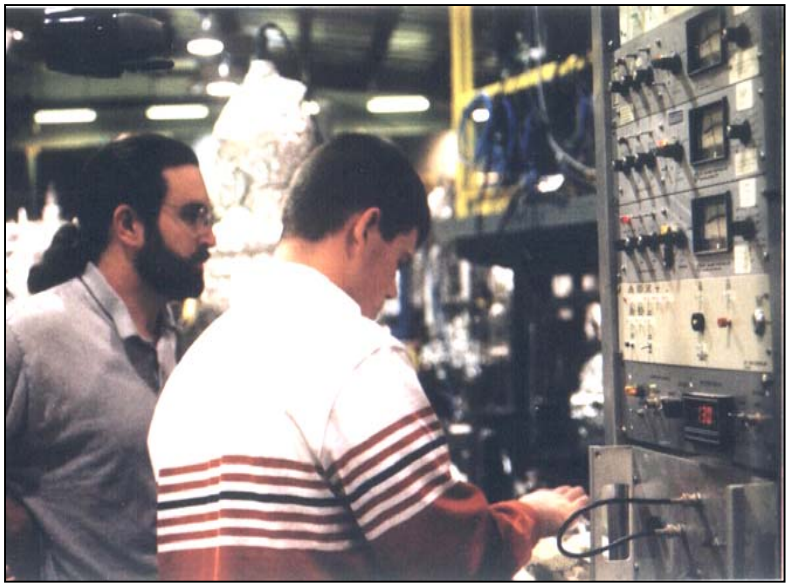
Remotely-controlled Experiment Opportunities for High School Students

Synchrotron Radiation Center Outreach, DMR - 0084402

The Synchrotron Radiation Center (SRC) has instituted a program that allows high school students to perform remote experiments using the storage ring from their school classrooms and homes via the internet. After touring the SRC facility and setting up the experiment on one of the beamlines, the students take data and control the experiment from a remote location by utilizing a web server and the Labview (TM) software.
(At right, Rick Cole, Evansville High School advanced placement chemistry teacher, is discussing the experiment with his students.)



The remote experiment project was organized by SRC outreach coordinator Chris Moore and SRC staff members Mark Bissen and Chad Hewitt. Rick Cole was instrumental in pushing this method of interacting with high school students because it permits students to experience how data are taken under actual laboratory conditions and provides a mesh with the school curriculum without disrupting it. Over the next year the SRC plans to involve more local high schools in the program. (At left, Chris Moore and Brookes Baumberger, student, are initiating the experiment.)

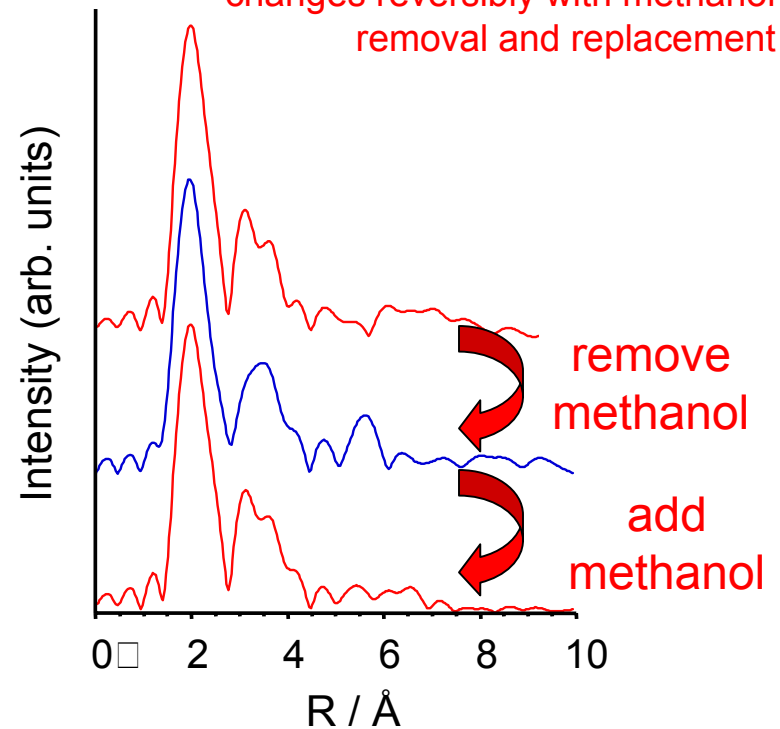
Surface-Driven Structural Transformations in ZnS Nanoparticles ...

