

BioFilm©

Lee van Hook,

Piltdown Research Institute, Munchausen University

Photographic chemistry has long been a complex combination of inorganic metal-halide and organic chemistries and polymer science. We at the P.R.I. have managed to add biology to this stew.

Silver has long been known as a toxic element to microbes, and so used as a drug to kill bacteria. But there are bacteria that can survive in environments high in silver. It has been reported that some bacteria can accumulate up to 25% of their dry biomass as silver^{1,2}, and so acquire resistance to the toxic effects of silver. Also, a recent article in the Proc. Nat. Acad.Sci.³ describes the intracellular deposition of silver grains in such shapes as hexagons and equilateral triangles. These crystals are on the order of tens of nanometers, but may have 'linear extents from a few to 200 nm or more'³.

Inspiration struck after a particularly messy session in the darkroom. These bacteria (*Pseudomonas stutzeri* AG259) deposit silver crystals smaller than those found in film, and at least some of these crystals are silver sulphide, probably Ag₂S³. Purple sulphur bacteria use light to oxidize H₂S to elemental sulphur, later to be oxidized to SO₄. Photographic film uses silver grains and light. *Viola!* All that was needed was to transfer the photochemistry genes from the purple sulphur bacteria into *Ps. stutzeri*, then short-circuit the H₂S-to-SO₄ process to make elemental sulphur available to be bound to silver. By careful selection, strains of *Ps. stutzeri* that preferentially produce crystals in hexagons or equilateral triangles can be produced. The new strain of bacteria (Munchausen strain INcrd Apr-1) was then incorporated into a very thin layer of agar, which is spread onto a clear polymer backing, much like that found on old rolls of Kodak Tech Pan that no one uses anymore. The agar contains sufficient nutrients to maintain the bacteria alive and metabolically active, but not sufficient to promote growth. This allows us to control the concentration and distribution of the bacteria in the agar. The agar also contains silver chloride. We now have a new kind of photographic film, based on biomaterials! (Unfortunately, space constraints and patent applications prevent our revealing the details of this procedure. We are sure the patent administrators at your institutions understand.)

The film is placed behind the lens of an ordinary camera, and exposed in the normal manner. The light impinging on the film releases toxic silver atoms from the silver chloride in the agar, and results in a frenzy of activity amongst the bacteria as they work to render the deadly metal harmless. The light also activates the recombinant photosynthetic system, producing the elemental sulphur the bacteria need to react with the silver and immobilizes it in crystals. Since our strain of bacteria kindly produce their crystals as hexagons and triangles, they pack nicely and tile the plane of the film in a compact manner. This results in the maximum possible optical resolution.

We must admit to pulling a dirty trick on our hapless accomplices. We place a large amount of silver chloride in the support agar so that the bacteria produce the maximum number of crystals possible. This greatly increases the speed and resolution of BioFilm©, but alas, it also kills the bacteria in spite of their best efforts to survive. We feel guilty about this.

This new film is still under research, but given the ubiquity of biofilms in the world, the possible applications are endless. Although perhaps some applications are best not thought about, given the ubiquity of biofilms. Who wants to think of what might be developing while cleaning the toilet?

References:

- 1) Pooley, F.D. 1982. Nature (London)296:642-643.
- 2) Slawson, R.M., J.T. Trevors, and H. Lee.1992. Arch. Microbiol. 158:398-404.
- 3) Klaus, T., R. Joerger, E. Olsson, and C.-G. Granqvist. 1999. Proc. Nat. Acad. Sci. 96:13611-13614.

Note added in proof:

It seems that Nature has once again anticipated Technology. A recently returned P.R.I. expedition was investigating reports of unusual pictographs in the Australian Outback. These pictographs were considered unusual in both the nature of the illustration and the "primitive" technology used to make them.

The pictographs took two forms, either horizontally banded, abstract representations rather like stretched silhouettes of objects like trees, or relatively sharp, highly realistic depictions of what seemed to be the same objects. The most surprising thing about the images was what they were made of: silver. Careful study of the pictographs revealed that in every case, they were only found on rocks surfaces in small caves, only rarely illuminated by the sun, and then only through a very narrow slit.

As the reader no doubt has surmised, the pictographs turned out to have been made by a mutant strain of purple sulphur bacteria that had been transfected with plasmid genes for precipitating silver from a co-occurring species of *Pseudomonas*.

In essence, the cave walls and entrance formed a natural pinhole camera, and the stretched images were formed by the movement of the sun across the sky. The more sharply focused images were the creations of aboriginal people who figured out what was happening. Using great foresight, they left behind artifacts for future archeologists to discover, in the form of boards with pinholes in them. The local inhabitants obviously used these boards to produce the focused image on the wall, moving the board as needed to compensate for the movement of the sun. After producing the image, the cave was then sealed up and only visited at night, using torches that burn with a reddish flame.

