

Intermediate Lab

PHYS 3870

Lecture 7

Poster Presentations

Poster Preparation for PHYS 3870

- We will plan on meeting as a group on Monday Nov 28 at 9:30 in the conference room for about 20 minutes to discuss to poster presentations for the final experiment.
- Will go over formatting and presentation issues, share a couple examples and answer questions.
- You may prepare one poster for the group, or individual posters, at your discretion.
- We will meet on Wednesday December 7 (the last day of class) as a group to go over the posters.
- We will project the posters on the large screen. Each group will have 5 minutes to outline their poster, followed by 10 minutes for discussion and questions from the audience.
- Please submit your poster by Tuesday afternoon at 5 pm so I will have time to print out an 11x17 inversion for the presentation session.
- Information on poster preparation found at [http://www.physics.usu.edu/dennison/3870-3880/Undergraduate%20Research%20Poster%20Preparation%20Web%20Page/Direction for USU Physics Research Posters.htm](http://www.physics.usu.edu/dennison/3870-3880/Undergraduate%20Research%20Poster%20Preparation%20Web%20Page/Direction%20for%20USU%20Physics%20Research%20Posters.htm)

Preparation and Printing of a Poster

- The examples were prepared using Microsoft PowerPoint and Adobe Acrobat.
 - The easiest way to prepare your own poster is to load an example into PowerPoint and then modify it to your content.
 - To begin from scratch, choose New Presentation, then indicate the type of layout you will use. Select the Page Setup from the File menu; change the “slides fixed for” to custom and adjust the paper size as needed. The slides should be landscape. Click okay.
- It is often a good idea to create a PDF format file using Adobe Acrobat; this can often avoid formatting problems that sometimes occur, particularly with equations and symbols.
- Posters can be printed at:
 - USU Engineering Computer Lab (third floor New Engineering Building). This is generally the cheapest and faster place to have this done.
 - Kinko’s is generally more costly and provides one day service.
- Paper selection:
 - The cheapest paper to use is standard matte paper; you may want to consider laminating this.
 - High gloss paper costs 2-3 times as much, but looks much better and is more durable.
 - A good alternative for high durability posters is to print directly onto a plastic medium; this avoids the need to laminate the poster.

Hints on Poster Layout

- Keep the material simple and concise with plenty of white space.
- Use colors sparingly to emphasize, differentiate, and add interest. (In general, it is better to keep the background light as people are used to that.)
- Pictures, graphs, and charts can be helpful in communicating a message quickly. Equations should be kept to a minimum, be large enough to read, and accompanied by definitions to explain significance of each variable. Label any diagrams and drawings. Clipart may be used for interest as long as it's not distracting.
- Font size should be such that a reader can stand at a distance of 5 feet and read the text. Typically nothing less than 20 point fonts should be used.
- Use underline text, bold face, *italics*, or *combinations* to emphasize words and phrases.
- Spelling counts. (Typographical errors do not reflect well on credibility or the presenter or on the university.)

Testing a Model?

- Steps in a Scientific Investigation [Baird, Ch. 5-3]
 - Clearly Identify:
 - The **problem** or question or interaction to be addressed.
 - The **system** to study and its boundaries.
 - The **significant variables** in observation—key is to set up experiment with isolated input and output variable(s)
 - **Develop a model** of the system—key is to quantitatively describe interaction of inputs with system (see below).
 - **Test the model** through experimentation—key to designing experiment is whether data will allow quantitative evaluation of model for given input variable(s) and output variable(s) [see Baird, Ch. 5 on Experimental Design]
 - **Evaluate the model** as a description of the system—key is to know how good is “good enough” and how to test this quantitatively [see Baird Ch. 6 on Experiment Evaluation]
 - **Refine the model** to cover:
 - More precise measurements
 - More general conditions
- Basic approach to develop and evaluate the usefulness of a model [Baird, Ch 4.1].
 - Know data and uncertainties (presumably)
 - Use this to identify system, inputs and outputs
 - Now develop a model
 - Then test model by comparison with data (first qualitatively, then quantitatively)

Things to Include on a Poster

General Format: While posters are not uniform in format, generally, most of the following will be included.