Jill Banfield, UC-Berkeley*

Future technologies will use nanometer-scale materials. We have shown that the removal of methanol from, or the addition of water to the surface of 3 nm zinc sulfide (ZnS) nanoparticles causes the small particle to change their internal structure at room temperature. Hence, nanoparticle structure is not fixed, but can respond to changes in the local environment.

The work required a combination of special synthesis techniques, synchrotron x-ray analysis (at the U Wisconsin Synchrotron Radiation Center and at the Argonne Advanced Photon Source) and molecular modeling.

The structure of ZnS nanoparticles, observed with EXAFS spectroscopy at the U Wisconsin Synchrotron Radiation Center, DMR-00-84402, changes reversibly with methanol removal and replacement



more details: Zhang et al, Nature ***424****, 1025, 2003*

*DOE DE-FG02-01ER 15218

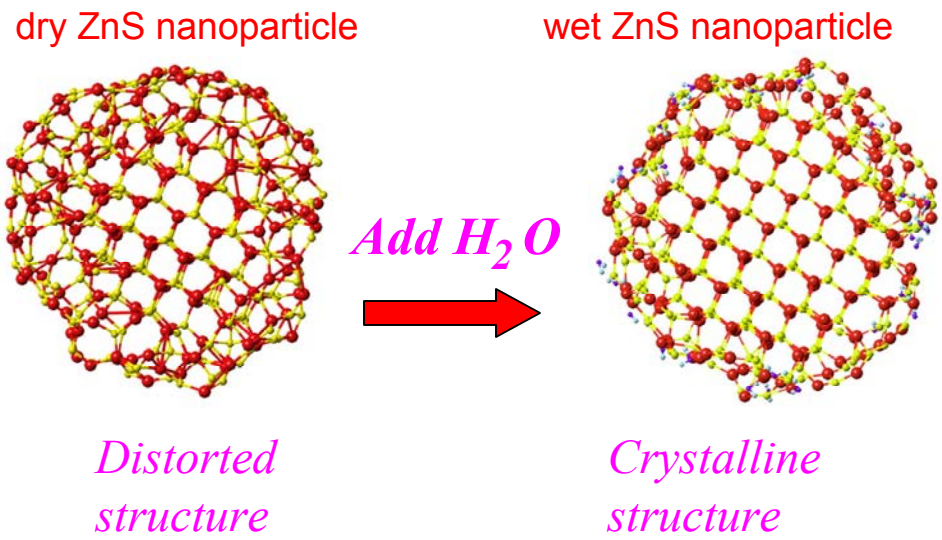
… just add water!
Jill Banfield, UC-Berkeley*

The observation has a number of consequences.

• Different surface molecules may allow choice of nanoparticle structure and properties.

• Given the strong influence of water, the structure and properties of environmental, technological, or extra-planetary nanoparticles may depend on the extent of hydration.

• Any nanoscale material or component may be susceptible to unpredictable structural change if exposed to water, or other adsorbates.



Further work to understand the surface sensitivity of nanoparticles will be performed by new graduate student, Carmen Goodell.

*DOE DE-FG02-01ER 15218

Hear a brief interview about this work on Science today, the UC radio program broadcast by the CBS network.

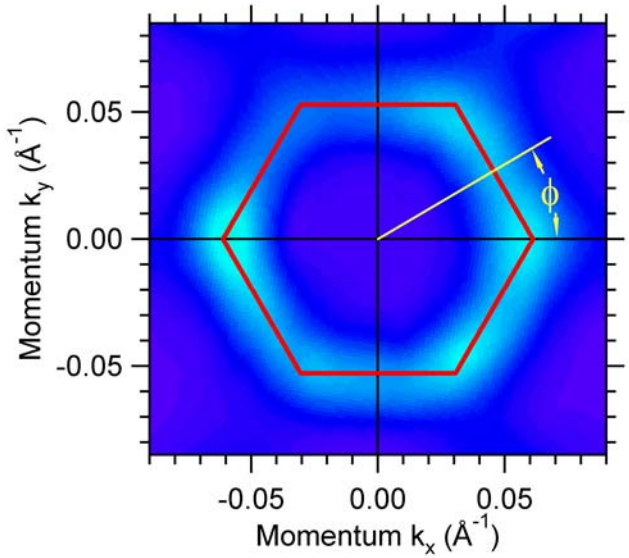
http://www.ucop.edu/sciencetoday/pages/archive/transcripts/2003/sci804.html
Program E. A Surprising Discovery Made on a Nanometer Scale

