9-15-2014

MRI: Acquisition of a SQUID Magnetometer for Analysis of Advanced Materials

Robert W. Meulenberg
Principal Investigator; University of Maine, Orono, robert.meulenberg@maine.edu

Robert J. Lad
Co-Principal Investigator; University of Maine, Orono, rjlad@maine.edu

David J. Frankel
Co-Principal Investigator; University of Maine, Orono, frankel@maine.edu

Michael D. Mason
Co-Principal Investigator; University of Maine, Orono, mmason@umche.maine.edu

Samuel T. Hess
Co-Principal Investigator; University of Maine, Orono, Sam.T.Hess@umit.maine.edu

My Desktop
Prepare & Submit Proposals
Proposal Status
Proposal Functions
Awards & Reporting
Notifications & Requests
Project Reports
Submit Images/Videos
Award Functions
Manage Financials
Program Income Reporting
Federal Financial Report History
Financial Functions
Grantee Cash Management Section Contacts
Administration
User Management
Research Administration
Lookup NSF ID

Preview of Award 1040006 - Final Project Report

Cover |
Accomplishments |
Products |
Participants/Organizations |
Impacts |
Changes/Problems
| Special Requirements

Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1040006
Project Title:	MRI: Acquisition of a SQUID magnetometer for analysis of advanced materials
PD/PI Name:	Robert W Meulenberg, Principal Investigator David J Frankel, Co-Principal Investigator Samuel T Hess, Co-Principal Investigator Robert J Lad, Co-Principal Investigator Michael D Mason, Co-Principal Investigator
Recipient Organization:	University of Maine
Project/Grant Period:	10/01/2010 - 09/30/2013
Reporting Period:	10/01/2012 - 09/30/2013
Submitting Official (if other than PD\PI):	Robert W Meulenberg Principal Investigator
Submission Date:	01/15/2014
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Robert W Meulenberg

Accomplishments

*** What are the major goals of the project?**

The goals of project 1040006 can be sumarized in the following statement: A superconducting quantum interference device (SQUID) magnetometer was purchased to answer crucial questions about the magnetic/electrical properties of a host of materials systems for many research groups at the University of Maine. Towards this goal, the following research projects were targeted: (i) ligand exchanged quantum dots, (ii) doped quantum dots, (iii) magnetite nanocrystals, (iv) high surface area gold nanostars, (v) Au/iron oxide core/shell nanoparticles, (vi) Ru/RuO2 nanowires, (vii) igneous and metamorphic rocks, (viii) photomagnetic properties of nanostrucutures, and (ix) magnetoresistance and Hall conductivity measurements.

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

Specific Objectives:

Significant Results:

The results obtained for the materials systems mentioned above have revealed information about intrinsic magnetization, particle-particle interactions, and surface contributions to magnetization. Examples of three specific activites follow:

1) Doped quantum dots

We have been studying both Co and Cu doped CdSe QDs. The Co doepd particle have have interesting structural properties, are superparamagnetic with a blocking temperature of ~5K. This is the largest reported transition temperature for Co doped CdSe. The magnetization curves exhibit hysteresis with coercive field on the order of ~50 Oe. The copper doped CdSe QDs are an interesting system. They do not dope as Cu(II), and are therefore magnetically silent. The optical properties of these materials are fascinating with a blue optical absorption edge and a ~1 eV Stokes shift resulting in a deep red emission.

2) Effects of excessive cleaning of colloidal quantum dots on magnetic properties

To date, we have undertaken much effort towards elucidating the magnetic properties of native capped CdSe QDs with a direct comparison to the typical magnetic response of doped QDs (both copper and cobalt doped CdSe). Both phosphorus and amine (natively) coated QDs exhibit a temperature independent magnetic susceptibility, suggestive of some sort of Pauli paramagnetism, and a low temperature (less than 50 K) Curie tail. This tail is not due to magnetic impurities, as much effort was undertaken by our group of devising proper sample holders and background subtraction methods.

