

2012

Microanalytical Reference Materials
May 15–17, 2012
Golden, CO
www.microbeamanalysis.org

MSC/SMC Annual Meeting

June 5–8, 2012
Halifax, Nova Scotia, Canada
<http://conference2012.msc-smc.org>

Electron Backscatter Diffraction

June 19–21, 2012
Pittsburgh, PA
www.microbeamanalysis.org

Inter/Micro – Applied Microscopy

July 9–13, 2012
Chicago, IL
<http://mcri.org/home/section/101/inter-micro>

Microscopy & Microanalysis 2012

July 29–August 2, 2012
Phoenix, AZ
www.microscopy.org

Denver X-ray Conference

August 6–10, 2012
Denver, CO
www.dxcicdd.com

European Microscopy Congress

September 16–21, 2012
Manchester, UK
www.emc2012.org.uk
Abstract deadline: March 16, 2012

Neuroscience 2012

October 13–17, 2012
New Orleans, LA
www.sfn.org

2013

Microscopy & Microanalysis 2013

August 4–8, 2013
Indianapolis, IN
www.microscopy.org

2014

Microscopy & Microanalysis 2014

August 3–7, 2014
Hartford, CT
www.microscopy.org

2015

Microscopy & Microanalysis 2015

August 2–6, 2015
Portland, OR
www.microscopy.org

2016

Microscopy & Microanalysis 2016

July 24–28, 2016
Columbus, OH
www.microscopy.org

More Meetings and Courses

Check the complete calendar near the back of this magazine and in the MSA journal *Microscopy and Microanalysis*.

Carmichael's Concise Review

Memory Storage with a Few Atoms

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High-density magnetic memory is typically fabricated from ferromagnetic materials. As the density is increased and the memory elements are more densely packed, the magnetic fields of neighboring elements interfere with each other. If materials without magnetic fields, referred to as antiferromagnetic, could be manipulated to store data, such limitations theoretically could be overcome. In a breakthrough study, Sebastian Loth, Susanne Baumann, Christopher Lutz, Don Eigler, and Andreas Heinrich used a low-temperature scanning tunneling microscope (STM) to assemble a device with just 12 antiferromagnetic atoms that could be manipulated to one of two states, demonstrating the ability to store data [1]. Until now, about one million atoms have been required to store a digital 0 or 1 in the most advanced magnetic storage systems.

Using the STM, Loth et al. imaged and then positioned iron atoms on a surface of copper nitride. This has been compared to moving billiard balls on a pool table using a cue with a sticky tip. The spins of neighboring iron atoms couple by an exchange interaction to become antiferromagnetic. This occurs at a low temperature (near absolute zero) called the Néel temperature because it was first described by Louis Néel who received the Nobel Prize in physics in 1970 for related discoveries. Such groups of atoms are said to exist in a Néel state. Loth et al. found that as few as 6 iron atoms could exist in a stable Néel state, in which the spin orientation alternates between neighboring atoms. Spin-polarized STM images of a linear chain of 8 atoms could clearly distinguish the two Néel states. The spin-polarized STM tip forms a magnetic tunnel junction in which the conductance alternates between high (parallel alignment of tip and sample states) and low (antiparallel alignment) as the tip passes from atom to atom along the chain. These are known as Néel states “0” and “1,” respectively. The magnetic state could intentionally be switched between state 0 and 1 by holding the STM tip stationary over any iron atom in the chain and increasing the applied voltage to a certain level. The voltage could then be lowered, and the state