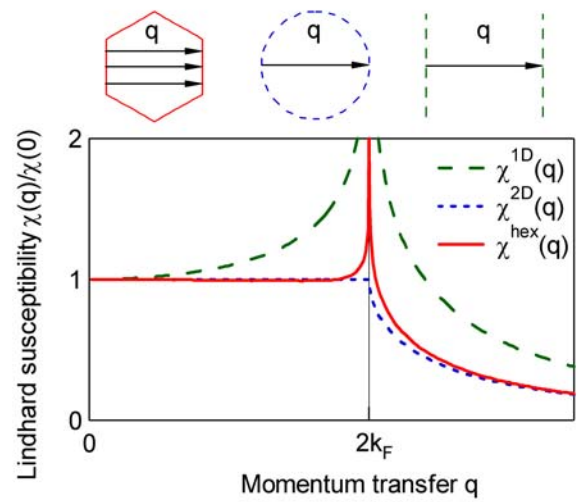
Indication of Charge Density Wave Formation in Bismuth

Christian Ast and Hartmut Höchst, Synchrotron Radiation Center,
University of Wisconsin-Madison DMR-0084402

Photoemission of bismuth Bi(111) reveals a small hexagonal 2D-Fermi surface centered in the surface Brillouin zone.Temperature dependent valence band spectra show an anisotropic energy gap to open at T<75 K. At T=11K the gap is Δ=4 meV at the corners and Δ =7.5 meV at the sides of the Fermi surface.

The Lindhard susceptibility $\chi(q)$ shown on the right indicates a singularity at $q=2k_F$ (Fermi momentum k_F) for a 1D-system while $\chi(q)$ of a 2D-systems is constant up to $2k_F$ and than diminishes. The lack of a $\chi(q)$ cusp is the reason why normally a 2D electron system can not exhibit a charge density wave (CDW). However, a 2D FS topology with extended regions that can be connected with the same wave vector of length $2k_F$ such as the parallel sections of the FS-hexagon develops a singularity (red line) leading to a CDW transition.





Phys. Rev. Lett. 90, 016403 (2003)

Nano-Technology in the Kitchen

Christian Ast and Hartmut Höchst, Synchrotron Radiation Center ,
University of Wisconsin-Madison, DMR-0884402

Conventional refrigerators based on vapor compression units are not very energy efficient and improper coolant disposal can have long lasting negative environmental side-effects. A very different cooling mechanism could come from thermoelectric (TE) converters. These converters do not require any coolant or moveable parts but rely solely on electrical current flowing through a material junction made of n- and p- type legs.

Recent computations of two-dimensional (2D) or one-dimensional (1D) nano- structures of bismuth (Bi) , or $Bi_{1-x}Sb_x$ alloys indicate high thermoelectric properties at room temperature with efficiencies surpassing that of today's household refrigerators.

We use high resolution photo emission spectroscopy with synchrotron radiation to explore the dimensionality and size effects of the valence and conduction bands of Bi based material. Our experiments concentrate on the states close to the Fermi level relevant to TE conversion. In this region photoemission offers the unique opportunity to also investigate the interaction of electrons with lattice phonons, which is an additional important ingredient in maximizing the thermoelectric figure of merit.

