
- Not too technical.

The introduction: Paragraph 1

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Organic solar cells offer the potential of a low-cost,[1] low-carbon source of electricity. Within the last five years, power conversion efficiencies have increased from 3%[2] to over 10%[3] today. However, to further increase energy conversion efficiencies, a larger proportion of the photogenerated charge carriers need to reach the contacts of the cell.[4] To achieve this, the lifetime (τ) and the mobility (μ) of the materials charge carriers must be maximized.[4] Researchers often use the Charge Extraction by Linearly Increasing Voltage (CELIV)[5,6] method to measure mobility[7,8] within research devices to guide both device and material development. However, since Juska[5,6] first pioneered the CELIV method, our understanding of organic semiconductors has considerably improved.[9,10] In particular, our understanding of charge transport in these material systems has considerably developed.[11] In this letter, we examine the underlying theoretical assumptions made by Juska[6] in the derivation of the CELIV measurement technique and hold them up to scrutiny against today's knowledge of organic semiconductor materials.[9] The ability to accurately measure mobility in organic semiconductors is essential if the material systems used in organic solar cells are to continue to be developed.

In Juska's[5] original paper, he derived the now well known equation to extract mobility from CELIV transients,

$$\mu = \frac{2}{3}\frac{d^2}{At_{\max}^2\left(1 + 0.36\frac{\Delta j}{j(0)}\right)}, \quad (1)$$

where, A describes the ramp rate (V/s) of a negative triangular voltage function applied to the cell; this voltage ramp usually starts at around 0 V and decreases to typically -1 V to -5 V of applied bias within 10–20μs; d is the thickness of the device; $\Delta j/j(0)$ is the ratio of the current due to charge being extracted from the organic semiconductor divided by the current due to the geometric capacitance of the device; and t_{max} is the time at which the maximum current is observed in the transient. A typical CELIV transient is depicted in Figure 1. In the derivation of Eq. (1), Juska described the most mobile carrier species as a uniform sheet of charge of carrier density n (m^{-3}), which extends across the device. As the voltage ramp is applied, Juska describes this charge sheet being uniformly swept to the extracting contact leaving a region of length $l(x)$, depleted of charge behind it. Juska assumed band like transport, neglecting the presence of traps. Today, however, it is well known that up to 90% of charge in a working organic solar cells resides in deep trap states;[12,13] and the deeper the trap the longer it will take for a carrier to be released. Thus, rather than a well defined sheet of charge being swept out of the device, it is far more likely that the charge sheet will become spread out and distorted by carrier trapping and escape events. Therefore, it may not be possible to neglect carriers traps in the derivation of the CELIV method. Furthermore, Juska assumed that the material had one constant free carrier mobility. However, today it is well known that the mobility is a strong function of carrier density and in turn carrier density is known to be a strong function of applied voltage;[14] thus the mobility of the material will change as the CELIV voltage ramp is applied to the device to extract the carriers. The relationship between mobility within a device and potential applied to it can be described by the equation,

$$\mu_{e/h} = \frac{1}{d}\int_0^d \mu_{e/h}^0 \frac{n_{e/h}^{free}(x,V)}{n_{e/h}^{free}(x,V) + n_{e/h}^{trapped}(x,V)} dx, \quad (2)$$

where $\mu_{e/h}^0$ is the mobility of free carriers, $n_{e/h}^{free}$ is the density of free carriers, $n_{e/h}^{trapped}$ is the density of trapped carriers, V is the applied voltage, and d is the device thickness; this equation explicitly states that the mobility of trapped carriers is

- Accessible to everyone, and should outline the problem in very general terms.
- Why care about solar cells?
- Why should I care about what you are writing about?

The introduction: Paragraph 2

Organic solar cells offer the potential of a low-cost,[1] low-carbon source of electricity. Within the last five years, power conversion efficiencies have increased from 3%[2] to over 10%[3] today. However, to further increase energy conversion efficiencies, a larger proportion of the photogenerated charge carriers need to reach the contacts of the cell.[4] To achieve this, the lifetime (τ) and the mobility (μ) of the materials charge carriers must be maximized.[4] Researchers often use the Charge Extraction by Linearly Increasing Voltage (CELIV)[5,6] method to measure mobility[7,8] within research devices to guide both device and material development. However, since Juska[5,6] first pioneered the CELIV method, our understanding of organic semiconductors has considerably improved.[9,10] In particular, our understanding of charge transport in these material systems has considerably developed.[11] In this letter, we examine the underlying theoretical assumptions made by Juska[6] in the derivation of the CELIV measurement technique and hold them up to scrutiny against today's knowledge of organic semiconductor materials.[9] The ability to accurately measure mobility in organic semiconductors is essential if the material systems used in organic solar cells are to continue to be developed.

