How to Read a Scientific Paper

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Reading a scientific paper is an **ACTIVE** task.
It requires thinking critically as you read.

- You will often have to read a paper more than once
- You often will not read a paper straight through
- Different sections of a typical paper:
    1. Abstract
    2. Introduction
    3. Methods
    4. Results & Discussion
    5. Conclusion
    6. References

Abstract

Abstract

- This is a **paper summary**
- A (tiny) bit of background & motivation
- Summarizes findings and main results
- Summarizes main conclusions

A scientific paper is not a mystery novel. The answer is on the abstract.

Dinner parties are popular events that have been estimated to occur 10^{12} times each year. We report on the Royal Society's 2024 new year's eve dinner party where two guests were murdered. We determined that several guests had motive because they submitted a paper that was negatively reviewed by the victims. Eyewitnesses reported that the victims were killed by a crossbow fired from the balcony. Only the butler had access to the balcony and everyone else was present in the dinning room. We found the murder weapon in the butler's private quarters. The butler subsequently confessed to the murders.

Abstract from CMP

Abstract

Electron transfer through molecular frameworks is central to a wide range of chemical, physical, and biological processes. We demonstrate a means to measure electronically and to quantify electron transfer through organic molecules and films. We show quantitative agreement with universal values of electron transfer inferred from biological, electrochemical, photochemical, and related systems. Scanning tunneling microscopy was used to image adjacent chains and molecular terraces of different length alkanethiolates in an ordered self-assembled monolayer lattice on Au{111}. In electron transfer measurements using a scanning tunneling microscope, both the driving force and the electrode separation can be continuously varied. This allows independent electronic measurement of the molecular bridges through which electron transfer takes place. The differences between the measured topography in scanning tunneling microscopy and the physical heights of these molecules can be understood in terms of the transconductance through individual chains using a two-layer tunnel junction model.

Note the terminology: Terms are often specific to each subfield

Electron Transfer through Organic Molecules, L. A. Bumm, J. J. Arnold, T. D. Dunbar, D. L. Allara, and P. S. Weiss, *J. Phys. Chem. B* **1999** 103 (38), 8122-8127. DOI: 10.1021/jp9921699

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Introduction

Introduction

- Details **background information**
- **Citations to background literature**
- Gives reader **context** to know what's going on and why the subject Is being studied
- Poses the **relevant questions** being answered in the paper
- So: **what is known, what is not known, and what they authors are trying to learn**

Introduction

Introduction

Many quantitative measurements of electron transfer efficiencies through molecular frameworks have been made. [1-35] These have generally applied optical spectroscopy,[4-9] electrochemistry,[10-15] or direct electronic measurements[16-26] to large ensembles of molecules. The values obtained are thus ensemble averages. Measurements of electron transfer through individual molecules are more difficult. Small ensembles of molecules have been measured using break junctions,[17] nanolithographically defined pores,[18] nanometer-scale contacts,[19] and nanometer-scale networks.[20] Carbon nanotubes are particularly amenable to single-molecule measurements because of their extreme lengths (micrometers). Measurements have been made of the molecular electronic properties on single-wall,[21] multiwall,[22-25] and ropes of single-wall[26] carbon nanotubes.

Understanding electron transfer at the molecular level will aid in developing molecular assemblies with unique properties and novel applications, such as photosynthetic systems [5,36] and molecular electronic devices. [37-43] In addition, measurements of the transconductances of contacts and of molecules will give us critical insight into the electronic couplings within and between molecules and at interfaces. Key to understanding electron transfer is the ability to make quantitative measurements on single molecules, features, or components. This will provide the capability to compare directly to inferred electron dynamics in biochemistry,[2,4,6,7,44] electrochemistry,[10-13] photochemistry,[5,36] and nanometer- and molecular-scale electronics.[37-43] In addition, we address how the scanning tunneling microscope is capable of imaging such “insulating” molecular structures and discuss the contrast mechanism in scanning tunneling microscopy (STM).

