

THE SAME THING THAT MAKES A CARROT ORANGE ALSO MAKES A MOLECULAR WIRE

Stephen W. Carmichael¹, Mayo Clinic

The atomic force microscope (AFM) has been used in many ways to extract information from biologic specimens. Now Gerry Leatherman, Edgar Durantini, Devens Gust, Tom Moore, Anna Moore, Simon Stone, Ziniu Zhou, Peter Rez, YangZhang Liu, and Stuart Lindsay have used conduction atomic force microscopy (CAFM) to demonstrate that a molecule of carotene can function as a molecular wire.

Leatherman *et al.* synthesized carotene and then examined the molecules with the scanning tunneling microscope (STM). They could image spots that averaged 2 nm in diameter, although the size of the spots varied widely due to the geometry of the probe tip. Interestingly, the number of spots increased with the concentration of carotene, but the average size of the spots did not change. This made it clear that they were able to image carotene molecules with the STM, and that the carotene did not form large aggregates. For these initial imaging studies the carotene was suspended in a film of dodecanethiol.

For CAFM, a conventional microscope was used with a force-sensing cantilever coated with platinum and connected to a low-noise current amplifier. Initial attempts to image carotene molecules in dodecanethiol films were not successful, probably because the carotene molecules protruded from the film and were moved or damaged during the scan. This problem was solved by putting the carotene in a film of docosanethiol, which is a molecule of about the same length as carotene. This is analogous to inserting a relatively flexible thread (the carotene) among stiff bristles of a hairbrush (the docosanethiol molecules). If the thread is inserted among shorter bristles (dodecanethiol), then the thread is unsupported and floppy. If the thread and stiff bristles are approximately the same length,

then the thread is supported and its end can be imaged. Conveniently, all of these linear molecules assembled as a monolayer, just as bristles of a hairbrush could be considered a monolayer. To carry this analogy further, the back of the hairbrush (the substrate that the carotene and the docosanethiol are attached to) is conductive (gold was used). The docosanethiol is an insulator, so when the surface was imaged by CAFM, the carotene molecules embedded in the film were seen to conduct a current, just as if you passed a ammeter probe over the surface of our hairbrush, and the threads were a conductive wire and the bristles non-conductive. The carotene was found to behave ohmically with a resistance of approximately 4.2 ± 0.7 gigaohms, over a million times more conductive than a saturated hydrocarbon molecule of similar length!

Now for the part about the carrots. Carotene is a natural molecule that gives color to carrots, and many other plants as well. The optical properties of carotene come from electronic states that are delocalized over a chain of about twenty carbon atoms connected by alternating single and double bonds. Apparently, this same molecular arrangement allows carotene to act as an ohmic resistor. This is interesting, but the real value of the CAFM, as shown by Leatherman *et al.*, is that it is possible to insert a conductive molecule into an insulating matrix and determine the electrical properties of the molecule in a straightforward manner. This technique will help us understand the mechanisms of molecular conduction as more molecular systems are studied in the future. ■

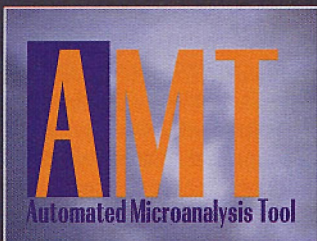
1. The author gratefully acknowledges Dr. Stuart Lindsay for reviewing this article.
2. Leatherman, G., E.N. Durantini, D. Gust, T.A. Moore, A.L. Moore, S. Stone, Z. Zhou, P. Rez, Y.Z. Liu, and S.M. Lindsay, Carotene as a molecular wire: Conducting atomic force microscopy, *J. Phys. Chem. B* 103:4006-4010, 1999.