Synchrotron light reveals the smallest inclusions in the oldest rock

Gelsomina “pupa” De Stasio, University of Wisconsin Madison, DMR-00-84402

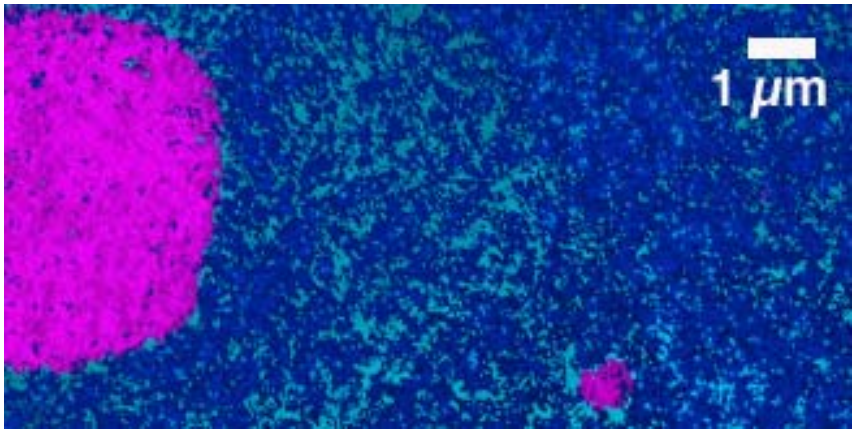
The oldest rock ever found is 4.4 billion years old. The age of the Earth is only slightly older: 4.5 billion years.

Recent analysis done at the Wisconsin Synchrotron Radiation Center revealed inclusions in that rock too small to be analyzed with any other instrument.

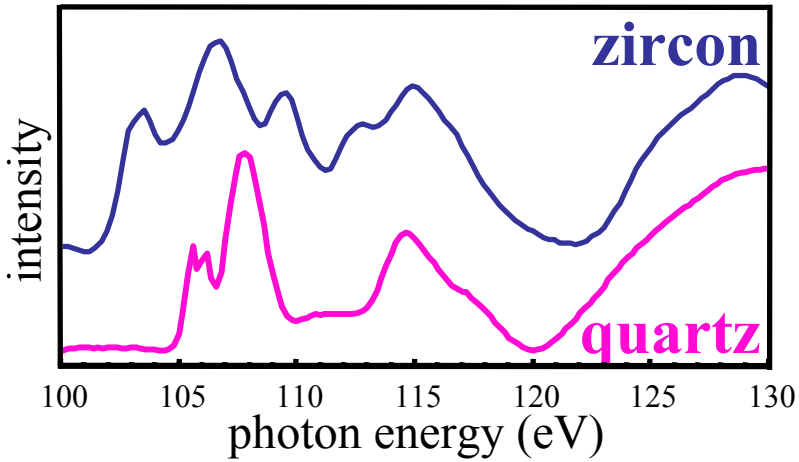
The SPHINX microscope proved that two inclusions, one 4 and one 0.8 micron in diameter are made of quartz.

These and other inclusions prove that the Earth was not an ocean of molten lava 4.4 billion years ago, as geology textbooks report, but had continents and water.

Ultramicroscopy, in press (2004).



SPHINX image of the oldest rock on Earth, showing a 4 micron and a 0.8 micron quartz inclusion (magenta) in zircon (blue).



Synchrotron light reveals the smallest inclusions in the oldest rock

Gelsomina “pupa” De Stasio, University of Wisconsin Madison, DMR-00-84402

Education:

Four undergraduates (Katherine Richter, Gordon Johnson, Andrew Gadtke and Jeffrey Spector), three graduate students (Bradley Frazer, Robert Erhardt and Matthew Daniels), and one post-doc (Benjamin Gilbert) contributed to this work. Undergraduate Richter from Bob Jones, was supported by NSF-REU 2002 program, and entered graduate school in 2003 at Notre Dame. Gadtke, Spector, and Johnson are still in college at UW-Madison. Graduate Frazer will receive his Ph.D. in physics from the EPFL-Switzerland at the end of 2003. Gilbert is currently doing a second post-doc at UC-Berkeley.

Outreach:

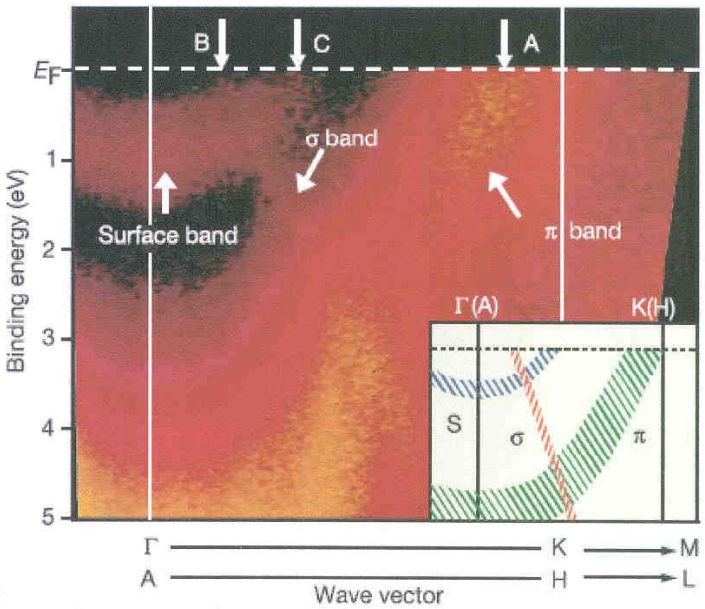
In 2003 the PI started to contribute actively and enthusiastically to the NSF-Center for the Integration of Research, Teaching and Learning. Most importantly, she is developing techniques for “instant-feedback” from large undergraduate and high school classes.

Multiple Superconducting Gaps in MgB_2 Unambiguosly Established

S. Souma, et al.
Synchrotron Radiaton Center University of Wisconsin-Madison

DMR-0084402

Magnesium diboride, MgB_2, has the highest transition temperature of the known metallic superconductors. The key to understanding its superconductivity lies with understanding the structure of the superconducting energy gap associated with the formation of the superconducting pairs. Recently, the existence of two kinds of superconducting gaps in MgB_2 has been suggested by specific heat and tunneling experiments. This is in contrast to both conventional and high-T_c superconductors, which generally exhibit a single gap. Work carried out at SRC by S. Souma, and collaborators [*Nature* 423 (2003) 465] reports experimental evidence for two-band superconductivity in MgB_2. They were able to separately observe the superconducting gaps of the σ and π bands, as well as a surface state band. The gaps have distinctly different sizes, which unambiguously establishes MgB_2 as a two-gap superconductor.



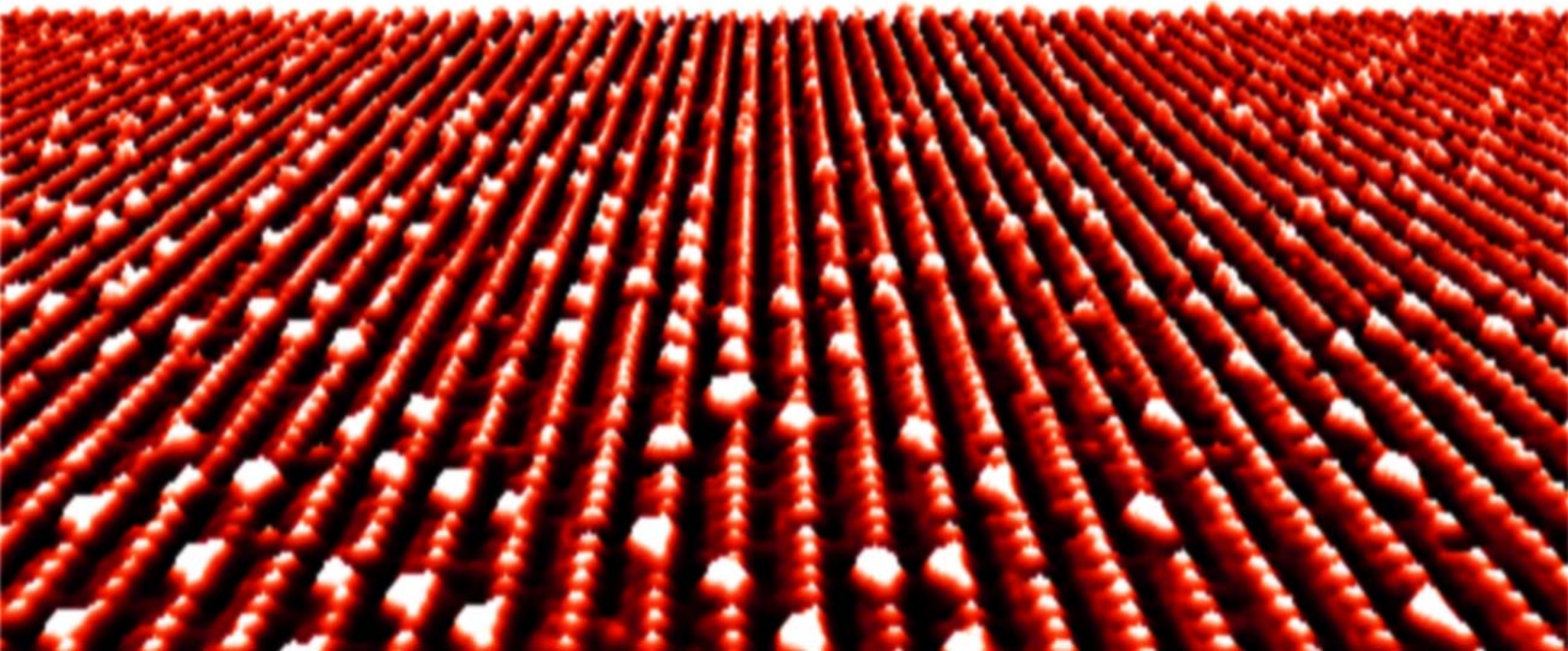
Low - Dimensional Electrons at Silicon Surfaces