We have also developed chemical methods in which we can selectively control the number of ligand molecules on the QD surface. Using titration methods, we can slwoly add more molecules onto the QD surface, and track the effect on the magnetic susceptibility. For QD with very few surface ligands, the observed magnetic susceptibility is close to the bulk CdSe value. This is signifcant, as we believe we are finally seeing proof that the surface molecules are indeed responsible for induced paramagnetism in QDs.

Finally, no evidence for ferromagnetic has been seen in any of our studied undoped QDs.

3) Induced magnetization via strain in nanostructures

In collaboration with Prof G.F Strouse at Florida State, we have been investigating the effect of strain of the magnetic properties of QDs. In experiments performed by my group at the Canadian Light Source, we compared the Se L3-x-ray absoprtion edge for wurtzite, cubic, and a psuedo-cubic (as coined by Prof. Strouse) CdSe QDs. An interesting observation was that the wurtzite and cubic data looks

indentical, but the psuedo-cubic edge was shifted to higher energy, similar to data for CdSe/ZnS core/shell materials (materials that posses a large lattice mismatch and have a large lattice strain). When observed via magnetometry, the data for the wurtzite and cubic were similar to the results reported above (namely, paramagnetic). The psuedo-cubic CdSe QD exhibited differences in the zero field and field cooled behavior in the magnetic susceptibility and looked to be superparamagnetic. A low temperature, we obserevd magnetic hysteresis. These results are quite exciting and we are in the process of following them up in more detail and for reproducibility.

Key outcomes or
Other achievements:

*** What opportunities for training and professional development has the project provided?**

This work has involved primarily two graduate students, one senior and one junior (but has included 2 other graduate students). This project has allowed the senior graduate student to truly become a leader and mentor to the entire group, including the junior graduate student on the project. This provides him with leadership skills that can only benefit him in his later scientific career. This student is now a post-doc at the Illinois Insitiute of Technology. All students involved in this porject Both students have become proficient in using the SQUID magnetometer that will be crucial towards advancements in their scientific careers.

*** How have the results been disseminated to communities of interest?**

All the PIs have been involved with several tours of 'nanotechnology research' to different constituents. These outreach groups include the local middle and high schools; several Maine legislators; participants in the UMaine Engineering EXPO; the UMaine Sensors REU program; and the UMaine Physics department "Summer Camp" (for young children). The tours highlight various nanotechnology research at UMaine and showcase the SQUID magnetometer.

Products

Books

Book Chapters

Conference Papers and Presentations

Inventions
Nothing to report.

Journals
J. T. Wright, D. Su, T. van Buuren, R. W. Meulenberg (). Observation of a Size Dependent Surface Crystal Field Interaction in Cobalt Doped CdSe Quantum Dots Using Soft X-ray Spectroscopy. *J. Phys. Chem. C*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

J. T. Wright, R. W. Meulenberg (2013). Effects of dopants on the band structure of quantum dots: A theoretical and experimental study. *Phys. Rev. B*. 88 045432. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Licenses
Nothing to report.

Other Products
Nothing to report.

Other Publications

Patents
Nothing to report.

Technologies or Techniques
Nothing to report.

Thesis/Dissertations
J.T. Wright. *THE EFFECTS OF DOPANTS ON THE MODIFICATION OF THE CONDUCTION BAND STATES OF CADMIUM SELENIDE QUANTUM DOTS*. (2013). University of Maine. Acknowledgement of Federal Support = Yes

Websites
Nothing to report.