- **Title** telling the name of the project, the people involved in the work, and their affiliation. The title should be large, descriptive, and concise.
- **Abstracts** stating what you set out to do, how you have done it, the key results, and the main findings and conclusions.
- **Introduction** that includes clear statements about the problem that you are trying to solve, the new ideas or items you are trying to discover or create, or the proofs that you are trying to establish. Note the background work that has led up to the current status of your research of creative work in this area. These should then lead to declaration of your specific project aims and objectives.
- **Theory or Methods** section that explains the basis of the techniques that you are using or the procedures that you have adopted in your study. You should also state and justify any assumptions, so that your results can be viewed in the proper context.
- **Results** section to show illustrative examples of the main results of products of your work.
- **Conclusions** section that discusses the main findings of your investigation and their value.
- **Further Plans** section that contains recommendations and thoughts about how the work could be continued. What kind of things could be done next? What are some possible long-term goals or outcomes?
- **Acknowledgements** section that allows you to thank organizations that might have provided financial support or the individuals who donated time to help with the project.

Adsorption Isotherms for Nitrogen (N₂) on Exfoliated Graphite

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Nitrogen (N₂) gas molecules interacting with an exfoliated graphite surface through van der Waals attraction adsorb to the surface of the substrate in a process known as physisorption. Adsorption isotherms are obtained by plotting the fractional coverage as a function of vapor pressure. These isotherms can then be used to determine the structural phase and thickness of the adsorbed layers at a given temperature and pressure.

PHYSICAL ADSORPTION

PHYSICAL ADSORPTION or **PHYSISORPTION** is the accumulation of particles at a surface due to weak physical (van der Waals) interactions.¹ The **SUBSTRATE** is the underlying material on which the **ADSORBATE** accumulates.² In this experiment, Nitrogen gas or N₂ (adsorbate) adsorbs to the surface of exfoliated graphite (substrate).

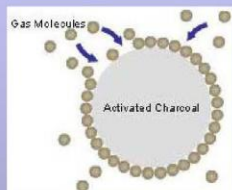


Fig. 1 Adsorption of gas molecules onto a charcoal surface. Illustration obtained from www.allrefer.com.

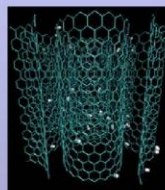


Fig. 2 Physisorption of H₂ molecules onto carbon nanotubes. Illustration obtained from www.pcbiubes.

ACCOMMODATION is the process by which adsorbate particles lose energy and physically adsorb to a substrate surface.² The adsorbate and substrate molecules interact through van der Waals forces, which are weaker, and more long range than chemical bonds. One way to picture accommodation is to consider a ball (adsorbate particle) bouncing along a cobble street (substrate), after several bounces, or interactions with the surface, it loses enough energy that it settles into a crevice on the street. Adsorbate particles that are distributed evenly across the surface are in a **COMMENSURATE** state. On the other hand, adsorbate particles in an **INCOMMENSURATE** state are not distributed in a well-defined pattern.

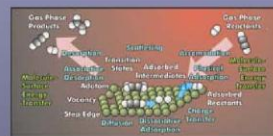


Fig. 3 Illustration of surface gas interactions, including accommodation. Illustration obtained from www.bnl.gov.

An important parameter to monitor during physisorption, is the **FRACTIONAL COVERAGE**, θ , which is defined as:

$$\theta = \frac{\text{number of adsorption sites occupied}}{\text{number of adsorption sites available}}$$

The fractional coverage as a function of pressure for a given temperature is known as an **ADSORPTION ISOTHERM**.² As molecules begin to adsorb to a substrate, they form a two-dimensional system on the surface. The formation of each additional layer is characterized by an abrupt increase in surface coverage.¹

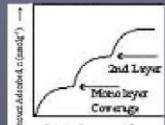


Fig. 4 Example of an adsorption isotherm. Illustration obtained from www.fishbase.org.

EXPERIMENTAL METHODS

In order for a two-dimensional liquid to adsorb to a surface, a substrate and adsorbate must be chosen such that the substrate-adsorbate interactions are sufficiently strong compared with the adsorbate-adsorbate interactions.² **DIATOMIC NITROGEN GAS (N₂)** is very inert. Since its interactions with other diatomic nitrogen molecules are limited, it is a good adsorbate. **EXFOLIATED GRAPHITE (C)** has a high surface-to-volume ratio, meaning that there is a lot of space for a two-dimensional adsorbed layer to form. Another advantage is its well-characterized surface structure of hexagonal planes.



