- ScienceWatch Home
- Inside This Month...
- Interviews

Featured Interviews
Author Commentaries
Institutional Interviews
Journal Interviews
Podcasts

- Analyses

Featured Analyses
What's Hot In...
Special Topics

- Data & Rankings

Sci-Bytes
Fast Breaking Papers
New Hot Papers
Emerging Research Fronts
Fast Moving Fronts
Corporate Research Fronts
Research Front Maps
Current Classics
Top Topics
Rising Stars
New Entrants
Country Profiles

- About Science Watch

Methodology
Archives
Contact Us
RSS Feeds

NEW HOT PAPERS - 2009

September 2009

PDF

Lane W. Martin talks with *ScienceWatch.com* and answers a few questions about this month's New Hot Paper in the field of Materials Science. The author has also sent along images of their work.

Article Title: Electric-field control of local ferromagnetism using a magnetoelectric multiferroic
Authors: Chu, YH;Martin, LW;Holcomb, MB;Gajek, M;Han, SJ;He, Q;Balke, N;Yang, CH;Lee, D;Hu, W;Zhan, Q;Yang, PL;Fraile-Rodriguez, A;Scholl, A;Wang, SX;Ramesh, R
Journal: NAT MATER, Volume: 7, Issue: 6, Page: 478-482, Year: JUN 2008
* Univ Calif Berkeley, Dept Mat Sci & Engn, Berkeley, CA 94720 USA.
* Univ Calif Berkeley, Dept Mat Sci & Engn, Berkeley, CA 94720 USA.
* Univ Calif Berkeley, Dept Phys, Berkeley, CA 94720 USA.
* Univ Calif Berkeley, Lawrence Berkeley Lab, Div Mat Sci, Berkeley, CA 94720 USA.
(addresses have been truncated)

SW: Why do you think your paper is highly cited?

This paper came about at a pivotal time for the field of multiferroics. *Science* magazine had put the field of multiferroics on the "Breakthrough of the Year: Areas to Watch" list (*Science* 318:1848-49, 2007) vs. 2008. This designation came at a time when multiferroics had been experiencing more and more attention in solid-state physics research and increasing participation in symposia focused on these materials at international meetings.

What multiferroics and magnetoelectrics were promising were novel, new functionalities in materials. By far, the most fundamental among them is the ability to control and manipulate magnetism with electric fields. Such a control has generally been deemed to be very difficult due to the intrinsic differences between electric field (a polar property) and magnetic fields (an axial property).

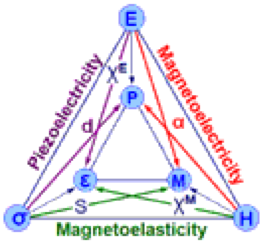
The question of what will make up the next generation of logic, memory, and sensing technology remains a heated one—this paper brought strong evidence to support the ideas and concepts that had been on the rise within the collective field and also demonstrated the powerful nature of these materials, which are indeed capable of modifying the ferromagnetic state of an adjoining layer by the application of an electric field to the multiferroic.

SW: Does it describe a new discovery, methodology, or synthesis of knowledge?

The paper describes a new spin on old materials and new ways of thinking about using them. The field of functional oxide materials is old and multiferroics themselves had been studied in Europe and the former Soviet Union throughout the second half of the last century.

Beginning in the early 2000s, multiferroics experienced a "renaissance," as new ideas, aided by advances in first principles calculations and synthesis capabilities, about how to create and engineer new multiferroic materials and utilize them in device structures, exploded onto the research scene. This was driven by the simple idea that these materials could have greater impact on future devices where electric fields could be used to control magnetism.

Figure 1 [+] details



Triangle: A big push in the field of multiferroics has focused...

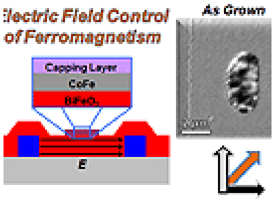
This paper represented the first real culmination of these ideas in a room temperature device—finally bringing together the ideas of an entire field in order to demonstrate the immense capabilities of oxide electronics.

With that said, the work really built upon the ideas of an entire field of study on oxide materials to demonstrate a simple new idea, a new pathway, to utilizing these materials in order to achieve electric field control of ferromagnetism at room temperature.

SW: Would you summarize the significance of your paper in layman's terms?

The modern world is built upon functional materials—materials that perform exotic tasks unbeknownst to most people on a daily basis, but are essential to our daily life. From computers to cell phones and beyond, we rely on the materials in such devices to give us unlimited information and place such capabilities in the palm of our hand.

Figure 2 [+] details



Switching: This figure describes the main essence of the paper...

As researchers and engineers push the cutting edge of capabilities, materials are called upon to do more and more. In the realm of computing, guided by the ever present words of Moore's Law—an observation made in 1965 by Gordon Moore, co-founder of Intel, which now states that the number of transistors on a chip doubles every 18 months—we've achieved more with less in so many ways.