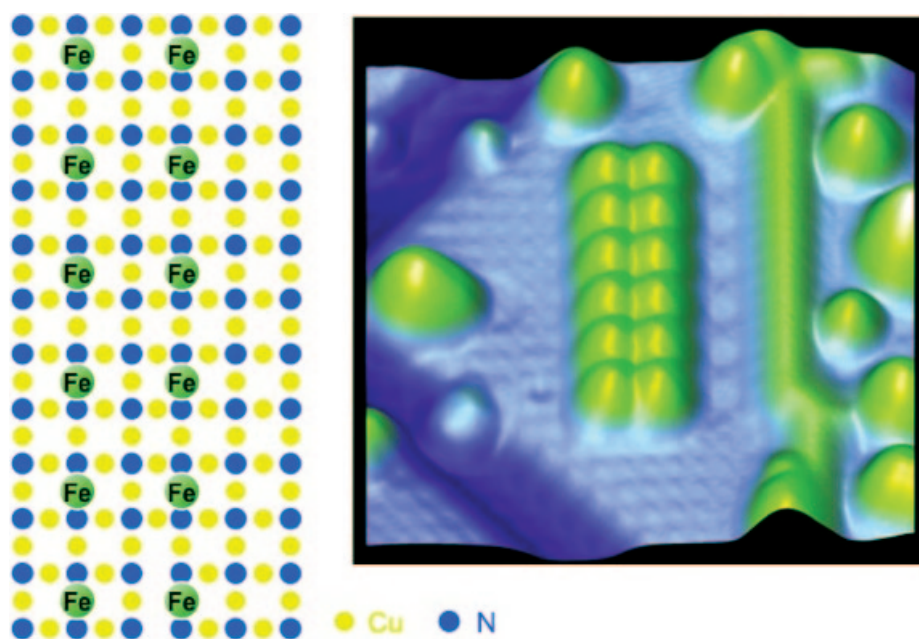


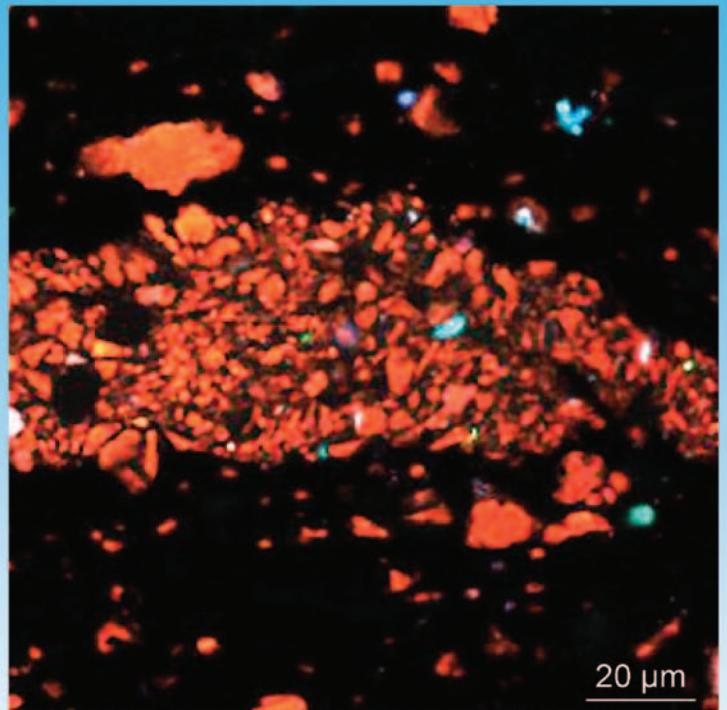
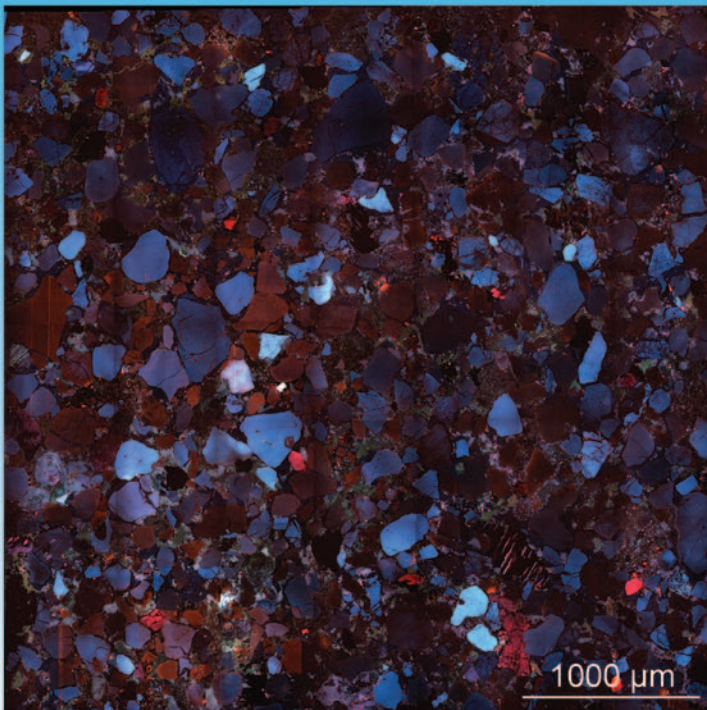
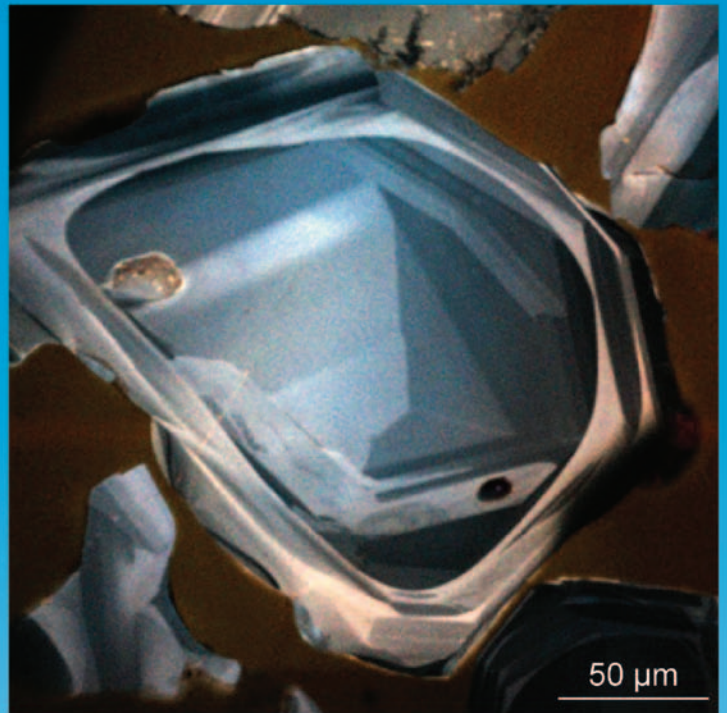
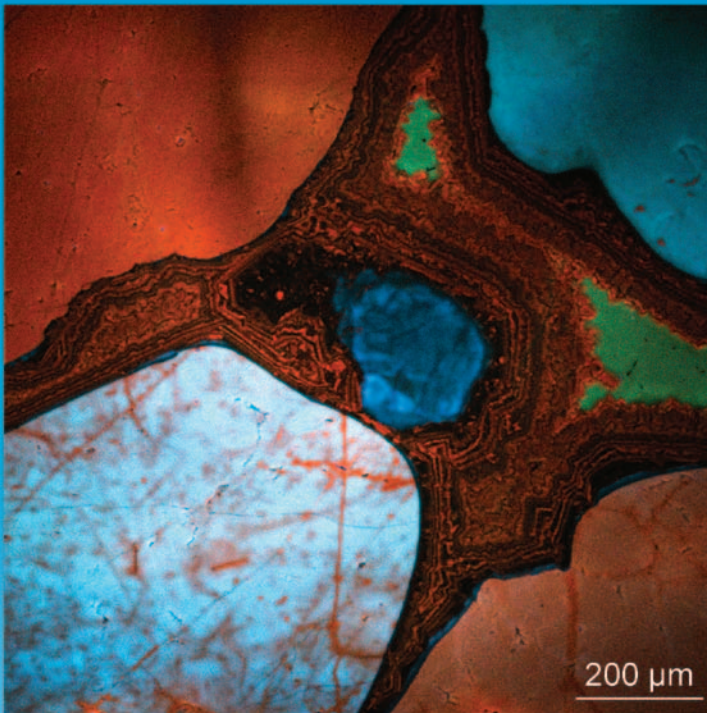
Figure 1: Layout of Fe atoms on a Cu₂N layer grown on Cu. In the STM image, each Fe atom appears as a green bump. The relatively large spacing between the Fe atoms was chosen to be able to image them as individual bumps in the STM; however, closer spacing and hence stronger magnetic interactions can be achieved. Courtesy of IBM–Zurich.

