## Microscopy TODAY Coming Events

### 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*.



# 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

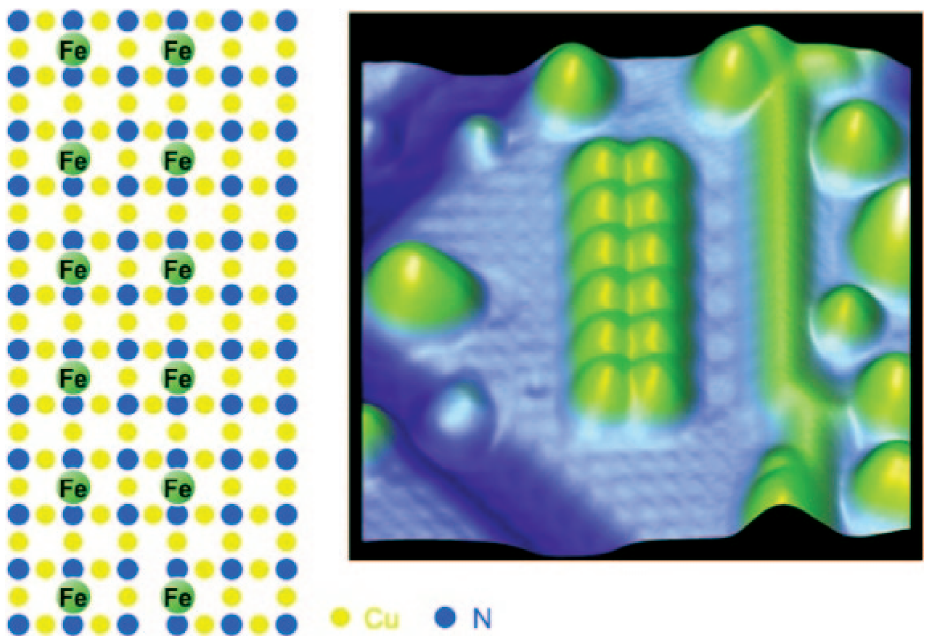



**Figure 1:** Layout of Fe atoms on a $Cu_2N$ layer grown on Cu. In the STM image, each Fe atom appears as a green bump. The relatively large spacing between the Fe atoms was chosen to be able to image them as individual bumps in the STM; however, closer spacing and hence stronger magnetic interactions can be achieved. Courtesy of IBM–Zurich.



doi:10.1017/S155192951200020X

https://doi.org/10.1017/S155192951200020X Published online by Cambridge University Press

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.

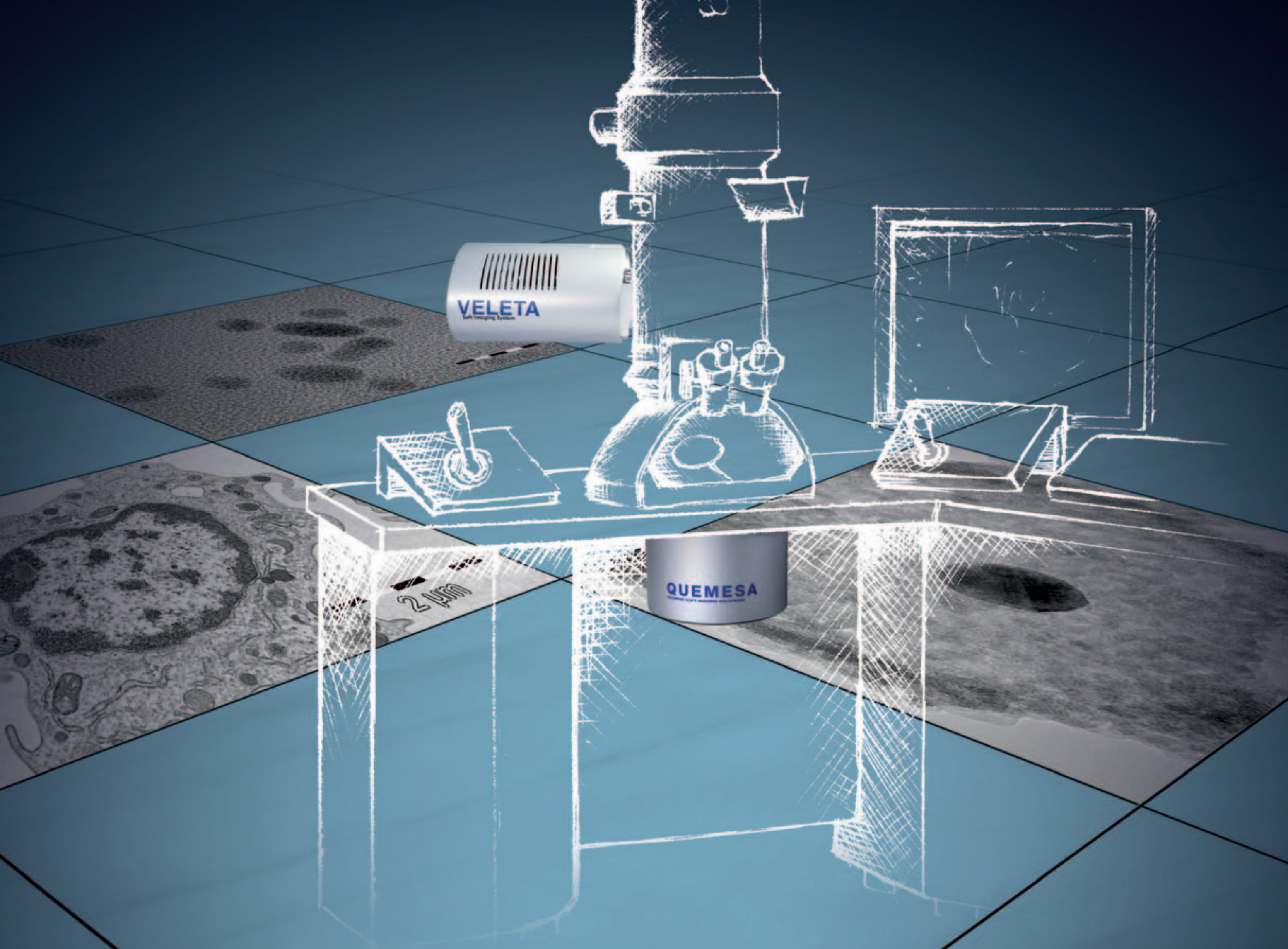
The absolute physical limit of how small a unit of memory storage can be has been pondered for decades. Whereas we still don't have the definitive answer to this, Loth et al. appear to be pointing us in the final direction.

## References

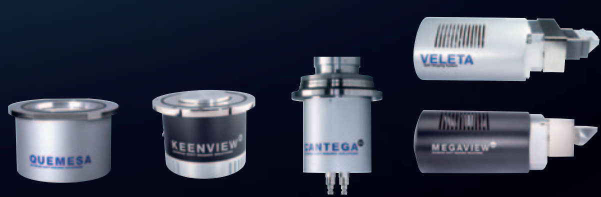
[1] S Loth, S Baumann, CP Lutz, DM Eigler, and AJ Heinrich, *Science* 335 (2012) 196–99.

[2] The author gratefully acknowledges Drs. Andreas Heinrich and Sebastian Loth for reviewing this article.

MT


VELETA
QUEMESA
2 µm




QUEMESA
KEENVIEW
CANTEGA
VELETA
MEGAVIEW