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- Introduce the general problem/area that you are going to solve.

The introduction: Paragraph 3

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- Explain to an expert in the field why this is important.
- But still keep the language simple and to the point.
- Cite retentive literature.

The introduction

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Organic solar cells offer the potential of a low-cost,[1] low-carbon source of electricity. Within the last five years, power conversion efficiencies have increased from 3%[2] to over 10%[3] today. However, to further increase energy conversion efficiencies, a larger proportion of the photogenerated charge carriers need to reach the contacts of the cell.[4] To achieve this, the lifetime (τ) and the mobility (μ) of the materials charge carriers must be maximized.[4] Researchers often use the Charge Extraction by Linearly Increasing Voltage (CELIV)[5,6] method to measure mobility[7,8] within research devices to guide both device and material development. However, since Juska[5,6] first pioneered the CELIV method, our understanding of organic semiconductors has considerably improved.[9,10] In particular, our understanding of charge transport in these material systems has considerably developed.[11] In this letter, we examine the underlying theoretical assumptions made by Juska[6] in the derivation of the CELIV measurement technique and hold them up to scrutiny against today's knowledge of organic semiconductor materials.[9] The ability to accurately measure mobility in organic semiconductors is essential if the material systems used in organic solar cells are to continue to be developed.

In Juska's[5] original paper, he derived the now well known equation to extract mobility from CELIV transients,

$$\mu = \frac{2}{3}\frac{d^2}{At_{\max}^2\left(1+0.36\dfrac{\Delta j}{j(0)}\right)}, \qquad (1)$$

where, A describes the ramp rate (V/s) of a negative triangular voltage function applied to the cell; this voltage ramp usually starts at around 0 V and decreases to typically -1 V to -5 V of applied bias within 10–20μs; d is the thickness of the device; $\Delta j/j(0)$ is the ratio of the current due to charge being extracted from the organic semiconductor divided by the current due to the geometric capacitance of the device; and t_{max} is the time at which the maximum current is observed in the transient. A typical CELIV transient is depicted in Figure 1. In the derivation of Eq. (1), Juska described the most mobile carrier species as a uniform sheet of charge of carrier density n (m^{-3}), which extends across the device. As the voltage ramp is applied, Juska describes this charge sheet being uniformly swept to the extracting contact leaving a region of length $l(x)$, depleted of charge behind it. Juska assumed band like transport, neglecting the presence of traps. Today, however, it is well known that up to 90% of charge in a working organic solar cells resides in deep trap states;[12,13] and the deeper the trap the longer it will take for a carrier to be released. Thus, rather than a well defined sheet of charge being swept out of the device, it is far more likely that the charge sheet will become spread out and distorted by carrier trapping and escape events. Therefore, it may not be possible to neglect carriers traps in the derivation of the CELIV method. Furthermore, Juska assumed that the material had one constant free carrier mobility. However, today it is well known that the mobility is a strong function of carrier density and in turn carrier density is known to be a strong function of applied voltage;[14] thus the mobility of the material will change as the CELIV voltage ramp is applied to the device to extract the carriers. The relationship between mobility within a device and potential applied to it can be described by the equation,

$$\mu_{e/h} = \frac{1}{d}\int_0^d \mu_{e/h}^0 \frac{n_{e/h}^{free}(x,V)}{n_{e/h}^{free}(x,V)+n_{e/h}^{trapped}(x,V)}dx, \qquad (2)$$

where $\mu_{e/h}^0$ is the mobility of free carriers, $n_{e/h}^{free}$ is the density of free carriers, $n_{e/h}^{trapped}$ is the density of trapped carriers, V is the applied voltage, and d is the device thickness; this equation explicitly states that the mobility of trapped carriers is

- This section of the paper should be littered with references to show that you have read other peoples work and understand what you are talking about.