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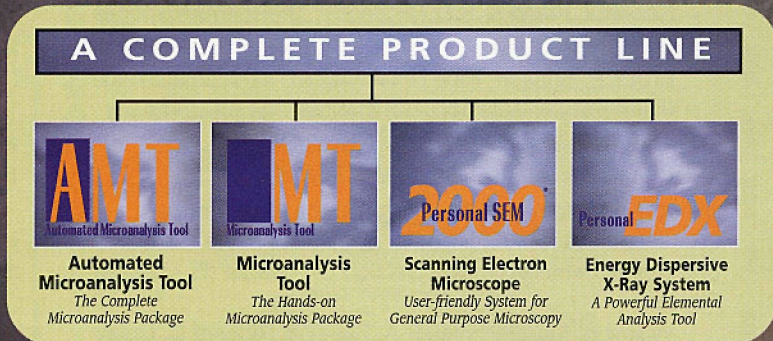


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MICROSCOPY & MICROANALYSIS 2000 HIGHLIGHTS

* ANNUAL GOLF TOURNAMENT

The thirteenth annual Golf Tournament will be played on August 13 at the Wyncote Golf Club in pastoral Oxford, PA. This seven-year-old course always appears in the Best-Of-Pennsylvania listings and regularly hosts regional golf association tournaments. The bus departs the convention center at 7:30 on 13 August.

While openings are currently sold out, one may be wait-listed for cancellations by calling Ms. Stacie Kirsch at (215)646-1478.

* SUNDAY EVENING RECEPTION

The opening reception will be held Sunday, August 13th from 7:00 PM to 10:00 PM at the Pennsylvania Convention Center Grand Ballroom. A full night of enchanting entertainment and ethnic diversity is the motif. Food stations will be spread out for everyone's dining pleasure. Beverages will be available.

Buses to the Convention Center will leave the Wyndham Franklin Plaza Hotel beginning at 6:00 PM and the return will begin at 9:30 PM. One admission ticket is included with full registration and additional tickets may be purchased at the door for \$50 each, children 3-11 at \$12.

* WEDNESDAY EVENING DINNER CRUISE

Float down the Delaware River aboard the elegant ship "Spirit of Philadelphia", filled with wonderful food and lively music. Sail by Penn's Landing, Old Christ's Church, the Ben Franklin Bridge, the New Jersey Aquarium, the Flagship "Olympia" and much more.

The cruise includes a five entry buffet with all of the condiments, salad, desserts, and coffee and tea. There are two dance bands as well as entertainment. Transportation from the Convention Center will be provided on Wednesday, August 16, departing at 6:00 PM. The ship departs at 7:00 PM from Columbus Blvd. at Lombard Circle. The cost, in addition to registration, is \$55.00.

While this event has been sold out, one should check at the M&M 2000 Hospitality Booth for possible cancellations.

* PHILLIES BASEBALL AT VETERANS STADIUM

Tickets have been obtained for the Philadelphia Phillies game with the Arizona Diamond Backs on Tuesday, August 15. Again these tickets have been sold out and one should

check with the M&M 2000 Hospitality Booth for possible cancellations.

* ATLANTIC CITY: HERE WE COME

Just a short bus ride away is your opportunity to visit America's favorite playground.

Buses will depart from the Convention Center at 4:00 PM on Saturday, August 12. The cost is \$37.00, in addition to registration, and includes round trip only.

* HOSPITALITY BOOTHS

The following local organizations will have special hospitality booths:

The South Philly Italian Market: With pasta food buffets and high-lighted with hanging meats and cheeses. Entertainment by the Do Wop Group-Corner.

Chinatown: A delightful selection of Chinese food and entertainment by the Mummers String Band.

The Philadelphia Sports Bar: Food from the bar—including the famous Philly Cheeze Steak Sandwiches. A series of interactive sporting games will add to the entertainment.

Atlantic City: The food you would expect, and look forward to, in Atlantic City—hot dogs, french fries, popcorn, water ice and salt water taffy.

A "casino", where no real money is used (play money will be handed out), will offer fun and games. There will be blackjack tables, a crap table, a roulette table and a Big Wheel table.

City of Philadelphia: Stop by their booth for information regarding current events

Our thanks to Ms. Stacie Kirsch (Electron Microscopy Sciences/Diatome and the 2000 LAC Chair) for the above information

■ Do not forget to stop by the *Microscopy Today* Booth (#452) and vote for the most creative and interesting entry in our Just For Fun Image Contest.

■ And be sure to visit the Evex Analytical Booth (#733) and register to receive a free version of Monte Carlo Simulation. Booth visitors may also receive a free Periodic Table Mouse Pad, while supplies last.