Recently, the question of what comes next after Si, has begun to press on the minds of many. This is where the cutting edge research at our national laboratories and research universities comes into play.

From using nanomaterials to the spin of electrons to do computations, the future is wide open. What this paper demonstrated, in the simplest form, is a set of materials that could enable this next generation of functional materials. By using electric fields to control ferromagnetic order, we begin a dialogue about the possibilities of today's research impacting tomorrow's.

In fact, the idea of using such multiferroic materials has even caught the eye of the folks at the International Technology Roadmap for Semiconductors and will be included in a section on emerging materials in 2009.

SW: How did you become involved in this research, and were there any problems along the way?

At the University of California, Berkeley, and Lawrence Berkeley National Laboratory, we had put together a strong program in multiferroic materials under the direction of Professor Ramamoorthy Ramesh. The group had been working on various multiferroic and magnetoelectric materials, including the material $BiFeO_3$ used in this study, for a few years when the idea to utilize the half-century-old concept of exchange bias with a magnetoelectric, multiferroic antiferromagnet instead of a classic antiferromagnet came up.

We assembled a team to attack the problem and I was among the first to join in on this work. This was truly a project build out of teamwork—both in the group at Berkeley with our colleagues at Stanford University, the Advanced Light Source, and the Swiss Light Source.

The problem we were attempting to address was very complicated and called on a wide range of skills. From bringing together dissimilar materials, to developing new device architectures, to pushing the edges of x-ray photoemission microscopy, there were many issues throughout the research process.

To get to the end result required countless long days and night shifts at the synchrotron, and amazing amounts of materials synthesis and device processing. Each piece of the puzzle offered its own trials and tribulations, but in the end we persevered and achieved something we were very proud of. Throughout the numerous iterations we basically invented processes, analyses, and synthesis techniques that were completely new to our research team.

SW: Where do you see your research leading in the future?

I think it is important to make it clear that this is just the beginning of this field of study. To really utilize these ideas in a device will require not just a new materials science, but engineering and device integration that could require years of development.

At the same time, from a fundamental science standpoint, we still have a number of open questions. The details of the magnetic coupling across interfaces in such structures has been the focus of much research in the past and adding dynamical switching to the system only makes it all that more important to develop new ideas and probes of these sorts of physics.

Other major questions include whether a device can be designed that will allow for deterministic 180° control of magnetism or if a single-phase system that is simultaneously both ferroelectric and ferromagnetic at room temperature with strong coupling can be developed.

The way we view our paper is that we added yet another brick to a bigger structure—each brick laid before ours enabled us to get where we are today, and our insights will hopefully enable that next level to go up in the future.

SW: Do you foresee any social or political implications for your research?

In a field like multiferroics, it is often hard to imagine how our research will impact the broader world around us. At this point, it would be presumptuous to say that our research will have significant social or political implications in the future.

What we can hope for is that our research leads to new ideas and devices that extend our capabilities—whether they be in computing, memory, or sensing applications—and that these discoveries enable our daily life to be just a little bit better.

Lane W. Martin, Ph.D.
Assistant Professor
Department of Materials Science and Engineering
University of Illinois, Urbana-Champaign
Urbana, IL, USA

KEYWORDS: MULTIFERROICS; MAGNETOELECTRICS; FERROMAGNETIC; OXIDE MATERIALS; MOORE'S LAW.

PDF

back to top

2009 : September 2009 - New Hot Papers : Lane W. Martin Discusses His Work in the Field of Multiferroics

THOMSON REUTERS

Site Search GO

Home About Thomson Reuters Press Room Contact Us

- ScienceWatch Home
- Inside This Month...
- Interviews

Featured Interviews
Author Commentaries
Institutional Interviews
Journal Interviews
Podcasts

- Analyses

Featured Analyses
What's Hot In...
Special Topics

- Data & Rankings

Sci-Bytes
Fast Breaking Papers
New Hot Papers
Emerging Research Fronts
Fast Moving Fronts
Corporate Research Fronts
Research Front Maps
Current Classics
Top Topics
Rising Stars
New Entrants
Country Profiles

- About Science Watch

Methodology
Archives
Contact Us
RSS Feeds

scienceWATCH.com
TRACKING TRENDS & PERFORMANCE IN BASIC RESEARCH

Interviews Analyses Data & Rankings

2009 : September 2009 - New Hot Papers : Lane W. Martin Discusses His Work in the Field of Multiferroics - Figures & Descriptions

NEW HOT PAPERS - 2009

July 2009

PDF

Lane W. Martin talks with *ScienceWatch.com* and answers a few questions about this month's New Hot Paper in the field of Materials Science. The author has also sent along images of their work.