Experimental method (Or methods section)

- Describe what you did in the experimental method.
- You must include enough detail so someone can repeat your experiment
- Here's the catch…. People don't like reading experiential sections they are boring!
- So describe what you did in really brief terms. Maybe a paragraph or two.
- Then put the rest of the text in the supplementary information (SI).

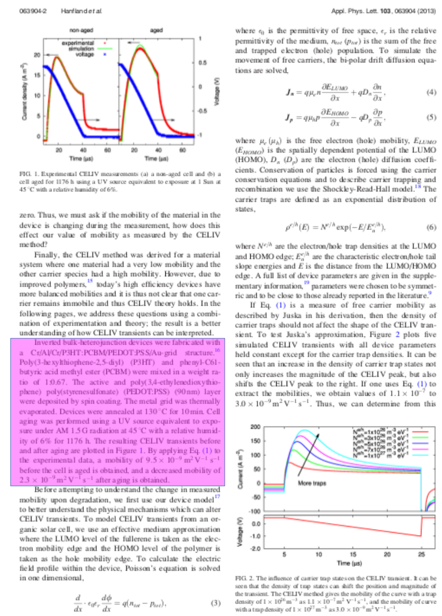

FIG. 1. Experimental CELIV measurements (a) a non-aged cell and (b) a cell aged for 1176 h using a UV source equivalent to exposure at 1 Sun at 45 °C with a relative humidity of 6%.

zero. Thus, we must ask if the mobility of the material in the device is changing during the measurement, how does this effect our value of mobility as measured by the CELIV method?

Finally, the CELIV method was derived for a material system where one material had a very low mobility and the other carrier species had a high mobility. However, due to improved polymers,[15] today's high efficiency devices have more balanced mobilities and it is thus not clear that one carrier remains immobile and thus CELIV theory holds. In the following pages, we address these questions using a combination of experimentation and theory; the result is a better understanding of how CELIV transients can be interpreted.

Inverted bulk-heterojunction devices were fabricated with a Cr/Al/Cr/P3HT:PCBM/PEDOT:PSS/Au-grid structure.[16] Poly(3-hexylthiophene-2,5-diyl) (P3HT) and phenyl-C61-butyric acid methyl ester (PCBM) were mixed in a weight ratio of 1:0.67. The active and poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate) (PEDOT:PSS) (90 nm) layer were deposited by spin coating. The metal grid was thermally evaporated. Devices were annealed at 130 °C for 10 min. Cell aging was performed using a UV source equivalent to exposure under AM 1.5 G radiation at 45 °C with a relative humidity of 6% for 1176 h. The resulting CELIV transients before and after aging are plotted in Figure 1. By applying Eq. (1) to the experimental data, a mobility of 9.5×10^{-9} m^2 V^{-1} s^{-1} before the cell is aged is obtained, and a decreased mobility of 2.3×10^{-9} m^2 V^{-1} s^{-1} after aging is obtained.

Before attempting to understand the change in measured mobility upon degradation, we first use our device model[17] to better understand the physical mechanisms which can alter CELIV transients. To model CELIV transients from an organic solar cell, we use an effective medium approximation where the LUMO level of the fullerene is taken as the electron mobility edge and the HOMO level of the polymer is taken as the hole mobility edge. To calculate the electric field profile within the device, Poisson's equation is solved in one dimensional,

$$\frac{d}{dx} \cdot \epsilon_0 \epsilon_r \frac{d\phi}{dx} = q(n_{tot} - p_{tot}), \quad (3)$$

where ϵ_0 is the permittivity of free space, ϵ_r is the relative permittivity of the medium, n_{tot} (p_{tot}) is the sum of the free and trapped electron (hole) population. To simulate the movement of free carriers, the bi-polar drift diffusion equations are solved,

$$J_n = q\mu_e n \frac{\partial E_{LUMO}}{\partial x} + qD_n \frac{\partial n}{\partial x}, \quad (4)$$

$$J_p = q\mu_h p \frac{\partial E_{HOMO}}{\partial x} - qD_p \frac{\partial p}{\partial x}, \quad (5)$$

where μ_e (μ_h) is the free electron (hole) mobility, E_{LUMO} (E_{HOMO}) is the spatially dependent potential of the LUMO (HOMO), D_n (D_p) are the electron (hole) diffusion coefficients. Conservation of particles is forced using the carrier conservation equations and to describe carrier trapping and recombination we use the Shockley-Read-Hall model.[18] The carrier traps are defined as an exponential distribution of states,

$$\rho^{e/h}(E) = N^{e/h} \exp(-E/E_u^{e/h}), \quad (6)$$

where $N^{e/h}$ are the electron/hole trap densities at the LUMO and HOMO edge; $E_u^{e/h}$ are the characteristic electron/hole tail slope energies and E is the distance from the LUMO/HOMO edge. A full list of device parameters are given in the supplementary information,[19] parameters were chosen to be symmetric and to be close to those already reported in the literature.[9]