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FRONT COVER IMAGE

Ragweed stem with pollen and pollen clusters. FESEM at 262X and 30 degrees tilt.

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The Eastern Analytical Symposium would like to announce . . .

the presentation of sessions specifically devoted to the needs of Pharmaceutical Analytical Chemists at the 2000 EAS. These sessions will take place during our annual meeting to be held October 29 – November 3, 2000 at the Atlantic City Convention Center in Atlantic City, New Jersey. Program highlights will include, but will not be limited to sessions on the following topics:

- Thermal Analysis for Polymorph Characterization
- Solids Characterization
- Methods Transfer
- Pharmaceutical Near-IR
- Dissolution
- Methods Validation
- HPLC of Pharmaceuticals
- Laboratory Investigations
- Pre-Approval Inspections

In addition, the roster of invited and contributed papers will be well complemented by both Short Course and Workshop presentations targeted at the attendees interested in more in-depth exposure to each of the above noted topics.

This program, combined with the new central location of Atlantic City, New Jersey, provides the Pharmaceutical Analytical Chemist with the right technical program in the right location for either picking up a new skill or sharpening existing ones.

This year, as always, EAS will continue to offer sessions, short courses, and workshops geared to the interests of all Analytical Chemists, spanning the range from microscopy to NMR, miniaturization, and separations based on chip technology.

EAS

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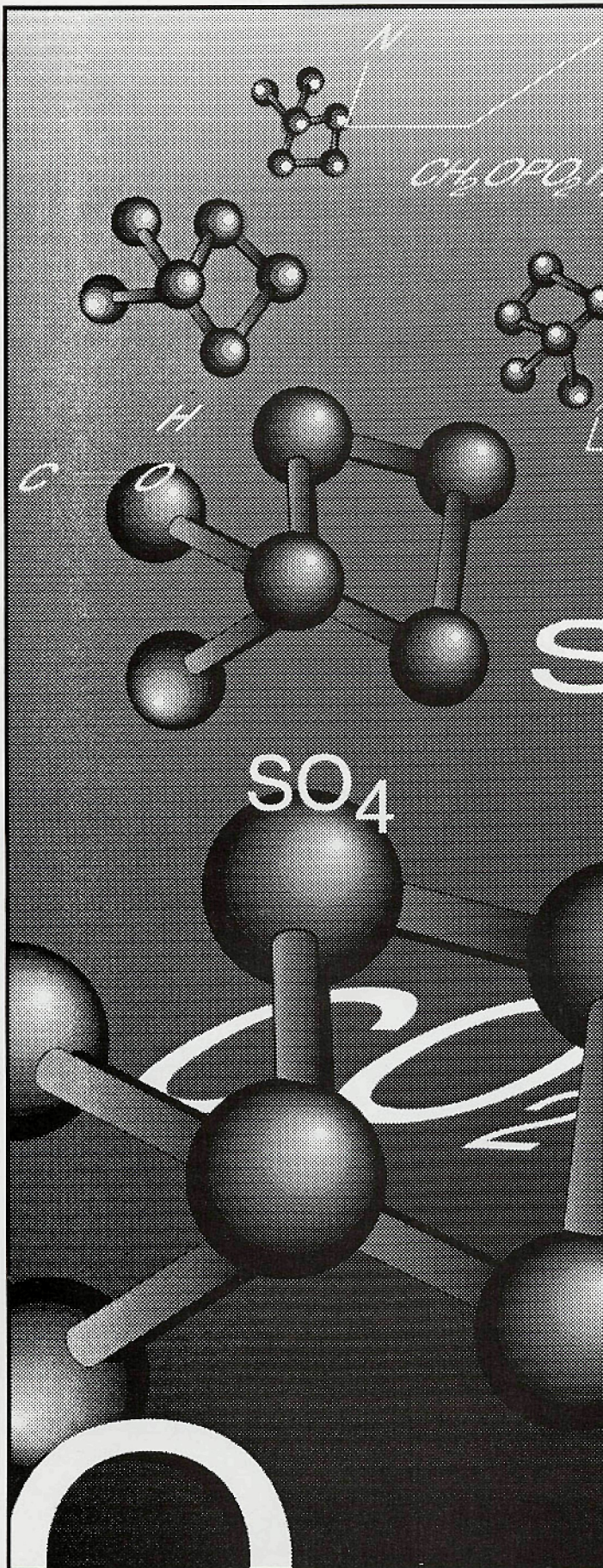
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COMING EVENTS