Fig. 5 a) Image of exfoliated graphite. b) Microscopic image of graphite. c) Illustration of graphite lattice structure—note the hexagonal planes. Images obtained from pubs.rsc.org, www.danajay.com, and www.benbest.com.



Fig. 6 a) Illustration of diatomic nitrogen molecule. b) Tank of nitrogen gas. Images obtained from www.wiki.org and forum.beyond3d.com.

Exfoliated graphite is loaded into a quartz tube which is connected to a gas handling system. The tube is evacuated to between 50 to 100 millitorr and baked out at 800-1000° C for 24 hours. After the graphite cools to room temperature, the quartz tube is backfilled with N₂ and placed in a glove bag to prevent contamination during transfer of graphite from the quartz tube to a copper cylinder. This cylinder is then connected to the sample outlet on the gas handling system (GHS).



Fig. 7 Copper cylinder for graphite containment with tube for nitrogen gas, N₂ input.



Fig. 8 Furnace used for graphite bake-out.



Fig. 9 Gas handling system.

Using N₂ gas at room temperature, and a standard volume connected to the gas handling system (GHS), we determine the dead volume, V_d, or volume of the cylinder that is not occupied by graphite. The cylinder is then cooled in a liquid nitrogen bath. The amount of N₂ gas entering the system is monitored. The expected increase in pressure of the graphite container is calculated and the actual vapor pressure increase is measured. The difference between these two pressures allows us to calculate the fractional coverage of adsorbed nitrogen as a function of pressure.

DATA REDUCTION

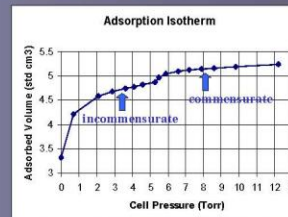


Fig. 10 Adsorption isotherm illustrating the structural phase transition from a 2-D liquid in monolayer (incommensurate) to a 7:7 solid monolayer (commensurate).

To find the total amount of nitrogen adsorbed to the graphite surface as a function of pressure (adsorption isotherm):

- The expected pressure for a known amount of N₂ gas introduced to the system is calculated using the ideal gas equation.
- The observed pressure (measured after the system reaches equilibrium) is subtracted from the expected pressure.
- This pressure difference is used in the ideal gas equation to find the amount of adsorbed nitrogen.

CONTINUING RESEARCH

No adsorption data has been taken yet. The experimental set-up took longer than expected due to instrument repair and shipping of parts. So far we have baked out the graphite and set up all of the instrumentation. Our continuing work is as follows.

1. Implement system for cooling cylinder with liquid nitrogen. This will probably include placing a liquid nitrogen dewar on a shelf that can be lowered and raised to cover the cylinder.
2. Plot adsorption isotherms for graphite baked out at 800°C for 24 hours.
3. Bake out graphite at 1000°C for 24 hours. Since the time the graphite was originally baked out, documentation was found naming 1000°C as the preferred bake out temperature for exfoliated graphite.
4. Plot adsorption isotherms for graphite baked out at 1000°C. Some of the graphite baked at 800°C was exposed to the atmosphere during transfer from the quartz tube to the glove bag—we would like to take another data set without contamination from the atmosphere.

REFERENCES

- 1 L.W. Bruch, M.W. Cole, and E. Zaremba, *Physical Adsorption: Forces and Phenomena*, 1st ed. (Dover, New York, 1997), pp. 2-9.
- 2 P.W. Atkins, *Physical Chemistry*, 4th ed. (Freeman, New York, 1990), pp. 874-885.
- 3 Teresa E. Burns, Ph. D. thesis, Utah State University, 1994.

Time Dependent Conductivity of Spacecraft Materials

By Justin Dekany
Physics Undergraduate Research
Mentor: JR Dennison

Abstract

A model has been developed that describes the behavior of current flow in highly insulating aerospace materials. Using a constant voltage chamber (CVC) that was designed and built at USU, voltage was applied across an insulating polymer and the resulting current decay was measured using a stable low-level electrometer. Current and voltage data were collected on the time scale of several hours to several days for Kapton HN, a common material typically used in spacecraft construction. The model used to describe conductivity as the material reaches a stable state, consists of two distinct components observed in the data. First, there is polarization, with an exponential time dependence, that results from the reorientation of the molecular dipoles in the material that orient parallel to the applied electric field. The second component of the transient current flow, diffusive conductivity, with a power law time dependence, results from a diffusion of charge injected into the material from the voltage plate. Results of the analysis are interpreted in terms of the polymer's complex molecular structure, blend of amorphous and nanocrystalline structure, and the nature of localized states used to determine the carrier density in insulating polymers.