Methods

Methods

- how authors went about obtaining their results
- Should have enough details that others can duplicate the results
- This is a difficult section to read through as it can be highly technical

Methods

Experimental Section

We prepared a two-component mosaic SAM using a stepwise procedure as described in ref 47. Briefly, a single-component SAM of 100% **12** was prepared from a 1 mM solution of thiol of **12** in ethanol. The Au{111} was prepared by vapor depositing Au onto freshly cleaved heated muscovite mica. The substrate was immersed in the alkanethiol solution for 18 h, removed, rinsed thoroughly in solvents, and then blown dry with N_2. Then, this single component SAM of **12** was heated for 1 h in neat ethanol at 78 °C, cooled, rinsed, and blown dry. Finally, the SAM was immersed into a 1 mM solution of the thiol of **10** in ethanol at room temperature for 6 h, rinsed, and blown dry. The SAMs were imaged by STM using constant current feedback. [52] Our images were acquired with a tunnel junction transimpedance of 100 GΩ or greater, where the tip is outside the SAM so that the monolayer surface is not perturbed. [47,53] The scanning tunneling microscope was enclosed in a controlled atmosphere using a constant dry N_2 purge. Similar results have been obtained using other length alkanethiol combinations and component ratios. [51,54] All the STM images shown here are presented unfiltered.

Results & Discussion

Results and Discussion

- Describes **what experiments were done**
- Explains the results
- The **interpretation section**
- (usually) contains most of the plots (graphs)
- Analyzes the data and **draws conclusions**
- Explains sources of **error and uncertainty**