If Eq. (1) is a measure of free carrier mobility as described by Juska in his derivation, then the density of carrier traps should not affect the shape of the CELIV transient. To test Juska's approximation, Figure 2 plots five simulated CELIV transients with all device parameters held constant except for the carrier trap densities. It can be seen that an increase in the density of carrier trap states not only increases the magnitude of the CELIV peak, but also shifts the CELIV peak to the right. If one uses Eq. (1) to extract the mobilities, we obtain values of 1.1×10^{-7} to 3.0×10^{-9} m^2 V^{-1} s^{-1}. Thus, we can determine from this

FIG. 2. The influence of carrier trap states on the CELIV transient. It can be seen that the density of trap states can shift the position and magnitude of the transient. The CELIV method gives the mobility of the curve with a trap density of 1×10^{26} m^{-3} as 1.1×10^{-7} m^2 V^{-1} s^{-1}, and the mobility of curve with a trap density of 1×10^{27} m^{-3} as 3.0×10^{-9} m^2 V^{-1} s^{-1}.

The physical meaning of charge extraction by linearly increasing voltage transients from organic solar cells

Robert Hanfland[1,2,3], Martin A. Fischer[1], Wolfgang Brütting[2], Uli Würfel[1,4], and Roderick C. I. MacKenzie[3,5a)]

View Affiliations

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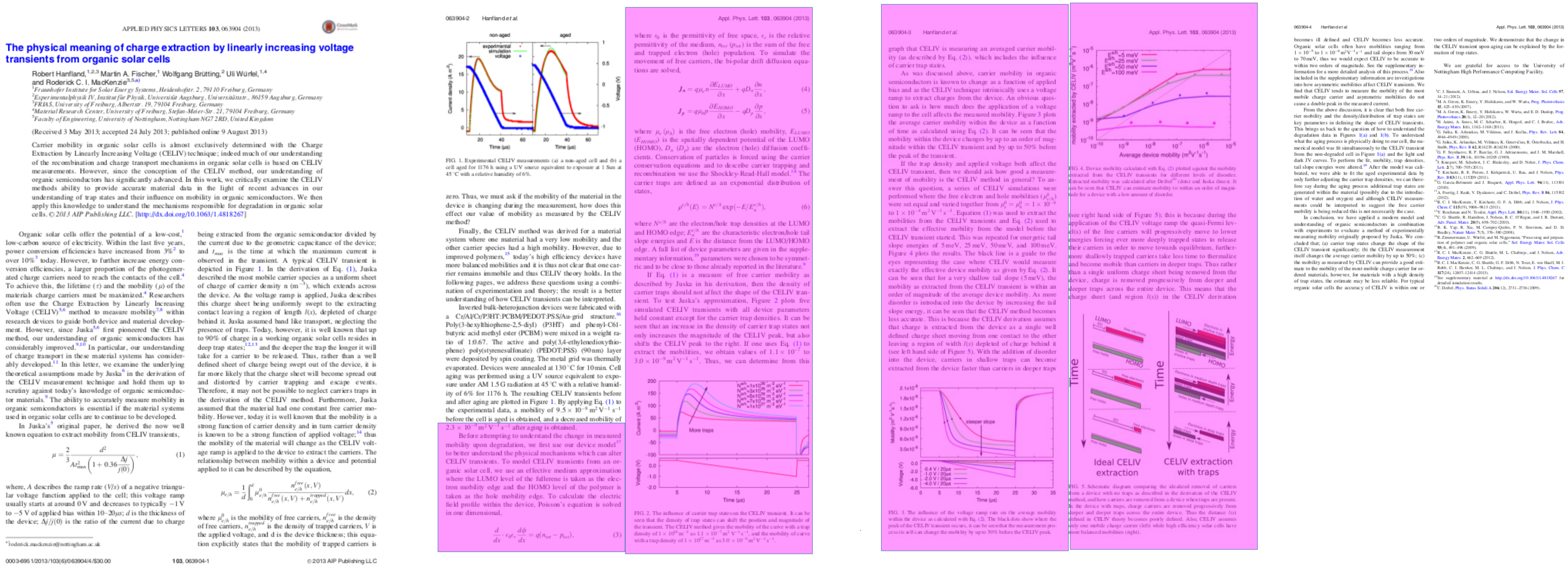
PDF   ABSTRACT   FULL TEXT   FIGURES   SUPPLEMENTAL   CITED BY   TOOLS   SHARE   METRICS

