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Micromagnetic Code Development of Advanced Magnetic Structures Final Report CRADA No. TC-1561-98

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Micromagnetic Code Development of Advanced Magnetic Structures

Final Report
CRADA No. TC-1561-98
Date Technical Work Ended: December 4, 1999

Date: March 23, 2001 Revision: 3

A. Parties

This project was a relationship between Lawrence Livermore National Laboratory (LLNL) and Read-Rite Corporation.

The Regents of The University of California
Lawrence Livermore National Laboratory
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Read-Rite Corporation
44100 Osgood Road
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B. Project Scope

The specific goals of this project were to:

- Further develop the previously written micromagnetic code DADIMAG (DOE code release number 980017)
- Validate the code

The resulting code was expected to be more realistic and useful for simulations of magnetic structures of specific interest to Read-Rite programs. We also planned to further the code for use in internal LLNL programs.

This project complemented LLNL CRADA TC-840-94 between LLNL and Read-Rite, which allowed for simulations of the advanced magnetic head development completed under the CRADA. TC-1561-98 was effective concurrently with LLNL non-exclusive copyright license (TL-1552-98) to Read-Rite for DADIMAG Version 2 executable code.

At the time of the CRADA, the prior collaboration with Read-Rite had produced several viable designs for practical CPP-GMR sensor heads including:

- An optimized material choice for the GMR multi-layer stack
- The identification of the major contributions to the noise expected in the integrated package (and the associated signal response required for successful practical operation of the sensor head)
- Significant reduction in re-deposited material during processing
- Some large signal responses from test structures

Deliverables

Read-Rite

- Written assessment of the relevant current geometry, media field and magnetic material property effects to be included in the extended software
- Written report on experimental validation of the DADIMAG software code

LLNL

- Updated DADIMAG software code
- Magnetic characterization experimental results relevant to code validation

C. Technical Accomplishments

The research effort consisted of further extensions and continued experimental validation of the previously developed micromagnetic code DADIMAG Version 2 (DOE code release number 980017).

These extensions included enhancements and modifications to the existing code, DADIMAG Version 2, suggested by Read-Rite personnel to produce more realistic and useful simulations for magnetic structures of specific interest to Read-Rite programs. Additional code was specifically developed for LLNL programmatic purposes.

There were three project tasks:

1. Extensions to the DADIMAG Software Code
2. Experimental Validation of the DADIMAG Software Code
3. Sensor Development

Task 1: Extensions to the DADIMAG Software Code

Specific items that were incorporated and validated were:

- A numerical treatment of smooth structure boundaries and a suitable mesh refinement scheme. The first of these planned extensions attempted to correct known geometric deficiencies in the existing code due to stair-stepping irregularities induced by the currently used rectangular mesh done by LLNL personnel.

- An LLNL improved mesh refinement scheme addressed the difficulties inherent in the widely different length scales interior to the micromagnetic regions and in the exterior magnetic structures. This adaptive scheme increased the accuracy of the simulations and decreased the computational times required for realistic simulations

Task 2: Experimental validation of the DADIMAG software code

An important component of this research program was the experimental validation of any additional features added to the numerical simulation. Both Read-Rite and LLNL personnel required access to structural characterization tools such as a Scanning Electron Microscope (SEM) and Atomic Force Microscopy (AFM) in addition to magnetic field response instruments such as a quasi-static probe station and Magnetic Force Microscopy (MFM) for their separate development programs.

Task 3: Sensor Development

Read-Rite personnel developed the design, fabrication, and characterization of any sensor test structures. LLNL personnel performed additional magnetic characterization experiments for code validation when necessary.

D. Expected Economic Impact

The expected economic benefit would result from higher-density information storage, retrieval, transmission and manipulation, thereby increasing performance of magnetically stored information equipment, and reducing the price of such equipment.

D.1 Specific Benefits:

Benefits to Industry
This project helped to design advanced magnetic heads developed through the use of the DADIMAG software.

Benefits to DOE
The direct benefit accrued from high density information storage, retrieval, transmission and manipulation are critical technologies in nuclear weapons predictive capabilities, scientific and engineering computing, simulations of laser driven implosions, weapons simulations, etc. The impact to DOD programs was in:

- Software engineering
- High performance computing
- Machine intelligence robotics
- Simulation and modeling

E. Partner Contribution

A new concept for magnetic sensors based upon nanofabrication and giant magnetoresistanc was at the core of the program. This sensor concept was first developed at LLNL. However, the successful introduction of these sensors into a useful, commercial product required the integration of these sensors with advanced magnetic write heads, air bearings, gimbals, etc. These were technologies in which Read-Rite, as one of the world's largest merchant manufacturers of magnetic heads, was the world's expert. Modification and extensions of the simulation code further enhanced this sensor concept.

LLNL personnel made the relevant program changes with Read-Rite personnel retaining end user access to updated versions of the simulation package.

Read-Rite personnel were primarily responsible for identifying the field and magnetic material properties germane to their research and development program.

F. Documents/Reference List

DADMIAG Version 3 is copyrightable, and thus licensable. Read Rite has expressed interest in a nonexclusive license to the source code of DADIMAG Version 3, and is presently in negotiations with THE REGENTS for such rights.

Reports

"Finite difference micromagnetic simulation with self-consistent currents and smooth boundaries", M. R. Gibbons, G. Parker, C. Cerjan and D. W. Hewett, Physica B 275, 11-16(2000).

"Embedded curve boundary method for micromagnetic simulations", G. J. Parker, C. Cerjan, and D. W. Hewett, J. Magn. Mag. Mat., 214, 130-138(2000).

"Micromagnetic simulations of submicron Cobalt dots", G. J. Parker and C. Cerjan, J. Appl. Phys., 87, 5514(2000).

"Nucleation and annihilation of magnetic vortices in submicron-scale Co dots", A. Fernandez and C. Cerjan, J. Appl. Phys., 87, 1395(2000).

Patent/Copyright Activity

Software program DADIMAG Version 3 will be submitted for copyright and will be processed through the LLNL code release process.

Subject Inventions

There were no patentable subject inventions.

Background Intellectual Property

Read-Rite Corp. has a license to the executable code of the DADIMAG version 2 of this computer program, LLNL license TL-1552-98.

Read-Rite Corporation has requested a license to the source code of DADIMAG, version 2, which is presently being negotiated. License TL-1552-98 will be amended to reflect those changes.

Read-Rite Corporation is also considering licensing DADIMAGV 3 source and object code.

G. Acknowledgement

Participant's signature of the final report indicates the following:

1) The Participant has reviewed the final report and concurs with the statements made therein.
2) The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.
3) The Participant certifies that all reports either completed or in process are listed and all subject inventions and the associated intellectual property protection measures generated by his/her respective company and attributable to the project have been disclosed and included in Section E or are included on a list attached to this report.
4) The Participant certifies that if tangible personal property was exchanged during the agreement, all has either been returned to the initial custodian or transferred permanently.
5) The Participant certifies that proprietary information has been returned or destroyed by LLNL.

Xizeng Shi 10-5-01

Xizeng (Stone) Shi — Date
Read-Rite Corporation

Charles Cerjan Oct 12, 2001

Charles J. Cerjan, Principal Investigator — Date
Lawrence Livermore National Laboratory

Karena McKinley 10/16/01

Karena McKinley, IPAC Director — Date
Lawrence Livermore National Laboratory

Attachment I – Final Abstract

Micromagnetic Code Development of Advanced Magnetic Structures

Final Abstract (Attachment I)
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- High performance computing
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E. Project Dates

December 4, 1998 – December 4, 1999