Results & Discussion

- **Figures**
  - often the key points in the paper
  - explained in the caption

Results & Discussion

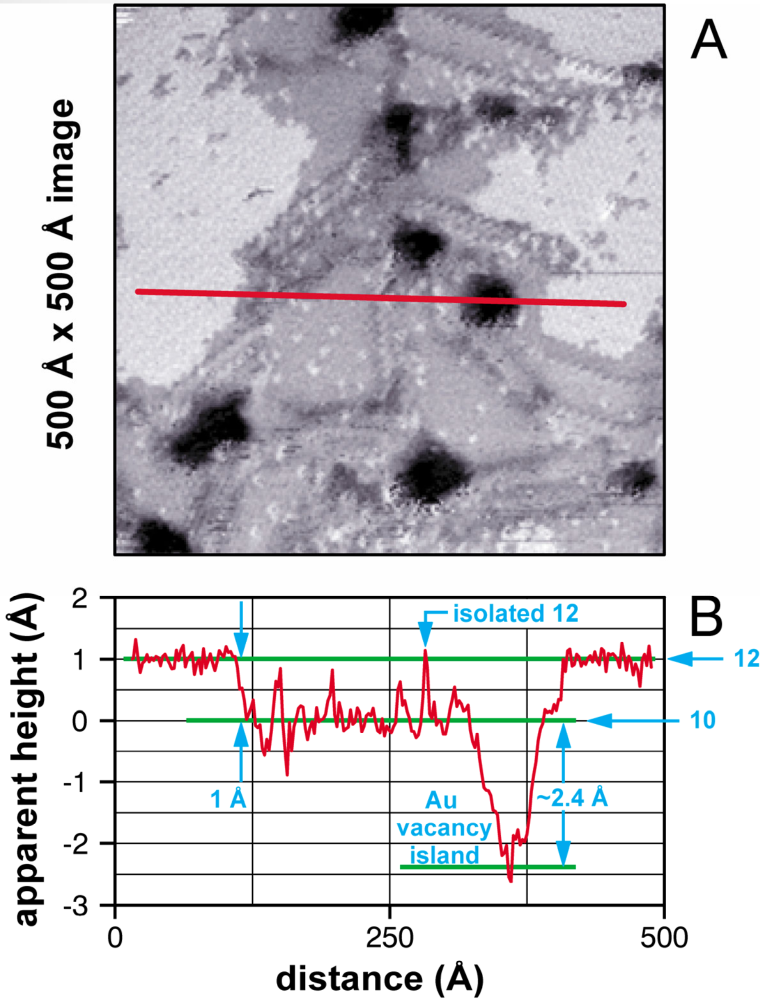


Figure 1 (A) STM image of a 500 Å × 500 Å area of the mixed composition mosaic SAM of **10** and **12** showing the alkanethiolate molecular lattice. The topographically higher (shown as brighter) regions are domains of **12**. These are present largely as well-ordered islands, remnants of the treatment in hot ethanol, which dramatically reduces the defect density. The islands of **12** are surrounded by the topographically lower **10**, displaying domain sizes and defect densities typical of SAMs formed at room temperature. These defects, the topographically lower (shown as darker) spots, are Au substrate vacancy islands (one atom deep depressions in the underlying Au{111} substrate) and the alkanethiolate structural domain boundaries (also darker). Interspersed molecules of **12** are observed in the regions of **10** and vice versa. The boundaries between the regions of **10** and **12** are well defined and are molecularly sharp. The image was recorded with a tip bias of +1.0 V and a tunneling current of 10 pA. (B) A topographic cross section extracted from A on the path shown by the red line. The STM topographic heights are shown for **12**, **10**, and a Au substrate vacancy island. Note that the height difference between the molecular terraces of **12** and **10** is 1.0 ± 0.2 Å, in contrast to the physical height difference of 2.2 Å. The cross section passes through a Au substrate vacancy island, 2.4 Å deep, and also through an isolated molecule of **12** in the **10** region.

Results & Discussion

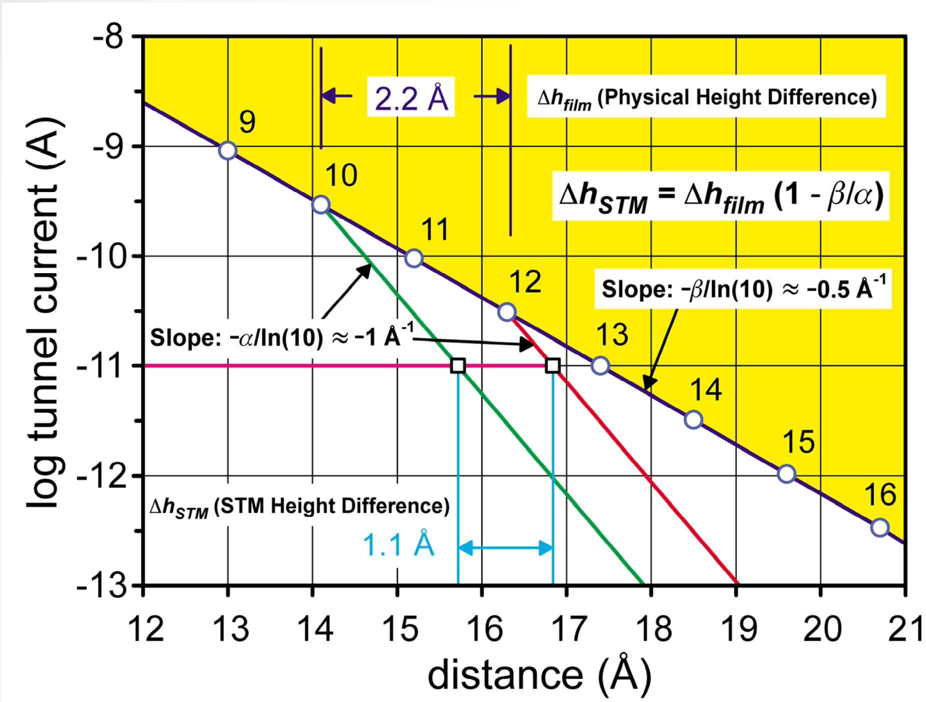


Figure 3 Semilogarithmic plot of the tunneling current vs tip−Au substrate separation for 1-alkanethiolates on Au{111} at a 1 V tip bias (adapted from ref 33). The open circles represent the hypothetical current−distance point for the tip just in contact with the ends of the alkyl chains with the total number of carbons indicated. These circles fall on a line with a slope $-\beta/\ln(10) = -0.5$ Å^{-1} ($\beta = 1.2$ Å^{-1} or 1.5 per methylene unit). The yellow region above this line corresponds to the condition where the tip has penetrated the alkanethiolate film. The lines intersecting the open circles at alkyl chain lengths of 10 (green) and 12 (red) carbon atoms, respectively, represent the tunneling current−distance relationship when the tip is outside the alkanethiolate film (above the ends of the alkanethiolate chains) with a slope of $-\alpha/\ln(10) = -1.0$ Å^{-1}. The tunneling current set-point value of 10 pA (magenta line) used for the data shown in Figure 1 positions the probe tip outside the films of both **10** and **12**.[47] The topographic height difference measured by STM is the distance between these two operating points, open squares. The relationship between the STM height difference Δh_{STM} and the physical height difference Δh_{film} is $\Delta h_{STM} = \Delta h_{film}(1 - \beta/\alpha)$, which for this diagram is $\Delta h_{STM} \approx 0.5\Delta h_{film}$.

