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Final Report Certification
for
CRADA Number 99-0550

Between

UT-Battelle, LLC

and

Seagate
(Participant)

Instructions:

Mark the appropriate statement in 1a or 1b below with an 'IX." Refer to the articles in the CRADA terms and conditions governing the identification and marking of Protected CRADA Information (PCI).

If no PCI is identified, the report will be distributed without restriction. If PCI is identified, the report distribution will be limited in accordance with the CRADA terms and conditions governing release of data. In all cases items 2 and 3 must be true. That is, the report cannot contain Proprietary Information and a disclosure must be filed prior to release of the report.

This certification may either be made by using this form or may be made on company letterhead if the Participant desires. A faxed copy of this completed form is acceptable.

The following certification is made for the subject final report:

1. (a) ☐ The final report contains information that qualifies as "Protected CRADA Information" (PCI). The PCI legend is printed on the report cover, and the PCI is clearly identified.

OR

(b) ☒ The final report does not contain "Protected CRADA Information." The "Approved for Public Release" legend is printed on the report cover.

2. The final report does not contain Proprietary Information.

3. By the signature below, the Participant has no objection to the public distribution of the final report due to patentable information.

For the Participant:

W. H. Butler William H Butler
(Name)

Principal Investigator
(Title)

Feb. 18, 2008
(Date)

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1. Abstract

ORNL assisted Seagate Recording Heads Operations in the development of CIP Spin Valves for application as read sensors in hard disk drives. Personnel at ORNL were W. H. Butler and Xiaoguang Zhang. Dr. Olle Heinonen from Seagate RHO also participated. ORNL provided codes and materials parameters that were used by Seagate to model CIP GMR in their heads.

2. Statement of Objectives

1. Develop a linearized Boltzmann transport code for describing CIP GMR based on realistic models of the band structure and interfaces in materials in CIP spin valves in disk drive heads.
2. Calculate the materials parameters needed as inputs to the Boltzmann code.
3. Transfer the technology to Seagate Recording Heads.

3. Benefits to the Funding DOE Office's Mission

The CRADA enabled USDOE funded research to enhance the competitiveness of an important industry where US based companies have the lead.

4. Technical Discussion of Work Performed by All Parties:

ORNL developed a Boltzmann transport code and calculated materials parameters from first principles. Seagate Recording Heads used this code and these parameters to model their CIP spin valves.

The semiclassical Boltzmann equation, with appropriate generalizations to include multilayers, provides a convenient approach for modeling CPP and CIP transport. Its solution is very fast and lends itself more readily to interpretation of the results. First-principle calculations are used to obtain some of the basic input into the Boltzmann equation, including the electronic band structure and transmission coefficients needed for boundary conditions at interfaces. Using realistic band structures and velocities for the electron states the linearized Boltzmann code yields results which are typically within 10% of experimental values (e.g. GMR and sheet resistance) without the need to `tune' adjustable parameters. The first-principle calculations are done once and for all for the materials and interfaces of interest, such as CoFe, Cu, and CoFe-Cu interfaces, providing a valuable interpretive and quantitatively predictive tool in device development.

5. Subject Inventions (As defined in the CRADA)

None.

6. Commercialization Possibilities

We did not consider establishing an intellectual property position on the code.

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7. Plans for Future Collaboration

Butler continues to collaborate with Seagate at his new position at the University of Alabama.

8. Conclusions

Butler has been told informally that the codes were very helpful to Seagate research in developing their CIP spin valves and in helping Seagate to become the world's leading hard drive company. Subsequently the symmetry-filter TMR systems discovered by Butler, Zhang, Schulthess and MacLaren, have revolutionized the hard drive read sensor. This new technology made CIP spin-valves obsolete for this application. Symmetry filter TMR systems and materials are now used in all hard drives made today.