Carrier mobility . Charge carriers . Solar cells . Organic semiconductors . Electric measurements

supinfo.pdf (398 KB)

Results/Discussion

- Some people/journals like to separate out the results section and the discussion of the results section.
  - I don't.


APPLIED PHYSICS LETTERS 103, 063904 (2013)

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- I tend to merge the results/discussion into an interesting story.

Conclusions

- 1 Paragraph max
- Summarize the key results

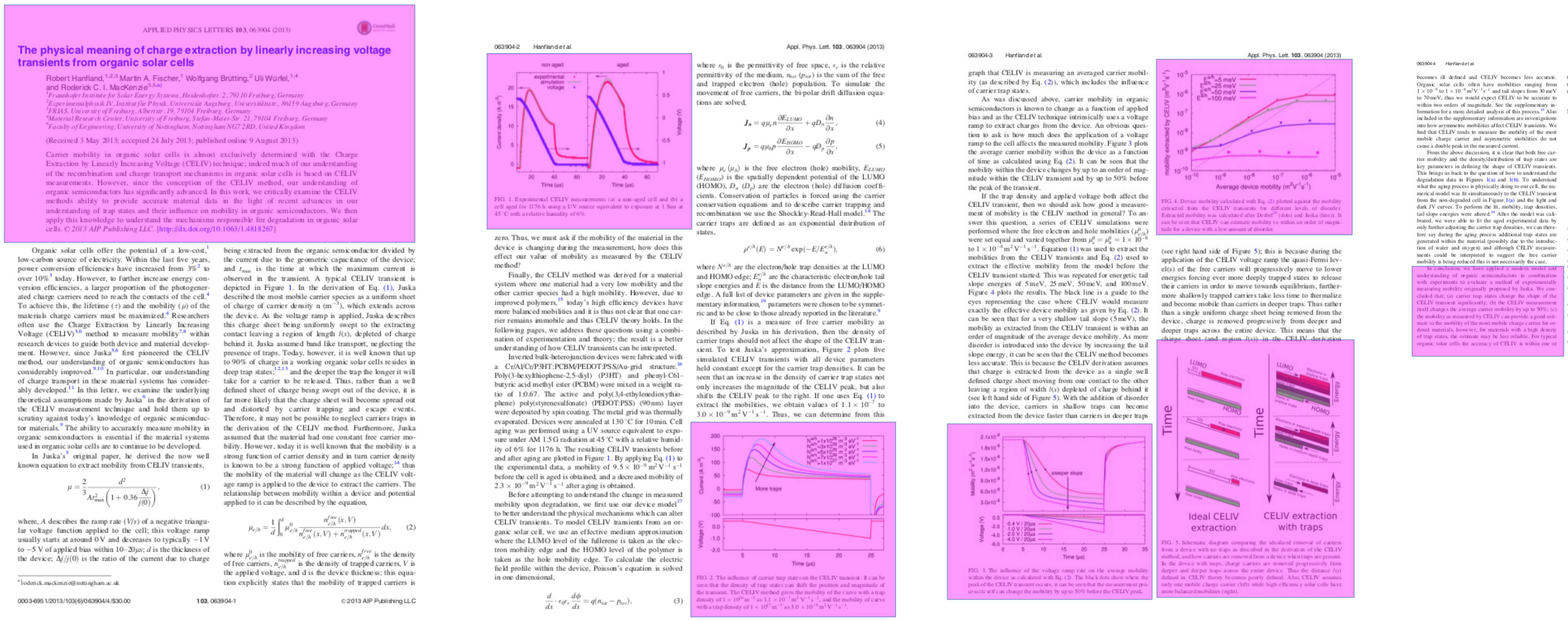
In conclusion, we have applied a modern model and understanding of organic semiconductors in combination with experiments to evaluate a method of experimentally measuring mobility originally proposed by Juska. We concluded that; (a) carrier trap states change the shape of the CELIV transient significantly; (b) the CELIV measurement itself changes the average carrier mobility by up to 50%; (c) the mobility as measured by CELIV can provide a good estimate to the mobility of the most mobile charge carrier for ordered materials, however, for materials with a high density of trap states, the estimate may be less reliable. For typical organic solar cells the accuracy of CELIV is within one or