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Images, dockwise from top left: (Top Left) Quartz arenite, granitic and metamorphic source. Image shows well developed overgrowth cement with multiple zoning. Sample prepared using the Gatan Ilion™ and imaged with Gatan ChromaCL2™ imaging system. Image courtesy of Dr. J. Schieber, Indiana University. (Top Right) Growth zonation in an individual zircon grain. Sample prepared using the Gatan Ilion™ and imaged with Gatan ChromaCL2™ imaging system. Image courtesy of Dr. J. Schieber, Indiana University. (Bottom Right) Provenance identification in shale. Single-source dominated provenance Barnett shale (Miss.) Texas, Low Grade Met. Ouchila orogeny. Source: Sevier orogeny. Low and medium grade metamorphic quartz. Sample prepared using the Gatan Ilion™ and imaged with Gatan ChromaCL2™ imaging system. Image courtesy of Dr. J. Schieber, Indiana University. (Bottom Left) Reservoir quartz of mixed provenance displaying healed fractures and chemical overgrowths. Sample prepared using the Gatan Ilion™ and super-image acquired using Gatan ChromaCL2™ imaging system and CHFS32.



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would remain stable. With modifications, they were able to demonstrate electrical switching at high speeds and energy in the femtojoule range. The smallest unit that could reliably store data (that is, be stable in one of the two Néel states) was two rows of six iron atoms. This was only possible below 5 degrees Kelvin, but the authors anticipate that larger assemblies will be stable at higher temperatures.