- ✓ July 27/29 '00: **International Kunming Symposium on Microscopy** (Chinese Electron Microscopy Society) Kunming, P.R. China. IKSM Office: IKSM@aphy.iphy.ac.cn
- ✓ July 29/August 5 '00: **Biological Atomic Force Microscopy** (Johns Hopkins School of Medicine) Baltimore, MD. bioafm@jhmi.edu, fax: (410)614-3797
- ✓ August 13/17 '00: **Microscopy & Microanalysis '00:** (MSA) Philadelphia, PA. Annamarie Dowling / Mary Beth Rebedeau: (708)361-6045, rebgroup@earthlink.net
- ✓ August 17/19 '00: **Fundamentals of Light Microscopy**
August 21/23 '00: **Polarized Light Microscopy**
Wellesley College, Wellesley, MA. Mary McCann: (617)484-7865
- ✓ August 22/26 '00: **Scanning Probe Microscopy of Polymers.** (American Chemical Society) Washington, D.C. Vladimir V. Tsukruk: ((515)294-6904
- ✓ September 3/8 '00: **11th International Congress of Histochemistry** York, U.K., www.med.ic.ac.uk/external/ichc_2000
- ✓ September 10/15 '00: **CLEO/Europe-IQEC 2000**
- ✓ September 11/15 '00: **Advanced FTIR Microscopy** (McCrone Research Institute) Chicago, IL, Nancy Daerr, (312)842-7100, ndaerr@mcri.org
- ✓ October 3/5 '00: **SEM Applications Course** Protrain/ANUEMU), Canberra, Australia: <http://online.anu.edu.au/EMU/00chapman.htm>
- ✓ October 8/13 '00: **3rd World Congress on Cellular and Molecular Biology.** Jena, Germany, www.uni-jena.de/wccmb
- ✓ October 11/19 '00: **Optical Microscopy & Imaging in the Biomedical Sciences.** (Marine Biological Laboratory), Woods Hole, MA. Carol Hamel: (508)289-7401, admissions@mbi.edu
- ✓ October 16/20 '00: **FLUORESCENCE 2000-Advanced Courses of Fluorescence Microscopy and Confocal Microscopy.** Lake of Garda, Italy. Dr. Annalisa Imberti: +390270646234, <http://users.unimi.it/~fl2000/>
- ✓ October 17/19 '00: **Fundamentals of Asbestos Analysis by Transmission Electron Microscopy** (MVA, Inc.) Norcross GA: (770) 662-8509
- ✓ November 12/16 '00: **International Symposium for Testing and Failure Analysis.** <http://www.edfas.org/istfa>
- ✓ November 13/17 '00, **8th Conference on Frontiers of Electron Microscopy in Materials Science** (National Research Institute for Metals) Matsue, Japan. <http://femms2000.llnl.gov/>
- ✓ November 13/17 '00: **Particle Isolation, Manipulation and Mounting for Additional Analysis** (McCrone Research Institute) Chicago, IL, Nancy Daerr, (312)842-7100, ndaerr@mcri.org
- ✓ November 19/23 '00: **First International Conference on Advanced Materials Processing** Rotorua, New Zealand. Prof. Nigel Sammes: n.sammes@walkato.ac.nz
- ✓ November 27/December '00: **Scanning Electron Microscopy** (McCrone Research Institute) Chicago, IL, Nancy Daerr, (312)842-7100, ndaerr@mcri.org
- ✓ December 9/13 '00: **40th Annual Meeting American Society for Cell Biology** San Francisco, CA. www.ascb.org/ascb
- ✓ January 20/26 '01: **Multiphoton Microscopy in the Biomedical Sciences** (SPIE) San Jose, CA. <http://spie.org/web/meetings/calls/pw01/conf/BO31.html>



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