- Keep it short, punchy, and tell the reader what you found out. Don't tell the reader again what you did.

These are not conclusions

- “All objectives were achieved” - the reader does not care.
- “The work was a success” - leave that up to the reader to decide.
- “We performed measurements on 100 solar cells” - no one cares.
- “We had highly efficient devices” - let the reader decide.

Finally, how much will people read of my paper/report?



- I'm afraid usually that's it.
- So make sure these parts are really good.

Lecture outline

- The process of knowledge dissemination
- What’s the point of references
- Clarity of writing
- Good figures and graphs.
- How to write a scientific paper
- **How to write a scientific report**
- How to write a thesis.
- How to do a literature review.
- Abstract/Method/Discussion/Conclusion
  - Abstract/Introduction/Results/Discussion/Conclusios

Lab reports

Generally lab reports take the same form as a paper:

`

- **Title**
  - Obvious
- **Abstract**
  - We have discussed this
- **Introduction**
  - We have discussed this
- **Methods**
  - This is what you did. i.e. your method used for doing the experiment
- **Results**
  - We have discussed this
- **Discussion**
  - We have discussed this
- **Literature cited**
  - We have discussed this

- You do generally however have more space in a lab report and they are in general more relaxed. You don't necessarily have to use so many references
- They are generally under 10 pages long and in size 12 text with diagrams/pictures/equations.

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- How to write a scientific report
- **How to write a thesis**
- How to do a literature review.

How to write a thesis

You guessed it the structure is pretty much the same:

+ indicates that the chapter can span multiple chapters.

- 1 page: **Title**
- 1 page: **Abstract**
- Chapter 1: **Introduction**
- Chapter 2+: **Methods**
- Chapter 3+: **Results**
- Chapter 4: **Discussion**
- Chapter 5: **Conclusion**

- So now you really know how to write any type of scientific document!

Your go

- Write a mini paper with a few sentences in each section.
- With one figure.
- I will come around and give you feedback.
- This should only take 5 min.

https://www.youtube.com/watch?v=UtHMeeJUKdo

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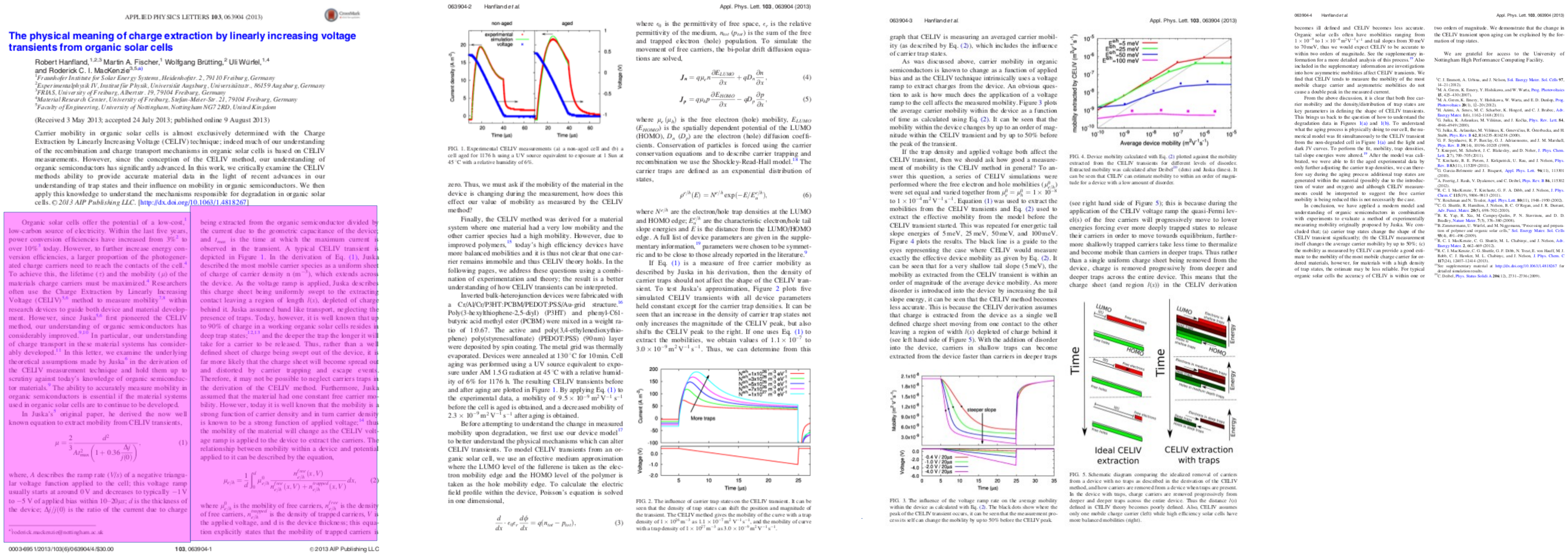
Literature review