J.N. Crain[1], J.L. McChesney[1], M. Bissen[2], C. Gundelach[2], S.C. Erwin[3], … , F.J. Himpsel[1]

[1]Dept. Physics, UW Madison, [2]SRC, [3]NRL

Synchrotron Radiation Center, University of Wisconsin-Madison DMR-0884402

Chains of metal atoms can now be assembled at stepped silicon surfaces, where they line up parallel to the step edges.



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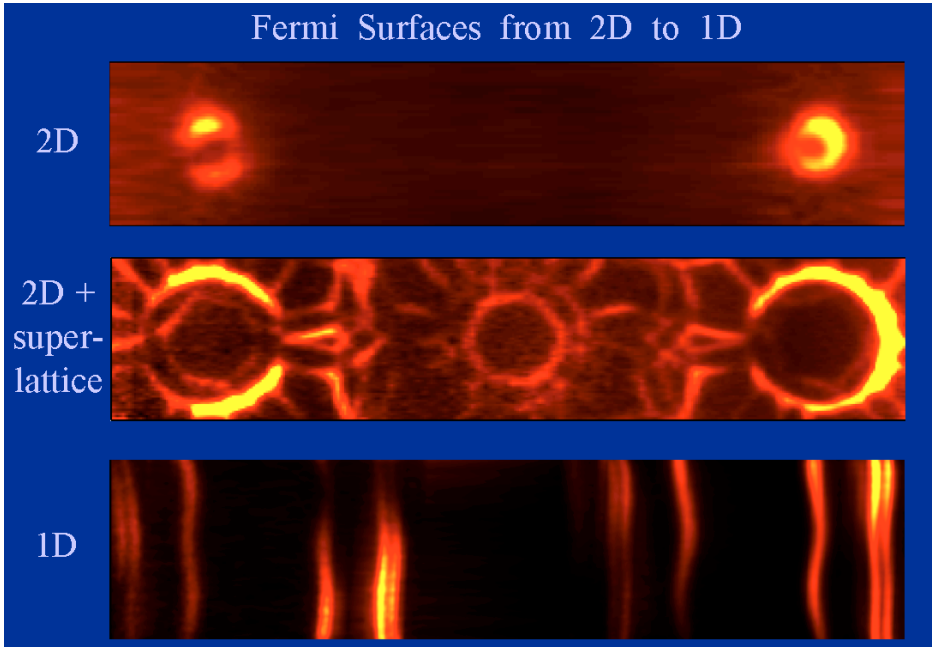
Synchrotron Radiation Center, University of Wisconsin-Madison DMR-0884402

In Franz Himpsel's group at the University of Wisconsin Madison there has been a multi-year effort to develop a new class of one-dimensional solids by attaching chains of metal atoms to stepped silicon surfaces.

The properties of the interesting electrons at the Fermi level are captured by plotting their momentum distribution, i.e., the Fermi surface.

The figure shows such Fermi surfaces for two- and one-dimensional states created by silver and gold on silicon. The simplest two-dimensional Fermi surface is a circle (top). One-dimensional Fermi surfaces of chain structures have a completely different, open topology (bottom) degenerating into straight lines in the truly one-dimensional limit.



Fermi surfaces of two- and one-dimensional structures formed by silver and gold on silicon surfaces. Circles in two dimensions become straight lines in one dimension.