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Meulenberg, Robert	PD/PI	1
Frankel, David	Co PD/PI	1
Hess, Samuel	Co PD/PI	1
Lad, Robert	Co PD/PI	1
Mason, Michael	Co PD/PI	1
Gilpin, Claire	Graduate Student (research assistant)	1
Shakeri, Behtash	Graduate Student (research assistant)	4
Wright, Joshua	Graduate Student (research assistant)	12
Lawson, Stuart	Undergraduate Student	2

Full details of individuals who have worked on the project:

Robert W Meulenberg
Email: robert.meulenberg@maine.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: PI

Funding Support: n/a

International Collaboration: No
International Travel: No

David J Frankel
Email: frankel@maine.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: co-PI

Funding Support: n/a

International Collaboration: No
International Travel: No

Samuel T Hess
Email: sam.hess@umit.maine.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: co-PI

Funding Support: n/a

International Collaboration: No
International Travel: No

Robert J Lad
Email: rjlad@maine.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: co-PI

Funding Support: n/a

International Collaboration: No
International Travel: No

Michael D Mason
Email: mmason@umche.maine.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: co-PI

Funding Support: n/a

International Collaboration: No
International Travel: No

Claire Gilpin
Email: gilpinc@uci.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Photomagnetic properties of conjugated organics

Funding Support: Departmental TA

International Collaboration: No
International Travel: No

Behtash Shakeri
Email: Behtash_Shakeri@umit.maine.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 4

Contribution to the Project: Correlation of ligand chemistry to induced magnetism in quantum dots

Funding Support: NSF

International Collaboration: No
International Travel: No

Joshua Wright
Email: darastrix354@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12

Contribution to the Project: Magnetic properties of doped quantum dots

Funding Support: NSF

International Collaboration: No
International Travel: Yes, Brazil - 0 years, 1 months, 0 days

---

Stuart Lawson
Email: Stuart_Lawson@umit.maine.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 2

Contribution to the Project: Magnetic properties of nanocrystal arrays

Funding Support: NSF

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Florida State University	Academic Institution	Tallahasse FL
University of North Texas	Academic Institution	Denton, TX

Full details of organizations that have been involved as partners:

Florida State University

Organization Type: Academic Institution
Organization Location: Tallahasse FL

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Prof. G.F. Strouse - magnetic quantum dots

University of North Texas

Organization Type: Academic Institution
Organization Location: Denton, TX

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Prof. M. Omary - Photomagneitsm in conjugated organics

What other collaborators or contacts have been involved?

YES

Impacts

What is the impact on the development of the principal discipline(s) of the project?

The results from this project have had some definite high impact towards the general field of nanoscience.

(i) Using a combination of magnetic susceptibility and x-ray absorption, we have unequivocally indentified the oxidation state of Cu dopant in CdSe as +1. This has been a contentious issue in the literautre, with arguments for the +2 oxidation state and "persistent holes" prevalent.

(ii) Our results on cobalt doped CdSe suggest that, at least in the Co:CdSe system, it is difficult to evenly dope every QD, as well as internally dope the QDs. We have also found evidence that small QDs doped with cobalt show magnetic hysteresis.

We expect our recent results detailed previously will be published in high impact journals in the forthcoming year.

What is the impact on other disciplines?

The most significant extension of our routine magnetometry analysis to other disciplines is the utilization of magnetometry to probe the
intrinsic magnetization of igneous and metamorphic rocks. This project brings together researchers from physics and geology.

What is the impact on the development of human resources?

This project has provided advanced training for four graduate students and one undergraduate student in magnetometry. The SQUID magnetometer has been used heavily in our REU program (REU: Sensors; PI: Vetelino)

What is the impact on physical resources that form infrastructure?

The purchase of the SQUID magnetometer has been a huge boost to the equipment infrastructure in both the Laboratory for Surface Science and Technolgy and the Department of Physics and Astronomy at the Unversity of Maine. This should aid us in recruiting faculty and students in the forthcoming years.

What is the impact on institutional resources that form infrastructure?
Nothing to report.

What is the impact on information resources that form infrastructure?
Nothing to report.

What is the impact on technology transfer?
Nothing to report.

What is the impact on society beyond science and technology?
Nothing to report.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.

Special Requirements

Responses to any special reporting requirements specified in the award terms and conditions, as well as any award specific reporting requirements.
Nothing to report.