The 12 iron atoms could comprise a bit of information, and this was measured to be just nine square nanometers. These bits could be assembled into bytes of 96 atoms, which corresponds to a single character (such as a letter in this word). These configurations were stable over a time scale of hours, and readout was achieved by topographic imaging with the STM. Such a dramatic decrease in the size and energy requirements for data storage could possibly be assembled into units that would be miniscule, consume proportionately less power, and generate much less heat.

The absolute physical limit of how small a unit of memory storage can be has been pondered for decades. Whereas we still don't have the definitive answer to this, Loth et al. appear to be pointing us in the final direction.

References

- [1] S Loth, S Baumann, CP Lutz, DM Eigler, and AJ Heinrich, *Science* 335 (2012) 196–99.
- [2] The author gratefully acknowledges Drs. Andreas Heinrich and Sebastian Loth for reviewing this article.

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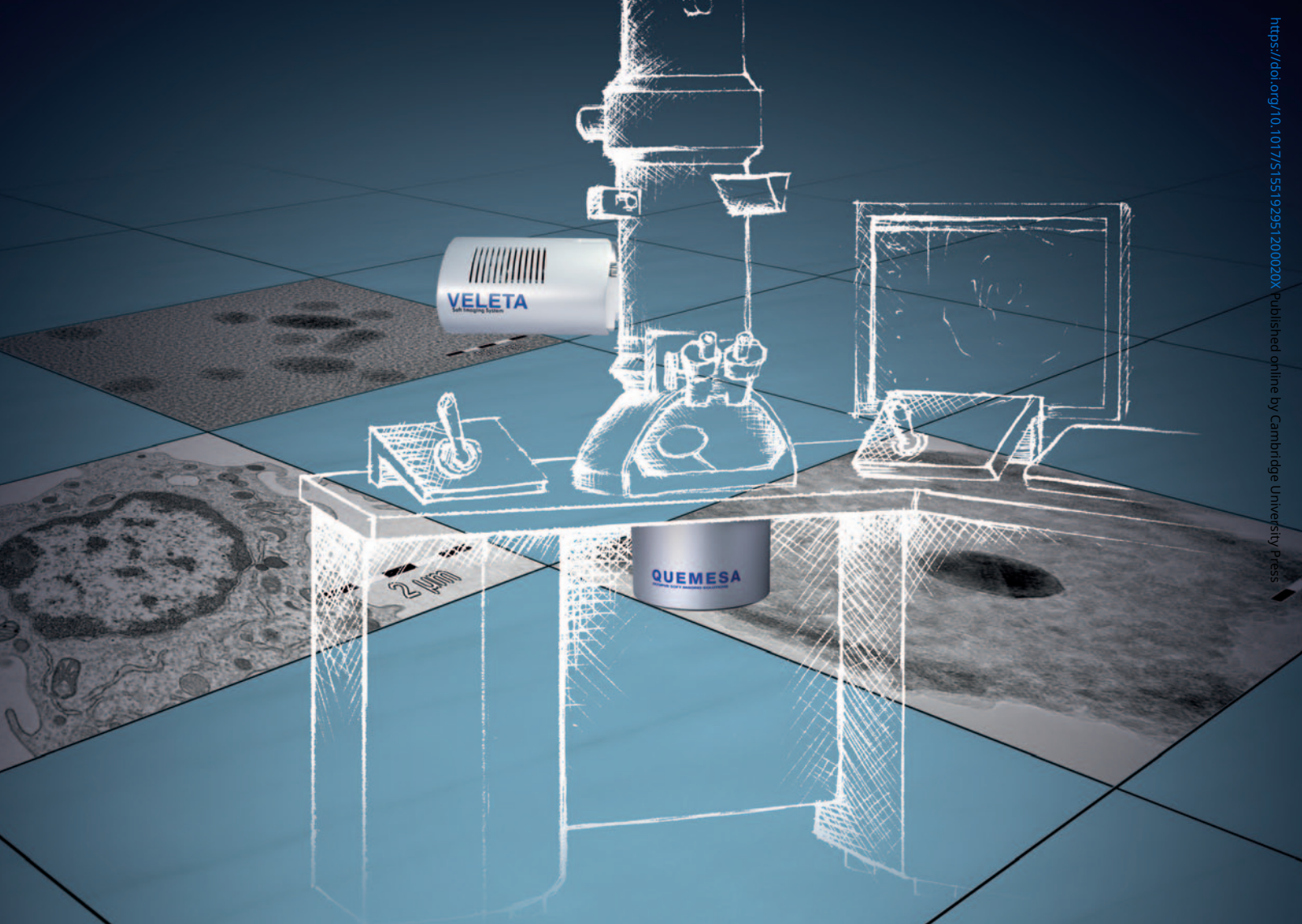
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