- This part of a paper can be though of as a mini literature review.



- Literature reviews, can be of any length
- This is a short one, they can be multiple pages
- Or even whole books.

Literature review

- *What is a literature review?*
  - It is a **summary** of all the **key literature** published **in a field**.

- *Why write a literature review?*
  - To show your reader (your supervisor) that you have read, and understand the main published works in your field.
  - They are also very useful to read if you are just getting into a field (They are sometimes called **review articles**).

- Coursework 1: will be to write a 3000 word (minimum) literature review on the topic if your MSc project.
- Due date on the last day of this term (Friday 7th April).

Literature review

- What a literature review should **not be**:
  - A description of what others have published in the form of a set of summaries
- What **should** a literature review be:
- It should be a critical discussion, showing insight and an awareness of differing arguments, theories and approaches.
- It should analyze of the relevant published work, linked at all times to your own purpose and rationale.

According to Caulley (1992) of La Trobe University:

- Compare and contrast different authors' views on an issue
- Group authors who draw similar conclusions
- Criticise aspects of methodology
- Note areas in which authors are in disagreement
- Highlight exemplary studies
- Highlight gaps in research
- Show how your study relates to previous studies
- Show how your study relates to the literature in general
- Conclude by summarising what the literature says

The purposes of the review are:

- To define and limit the problem you are working on
- To place your study in an historical perspective
- To avoid unnecessary duplication
- To evaluate promising research methods
- To relate your findings to previous knowledge and suggest further research

In summary: **A good literature review, therefore, is critical of what has been written, identifies areas of controversy, raises questions and identifies areas which need further research.**

How to write a literature review:

- You will need to group together, compare and contrast the varying opinions of different writers on certain topics.
- What you must not do is just describe what one writer says, then describe what the next writer says and so on ...
- Your structure should be dictated instead by topic areas, controversial issues or by questions to which there are varying approaches and theories. Within each of these sections, you would then discuss what the different literature argues, remembering to link this to your own purpose.
- If there is disagreement in the field, you need to indicate clearly that you are aware of this.
- At the end of the review you should include a summary of what the literature implies.

Overall stratagy

- Decide what you need to read, your supervisor may suggest one or two good papers to start with.

- Before you start reading it may be useful to compile a list of the main areas and questions involved, this list may change as you read.

Make sure that:

- You include a clear, short introduction which gives an outline of the review, including the main topics covered and the order of the arguments, with a brief rationale for this.

- Split your review up into relevant subsections based around topics in your field.

- Include a short summary at the end of each section.

- You always acknowledge opinions which do not agree with.

- If you ignore opposing viewpoints, your argument will in fact be weaker.

How to get started!

- When I’m learning about a new topic I try to find **easy to understand** things first.
- I always **start** with Wikipedia and general articles on the web (for an hour or so)
- I then use scholar.google.com to search for key words and try to identify key papers which look interesting.
- Then, try also to identify key people or groups working on a topic and find what they are doing.
- Figure out who you respect in a field and who you don’t respect.
- Follow references at the bottom of papers.

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