The Basics of Conductivity

The primary goal when analyzing samples in the CVC is to determine the conductivity of the material. This is done by measuring current in the system as a function of time. Starting with Ohm's Law:

$$V = I \cdot R$$

Then dividing by a distance and using the relationship $R = \frac{\rho \cdot d}{A}$, resistance is equal to the resistivity ρ times a distance d divided by an area A , then gives:

$$\frac{V}{d} = \frac{I \cdot R}{d} = \frac{V}{d} = \frac{I \cdot \rho \cdot d}{A \cdot d} = \frac{V}{d} = \frac{I}{A} \cdot \rho$$

Since resistivity is the inverse of conductivity, $\rho = \frac{1}{\sigma}$ and the electric field is defined as a potential voltage over some distance, $E = \frac{V}{d}$, this gives:

$$\frac{V}{d} = \frac{I}{A} \cdot \rho = \frac{V}{d} = \frac{I}{A} \cdot \frac{1}{\sigma} = E = \frac{I}{A \cdot \sigma}$$

Rearranging this expression gives $I = A \cdot \sigma \cdot E$. Since the electric field and electrode area are constant, by simply measuring the current through sample, the conductivity can be determined.

What is Kapton?



Fig 1: (a) Kapton is a commonly used insulating polymer that has a high resistivity. (b) Polarization of the molecules aligning parallel to the electric field. The nature of localized states used to determine the carrier density in insulating polymers is difficult to predict due to its disordered and complex molecular structure.

Methods

Measuring small currents is a challenge, even in a simple constant voltage chamber (CVC) such as ours. The insulating polymer, Kapton HN, is placed inside the chamber to measure the current flow as a result of an applied electric field. The data that are collected from the chamber are then used to analyze the corresponding time dependent decay currents which has allowed us to generate a conductivity model for this material.



A simple block diagram of the CVC where the insulating polymer, Kapton HN, is represented by a simple resistor. An electric field is generated inside the CVC that is directed through the Kapton HN sample. This setup allows us to measure the corresponding decay currents, typically in the domain of femtoamps, that occur as a result of the electric field.

A CVC is used to create an environment capable of accurately measuring small currents. Once the atmosphere has been evacuated from the chamber, a voltage (100V-500V) is applied to a voltage plate creating an electric field which induces a current through the sample. Current data collected using a stable, low level electrometer are then analyzed to determine the effect an electric field has on the polarization of the molecule in the polymer and the diffusion of injected charge as it reaches a stable state.

Found inside the CVC are the electrode plate assembly (standing up) and the voltage plate (lying down). The sample is placed between the two. Voltage is applied to the voltage plate and the injected electrons propagate through the sample and reach the electrode, which are connected to the low level electrometer.

Kapton HN Data Set
50 μm thick sample with 500 V Applied Potential

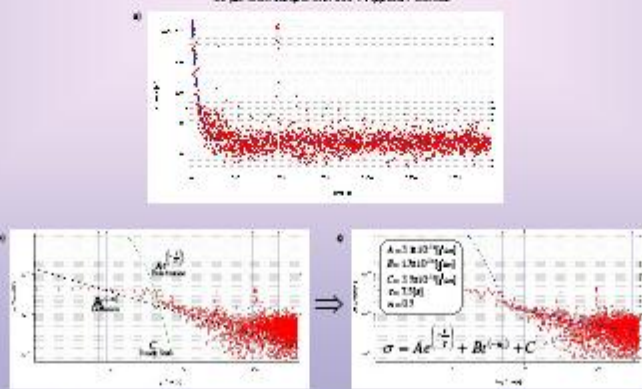
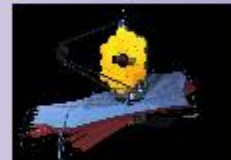


Fig 2: (a) Current vs Time plot of a typical data run for Kapton HN with conductivity model overlay. (b) Log Current vs Log Time for the same data run. The green curve is the polarization effect, $A \cdot e^{-t/\tau}$, the black curve is diffusion, $B \cdot t^{-1/2}$, and the purple curve is the constant steady state conductivity, C . (c) Summing all the terms into one continuous equation yields the blue curve. The values for the fitting parameters are given.