As it turns out, the bacteria were orthochromatic. ■

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October 17/19 '00: **Fundamentals of Asbestos Analysis by Transmission Electron Microscopy**
(MVA, Inc.) Norcross GA: (770)662-8509

✓ March 12/16 '00: **High Resolution Electron Microscopy in Materials Science Symposium** (TMS Physical Metallurgy Committee) Nashville, TN, Diane Albert, Los Alamos Natl Lab: (505)665-2266, Fax: (505)667-5268

✓ March 12/17 '00: **Pittsburgh Conference** New Orleans, LA, www.pittcon.org

✓ March 15/17 '00: **TEM Specimen Preparation Course**. (South Bay Technology & FEI Company) Univ. of Central Florida, Orlando FL. Lucille Giannuzzi: lag@mail.ucf.edu

✓ April 3/4 '00: **Microscopy of Composite Materials V** (RMS & Oxford Centre for Advanced Materials and Composites) St. John's College, Oxford, U.K. +44-1865-248768, Fax: +44-1865-791237

✓ April 9/14 '00: **Light Microscopy For The Biomedical Sciences (LMBS)**. (University of North Carolina) Chapel Hill, NC. Dr. Wayne Litaker: (919)966-1730

✓ April 11/14: **Analytica 2000** Munich Germany, Kallman and Associates (201) 652-3938

✓ April 9/13 '00: **FOCUS ON MICROSCOPY 2000** (12th Annual Meeting of International Conference on Confocal Microscopy). Shjirahama, Japan. <http://lasie.ap.eng.osaka-u.ac.jp/fom>

✓ April 11/13 '00: **MICRO 2000** (Royal Microscopical Society) London www.rms.org.uk/mic2000.html

✓ April 30/May 4 '00: **2000 Annual Workshop on SIMS** Lake Tahoe, NE www.simsworkshop.org

✓ May 4/12 '00: **Analytical & Quantitative Light Microscopy** (Marine Biological Laboratory) Woods Hole, MA. Carol Hamel: (508)289-7401, admissions@mbi.edu

✓ May 9/12 '00: **SCANNING 2000** San Antonio, TX., Mary K. Sullivan: (201) 818-1010, Fax: (201)818-0086, scanning@fams.org

✓ May 11/13 & 15/17 '00: **Quantitative Image Analysis** (NC State University) Raleigh, NC. (919)515-2261, www2.ncsu.edu/cpe/

✓ May 16/23 '00: **Microinjection Techniques in Cell Biology** (Marine Biological Laboratory) Woods Hole, MA. Carol Hamel: (508)289-7401

✓ May 22/June 2 '00: **PASEM 2000** (Univ. of Maryland) College Park, Md., Tim Mauge: (301)405-6898, tm11@umail.umd.edu

✓ June 10/17 '00: **Optical Microscopy in the Biological Sciences**. (Univ. of Texas Health Science Ctr) San Antonio, TX. www.uthscsa.edu/gsb/cs/home.html

LEHIGH MICROSCOPY SCHOOLS

✓ June 12/16 '00: SEM and X-ray Microanalysis

✓ June 11 '00: Introduction to SEM and EDS

✓ June 19/23 '00: Advanced Scanning Electron Microscopy

✓ June 19/23 '00: Quantitative X-ray Microanalysis

✓ June 19/22 '00: Analytical Electron Microscopy

✓ June 20/23 '00: Atomic Force Microscopy

✓ June 22/24 '00: Thin Specimen Preparation

✓ June 19/23 '00: Microdiffraction

✓ June 21/23 '00: Cryo SEM

For further information, contact Ms. Sharon Coe at Tel.: (610)758-5133 or by eMail at sharon.coe@lehigh.edu

3D MICROSCOPY OF LIVING CELLS

June 19/29 '00: 3D Microscopy of Living Cells

July 1/3 '00: 3D Image Processing

Univ. of British Columbia, Vancouver, BC, www.cs.ubc.ca/spider/ladic/course/bulletin.html

✓ June 22 '00: **16th Annual Short Course on Molecular Microspectroscopy** (Miami University) Oxford, OH. <http://www.muohio.edu/~sommerraj>

✓ June 23 '00: **2nd International Conference on Scanning Probe Microscopy in Biomaterials Science**. Bristol, U.K., Dr. Klaus Jandt: K.jandt@bris.ac.uk

✓ June 26/30 '00: **7th Asia-Pacific Conference on Electron Microscopy** Singapore. eMail: micngml@nus.edu.sg or medlab2@nus.edu.sg <http://www.med.nus.edu.sg/micsc7/apem>

✓ July 2/5 '00: **International Kunming Symposium on Microscopy**, Kunming, China. <http://www.iphy.ac.cn/microsc/IKSM.html>

✓ July 9/14 '00: **2nd Meeting of the International Union of Microbeam Analysis Societies**. Kailua-Kona, Hawaii. www.microanalysis.org/iumas2000

✓ July 9/14 '00: **12th European Congress on Electron Microscopy**. Bruno, Czech Republic. <http://www.eurem2000.isbrno.cz/regform.html>

✓ July 17/19 '00: **Electron Microprobe Analysis by Wavelength Dispersive Spectroscopy**. (MIT) Cambridge, MA. E-probe-www.mit.edu, (617)253-1995.

✓ July 27/29 '00: **International Kunming Symposium on Microscopy** (Chinese Electron Microscopy Society) Kunming, P.R. China. IKSM Office: IKSM@aphy.iphy.ac.cn

✓ August 13/17 '00: **Microscopy & Microanalysis '00**: (MSA) Philadelphia, PA. Annamarie Dowling / Mary Beth Rebedeau: (708)361-6045, rebgroup@earthlink.net

✓ 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

✓ 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

✓ November 12/16 '00: **International Symposium for Testing and Failure Analysis**. <http://www.edfas.org/istfa>

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*Nancy Daerr, McCrone Research Institute,
2820 S. Michigan Ave., Chicago, IL 60616-3292
Phone (312) 842-7100; Fax (312) 842-1078
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