Results & Discussion

- **Equations**
  - need to read text to understand
  - May also in introduction as background

$$\Delta h_{\mathrm{STM}} = \Delta h_{\mathrm{film}}(1 - \beta/\alpha)$$

Conclusion

Conclusion

- a concise summary of the study's main findings, implications, and significance
- explains why the research should matter to the reader
- The take-home message
- interprets the findings at a higher level of abstraction than the Discussion
- relates the findings to the motivation stated in the Introduction

Conclusion

Conclusions

We are able to compare the transconductance of these molecules accurately using STM because the molecularly sharp **10/12** boundaries of the mosaic SAM enables the imaging of ordered domains in the identical conformation within the same image using the same STM probe tip. It is a necessary condition for imaging these films that the STM probe tip remains outside the film, which is achieved by using a low tunnel junction transconductance ($\lesssim 10^{-11}\ \Omega^{-1}$), as can be seen in Figure 3. The STM tunneling junction is then composed of two layers, the film and the tip−film gap. The film is imaged with constant tunneling current where the scanning tunneling microscope constrains the tunnel junction transconductance to be constant by changing the tip−film gap to compensate for changes in film transconductance and film thickness. The transconductance of the molecules of the film are exponentially dependent on their length with the decay constant β and a preexponential factor B, while that of the tip−film gap depends on α and A. Because **10** and **12** are from a homologous series, the 1-alkanethiols, we can assume that β, B, α, and A are the same for both **10** and **12**. The transconductance of **10** is 10-fold higher than that of **12** because it is shorter (two methylene units). The STM measured **10/12** height difference is less than the actual physical height difference because it convolves the physical and the electronic properties of the film into a surface of constant tunneling current the STM constant-current topograph.

We have shown that the measured values of electron transfer can be connected quantitatively with widespread transconduction phenomena of molecular frameworks and films. STM has the advantage that both the driving force and the tunneling distance can be varied independently for studies of electron transfer through single molecules and molecular assemblies. We are working toward quantifying the conductivity of inserted conjugated molecules[27] and of related films and the effects of chemical substitutions on electron transfer properties.

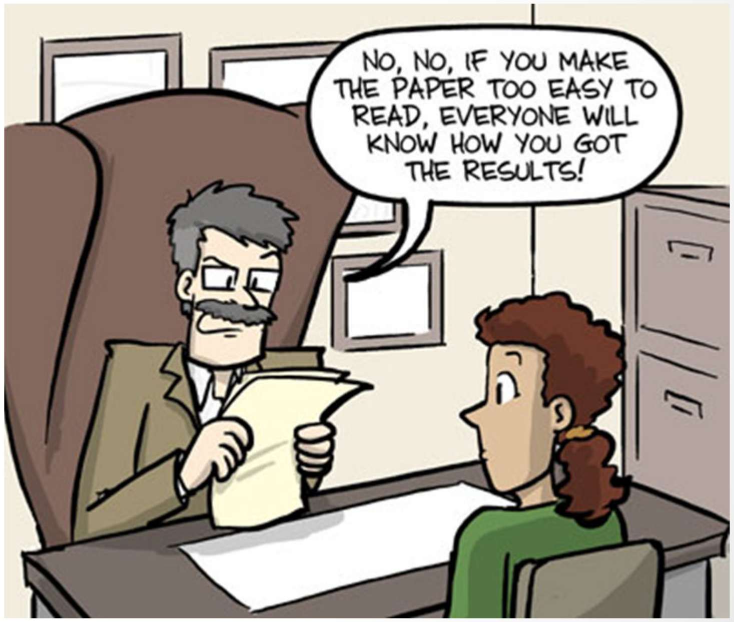
What is the point of a paper?