Applications

Due to its extremely high resistivity (a quantity that expresses a material's ability to resist the flow of electrons, see left/middle panel) and its ability to withstand the harshest space environment, Kapton has many applications in constructing modern spacecraft. Specifically, Kapton will be used as the primary Sun shield for the James Webb Space Telescope (JWST). This protects the delicate optics from radiation emitted by the Sun and is critical in passively cooling JWST to 40K.



In this image of the James Webb Space Telescope, the Sun shield is shown in blue. To get some sense of scale for this representation, the Kapton shield is about the size of a sports court.

Model

The conductivity model can be interpreted as essentially three distinct time varying components of the transient conductivity through the material. Conductivity model for Kapton HN where A and C are fitting parameters, t is time, τ is the polarization decay time and n is a power law fitting parameter.

$$\sigma = A e^{-\frac{t}{\tau}} + B t^{-n} + C$$

Initially, for small time scales there is a polarization term, $A e^{-t/\tau}$ which is exponential in time. This term shows how the alignment of the molecules with applied electric field (see Fig.1.b) contribute to the measured current. This charge transport process can be visualized in Fig. 3.a. For intermediate time scales the model is dominated by a power law time dependent term, $B t^{-n}$ which describes the diffusion of injected charge into trapped states as the space charge distribution becomes uniform. Charge diffusion is shown in Fig. 3.b. Finally, there is a constant term, C that is left as the polarization and diffusion terms decay giving a minimal contribution to the dark conductivity model. This constant term is known as the steady state current that flows through the material once available trap sites have been filled. Steady state conduction is represented in Fig. 3.c. Figure 2 shows the total current and component currents for a typical data set.



Fig 3: (a) Polarization of the molecule aligning parallel to the electric field. (b) Charge diffusion. Initially charge is introduced on the left and then propagates to the right through the sample. (c) Steady state current flow. The amount of charge injected into the material equals the charge that escapes the material.



Methods for Determining Crossover Energies

Jonathan Abbott

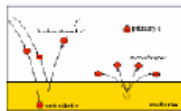
Department of Physics, Utah State University, Logan, UT 84322-4415

Mentor: JR Dennison



INTRODUCTION

When a material is irradiated with electrons, photons, or ions, electrons leave the surface. In the case of electrons, the yield is measured as the ratio of the number of electrons emitted to the number incident on the material. 1.0

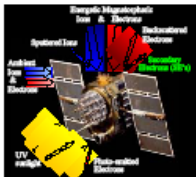


The yield is dependent on the energy of the incident particle. The energy where the material changes charging polarity is called the crossover energy.

APPLICATIONS

Spacecraft adopt potentials in response to the plasma environment.

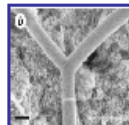
Secondary Electron (SE) emission is an important physical process (and source of current) in spacecraft charging.



Incident and Emitted Currents that Result in Spacecraft



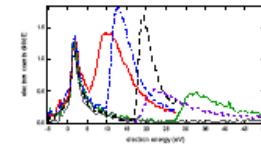
Almost one third of all spacecraft failures and anomalies due to the space environment result from plasma-induced spacecraft charging resulting from electron emission. The second crossover energy is a key parameter in the computer modeling of spacecraft materials.



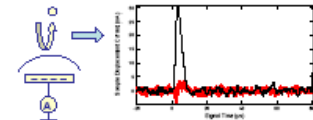
Scanning electron microscopes are based on electron emission. Scanning electron micrograph of carbon nanotube Y junction which has important applications in nanoscale transistors and other electronic nanodevices. SEM applications in biology often coat samples with carbon.

FUTURE WORK

During the coming months, I will be finding crossover energies in insulators. This is more challenging because care must be taken to not damage the samples with too large a built up potential.



DC Spectra: This method only works for insulators because it depends on the charging of the material. By measuring the energy spectrum of the emitted electron, and comparing the peak to a reference peak, one can determine the crossover energy. In this figure, the peak on the left is the reference peak.