Article Title: Electric-field control of local ferromagnetism using a magnetoelectric multiferroic
Authors: Chu, YH;Martin, LW;Holcomb, MB;Gajek, M;Han, SJ;He, Q; Balke, N;Yang, CH;Lee, D;Hu, W;Zhan, Q;Yang, PL;Fraile-Rodriguez, A; Scholl, A;Wang, SX;Ramesh, R

Return to interview.

Figures and descriptions:

Figure 1:

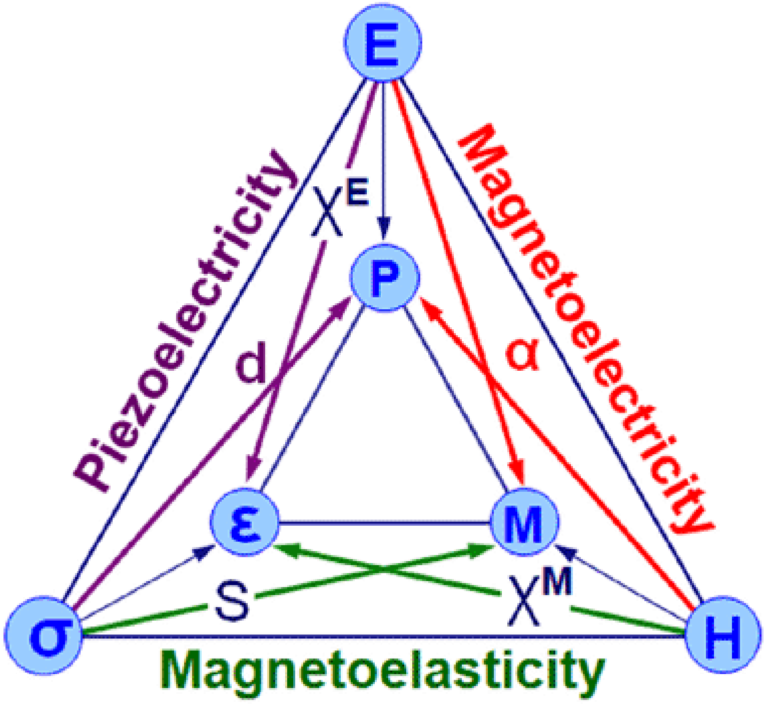


Figure 1: Triangle

A big push in the field of multiferroics has focused on engineering strong magnetoelectric coupling. The magnetoelectric effect describes the coupling between electric and magnetic fields in matter. Strong magnetoelectric coupling in materials would enable a new generation of devices where we could say manipulate magnetic data bits with an electric field. Another idea is to evolve computational capabilities to utilize not only the presence of charge, but the spin of the electrons. The so called field of *spintronics* would need materials that can respond quickly to small applied fields (typically we envision materials working with small electric fields to keep power consumption, heating, etc. to a minimum) and have deterministic control of electron spins (i.e., magnetic order). Magnetoelectric materials – like some multiferroics – offer exciting opportunities for making these types of devices a reality.

Figure 2:

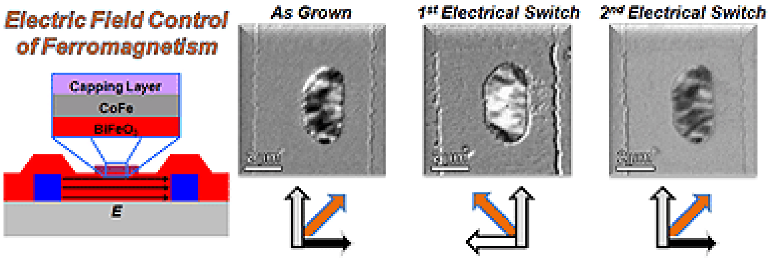


Figure 2: Switching

This figure describes the main essence of the paper we've been discussing. We were attempting to show that we could *control ferromagnetism with an electric field.* On the left is a schematic of a cross-sectional view of the device we used in this study. Very simply, it consisted of a ferromagnetic materials ($Co_{0.9}Fe_{0.1}$, here called CoFe) in contact with the magnetoelectric, multiferroic $BiFeO_3$. The device structure allowed us to apply electric fields in the plane of the film between the blue electrodes. This enabled deterministic control of the ferroelectric switching in the $BiFeO_3$. The antiferromagnetic order in $BiFeO_3$, in turn, coupled to the ferroelectric order and upon a change in the ferroelectricity a corresponding change in the antiferromagnetism is obtained. This antiferromagnetic order is then coupled to the ferromagnetic order in CoFe via an exchange interaction. Demonstrated on the right is what happens to the ferromagnet upon application of an electric field. The magnetic domain structure is observed to switch back-and-forth by 90° rotations as imaged via x-ray magnetic circular dichroism photoemission electron microscopy.

Return to interview.

PDF

back to top

2009 : September 2009 - New Hot Papers : Lane W. Martin Discusses His Work in the Field of Multiferroics - Figures & Descriptions