A paper is written as a means of archiving and storing information derived from an experiment

A paper isn't meant to tell you a story, or maintain your interest- that's not how it's written (sadly)

So you'll have to read a scientific paper a bit differently…

Often have page limits so every sentence/word is important



How I read a paper

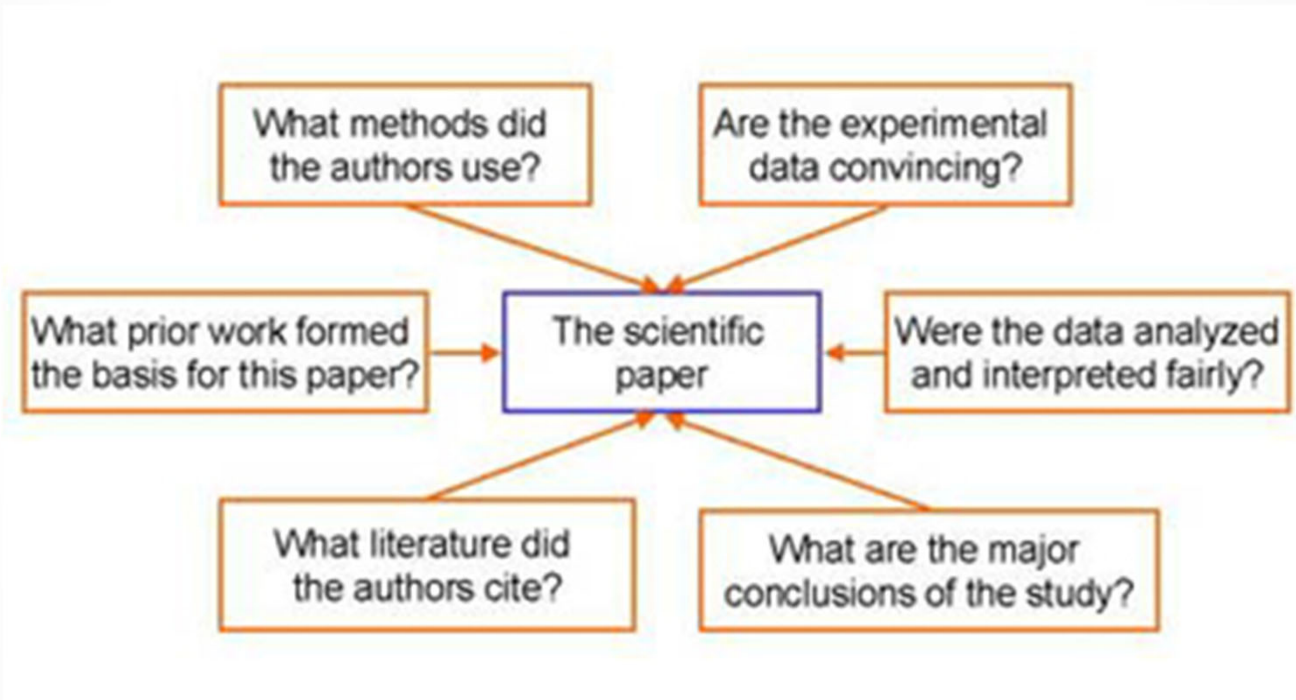
1. Start with the abstract- it's a great summary!
2. Read the Intro and conclusions - Similar to the abstract but with more details
3. Try to figure out which plots correspond to each conclusion and examine those plots
4. Now I'm ready to read the paper through as it's written- I have some baseline idea of what the main points are and which plots are important
5. Think about the main measurement posed in the paper and the results. Do I understand them.
6. If I can't, I read the paper again!

Questions to ask yourself as you read a paper

- What specific problem does this research address?
- What are the specific findings? Am I able to summarize them succinctly?
- What evidence supports the findings? Do I believe the evidence/methods?
- Is there an alternative explanation to the findings presented? Has this been addressed?
- How do these findings relate to what I'm working on/interested in?
- How might I apply these methods/results to my work?

Hard work to read papers

- I often find that I can only read a few papers before I need a break
- Often start skimming the paper so not really understanding it
- Often need to stop reading paper to look up reference for additional details
- If trying to reproduce results, I often need to read paper many many times to fully understand all of the details
- We often have paper reading sessions with students and it is not uncommon to only get through 1 paragraph in an hour.


What methods did the authors use?
Are the experimental data convincing?
What prior work formed the basis for this paper?
The scientific paper
Were the data analyzed and interpreted fairly?
What literature did the authors cite?
What are the major conclusions of the study?