$E_{in} = 2-3 \text{ keV}$ used to charge sample negative
 Pulsed-probing beam and sample displacement current used to determine potential

$$\bar{E}_1 = \bar{E}_{ref} - Q\phi$$

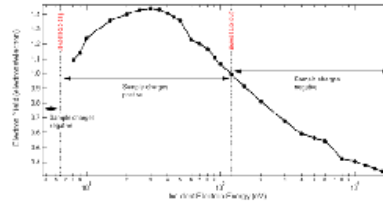
$$E_2 = 1200 \pm 10 \text{ eV}$$
 Steady state condition used to calculate E_2

Mirror Potential: This method also depends on the charging of the material. As the material is charged up to a large negative potential, the potential on the surface will adjust to equal the second crossover energy minus the incident beam energy (Thomson, 2004). The crossover energy can be calculated from $E_c = E_i - |eV_s|$, where E_i is the incident beam energy, V_s is the surface potential, and E_c is the second crossover energy (Reimer, 1986). The surface potential is measured by probing the sample with an electron beam energy smaller than the expected surface potential, and increasing the energy until a displacement current is seen.

ABSTRACT

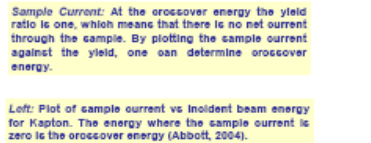
The energy at which a material changes charging polarity when irradiated by electrons, photons, or ions is called the crossover energy. Crossover energies are important in spacecraft charging models as well as in SEM imaging of insulator materials. Several methods are presented for determining the crossover energy using an electron beam incident on conducting and insulating materials. Also the crossover energies for gold and titanium are presented.

METHODS



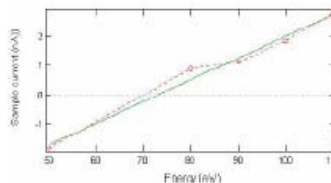
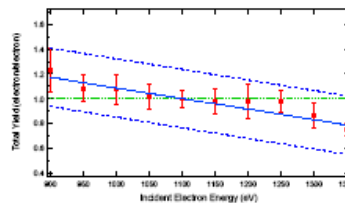
Total Yield: One measures the yield as a function of energy and plots the data. A figure similar to the one at left is obtained. By interpolating the data one can determine the crossover energies. Useful for getting an estimate of what energies to investigate more closely.

Left: Plot of the yield versus incident energy shows the regions where the sample charges positive or negative. The points where the sample charging switches polarity are called the crossover energies. Note the log scale on the bottom for clarity (Abbott, 2004).

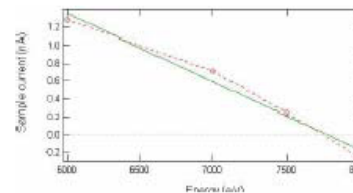


Sample Current: At the crossover energy the yield ratio is one, which means that there is no net current through the sample. By plotting the sample current against the yield, one can determine crossover energy.

Left: Plot of sample current vs incident beam energy for Kapton. The energy where the sample current is zero is the crossover energy (Abbott, 2004).



Plots of sample current vs incident energy for gold. Top: Plot shows the first crossover energy at 70 eV. Bottom: Plot shows the second crossover energy at 7700 eV.



REFERENCES

- Dennison et al. "Material Characterization at Utah State University: Facilities and Knowledgebases of Electronic Properties of Materials Applicable to Spacecraft Charging." Proceedings of 8th Spacecraft Charging Conference, Huntsville Marriott Hotel, Huntsville, AL (2005).
- Clint Thomson, "Measurements of the Secondary Electron Emission Properties of Insulators," PhD dissertation, March 2004.
- J.D. Abbott, A.M. Sim, unpublished data on titanium, Sep 2004.
- R.D. Leach, M.B. Alexander, "Failures and Anomalies Attributed to Spacecraft Charging," NASA reference publication 1364, NASA Marshall Space Flight Center, Nov 1994.
- Reimer, L. Scanning Electron Microscopy. Physics of Image Formation and Microanalysis, (Springer-Verlag, 1985), pp. 110-121
- JR Dennison et al. Final Report III: Materials Reports, NASA Space Environments and Effects Program Grant, "Electronic Properties of Materials with Application to Spacecraft Charging," September 2002.

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