REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

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1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
27-09-2018	Final Report	1-Oct-2011 - 30-Sep-2017

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Final Report: Exchange-coupled Hybrid Nanocomposite Magnets	W911NF-11-1-0507
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER 611102
6. AUTHORS	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES	8. PERFORMING ORGANIZATION REPORT NUMBER
University of Texas at Arlington 701 South Nedderman Drive Box 19145 Arlington, TX 76019 -0145	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)	10. SPONSOR/MONITOR'S ACRONYM(S) ARO
U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211	11. SPONSOR/MONITOR'S REPORT NUMBER(S) 60580-MS.21

12. DISTRIBUTION AVAILIBILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Ping Liu
UU	UU	UU	UU		19b. TELEPHONE NUMBER 817-272-2815

Standard Form 298 (Rev 8/98)
Prescribed by ANSI Std. Z39.18

RPPR Final Report
as of 04-Oct-2018

Agency Code:

Proposal Number: 60580MS **Agreement Number: W911NF-11-1-0507**

INVESTIGATOR(S):

Name: Ph.D Ping Liu
Email: pliu@uta.edu
Phone Number: 8172722815
Principal: Y

Organization: **University of Texas at Arlington**
Address: 701 South Nedderman Drive, Arlington, TX 760190145
Country: USA
DUNS Number: 064234610 EIN: 756000121

Report Date: 31-Dec-2017 Date Received: 27-Sep-2018
Final Report for Period Beginning 01-Oct-2011 and Ending 30-Sep-2017
Title: Exchange-coupled Hybrid Nanocomposite Magnets
Begin Performance Period: 01-Oct-2011 **End Performance Period:** 30-Sep-2017
Report Term: 0-Other
Submitted By: Ph.D Ping Liu Email: pliu@uta.edu
Phone: (817) 272-2815
Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: **STEM Participants:**

Major Goals: The major tasks and objectives of this project include:

Modeling analysis of inter-phase interactions in exchange-coupled hybrid magnets;

Investigation of interface effect on the inter-phase interactions;

Fabrication of hard/hard, hard/semi-hard, hard/hard/soft nanocomposite hybrid magnets;

Fabrication of anisotropic bulk hybrid magnets.

Accomplishments: We have succeeded in synthesizing a variety of magnetic nanoparticles and nanostructured hybrid and composite systems. Among which we prepared cobalt nanowires with high aspect ratio via a solvothermal chemical process, with a diameter of about 15 nm and a mean length of 200 nm. Based on the shape anisotropy and orientation of the nanowire assemblies, a record high room-temperature coercivity of 12.5 kOe has been measured in Co nanowires which is corresponding to an energy density of >40 MGOe (assuming a 100% mass density).
It was observed in our experiments that not only the coercivity, the remanent magnetization of the nanowire sample also increased greatly upon alignment, leading to the remanent magnetization ratio Mr/Ms of 0.92 (in comparison with ~0.5 of un-aligned samples), which is an almost doubled value compared to the randomly aligned system (while the saturation magnetization remained unchanged). Consequently, the “squareness” of the loop is significantly increased (to 0.78 from ~0.6). This change is a typical Stoner-Wohlfarth behavior of a single-domain particle system upon magnetic alignment. Based on the model, for an ideal single-domain particle system with identical magnetic properties of each particle, the magnetically aligned assemblies will gain coercivity and remanence values twice that of the corresponding randomly oriented system. This “sharp” behaviour has been rarely observed in actual hard magnetic materials for the reason that identical single-domain particles are difficult to prepare experimentally. The present results also support the statement that the total anisotropy field of the nanowire system is the sum of the magnetocrytalline anisotropy field and the shape anisotropy field (16.6 kOe in total, at room temperature).

Training Opportunities: Nothing to Report

Results Dissemination: Nothing to Report

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as of 04-Oct-2018

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: Faculty
Participant: J. Ping Liu
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Co-Investigator
Participant: Narayan Poudyal
Person Months Worked: 12.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Graduate Student (research assistant)
Participant: Kinjal Gandha
Person Months Worked: 12.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

ARTICLES:

RPPR Final Report
as of 04-Oct-2018

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published
Journal: Journal of Alloys and Compounds
Publication Identifier Type: Publication Identifier:
Volume: 0 Issue: 0 First Page #: 0
Date Submitted: Date Published:
Publication Location:
Article Title: Self-nanoscaling in FeCo alloys prepared via severe plastic deformation
Authors:
Keywords: plastic deformation, FeCo
Abstract: Nanocrystalline Fe100?xCox (x = 20, 35, 50, 60) alloys have been prepared by mechanical alloying of Fe and Co powders via high energy ball milling. The alloy formation process and microstructure evolution of the samples have been investigated. Energy filtered transmission microscopy (EFTEM) observations revealed the strip formation of the Fe and Co phases at an initial stage of milling. The final grain size of the equiaxed grains in the obtained alloys reached 8 nm upon milling for 20 h. The saturation magnetization of the mixtures of Fe and Co increases with milling time, indicating an increasing homogeneity in composition and the phase formation. It is found that the saturation magnetization is also dependent on the Co content, which reaches the highest value of 240 emu/g at Fe65Co35. The phase transformation of the as-prepared FeCo alloys was also studied using differential scanning calorimetry.
Distribution Statement: 1-Approved for public release; distribution is unlimited.
Acknowledged Federal Support:

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published
Journal: Journal of Applied Physics
Publication Identifier Type: Publication Identifier:
Volume: 0 Issue: 0 First Page #: 0
Date Submitted: Date Published:
Publication Location:
Article Title: Effect of pressure loading rate on the crystallographic texture of NdFeBnanocrystalline magnets
Authors:
Keywords: compaction, density
Abstract: Plastic deformation of NdFeB nanocrystalline magnets has been performed at relatively low temperatures but high pressures compared to conventional hot deformation. The effect of deformation conditions on the crystallography texture of the anisotropic NdFeB magnets has been studied. It was observed that both deformation temperature and pressure loading rate significantly affect final crystallographic texture and thus magnetic properties. Energy product increases from 31 to 44 MGOe by simply reducing pressure loading rate from 300 MPa/min to 50 MPa/min. Microstructure observations confirm that better crystallographic texture has been obtained in the deformed magnets with a lower pressure loading rate.
Distribution Statement: 1-Approved for public release; distribution is unlimited.
Acknowledged Federal Support:

RPPR Final Report
as of 04-Oct-2018

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published
Journal: Journal of Applied Physics
Publication Identifier Type: Publication Identifier:
Volume: 0 Issue: 0 First Page #: 0
Date Submitted: Date Published:
Publication Location:
Article Title: Effect of magnetic fields on melt-spun Nd2Fe14B-based ribbons
Authors:
Keywords: melt spinning, magnetic field
Abstract: The effect of a magnetic field on microstructure and magnetic properties of Nd2Fe14B-based melt-spun ribbons is investigated. The magnetic field was applied in perpendicular or parallel direction to the ribbon plane during quench with a field strength up to several kilo Oersteds. The XRD patterns and TEM graphs show a strong grain size reduction upon the magnetic field application. The magnetic field also enhances the (00l) texture of ribbons when the field is perpendicular to the ribbon plane. The refined microstructure with significantly reduced grain size leads to enhanced magnetic exchange interactions between the hard and soft phases in the Nd2Fe14B/Fe nanocomposite ribbons. This magnetic field-assisted melt-spinning technique is promising for producing nanocomposite magnets with enhanced energy density.
Distribution Statement: 1-Approved for public release; distribution is unlimited.
Acknowledged Federal Support:

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published
Journal: Journal of Magnetism and Magnetic Materials
Publication Identifier Type: Publication Identifier:
Volume: 0 Issue: 0 First Page #: 0
Date Submitted: Date Published:
Publication Location:
Article Title: Exchange-couplednanoscaleSmCo/NdFeBhybridmagnets
Authors:
Keywords: hybrid magnets, Curie temperature, exchange coupling
Abstract: NanoscalehybridmagnetscontainingSmCo5 and Nd2Fe14B hardmagneticphaseshavebeenproduced via anovel‘‘in-one-pot’’processingroute.Thegrainsizeoftheprocessedbulkcompositematerialsis controlledbelow20nm.Therefinementofthenanoscalemorphologyleadstoeffectiveinter-phase exchangecouplingthatresultsinsingle-phaselikemagneticproperties.Energyproductof14MGOe was obtainedintheisotropicnanocompositemagnetsatroomtemperature.Atelevatedtemperatures, the hybridmagnetshavegreatlyimprovedthermalstabilitycomparedtotheNd2Fe14B single-phase counterpartandhavesubstantiallyincreasedmagnetizationandenergyproductscomparedtothe single-phaseSmCo5 counterpart.
Distribution Statement: 1-Approved for public release; distribution is unlimited.
Acknowledged Federal Support:

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published
Journal: Smart Nano Systems in Engineering and Medicine
Publication Identifier Type: Publication Identifier:
Volume: 0 Issue: 0 First Page #: 0
Date Submitted: Date Published:
Publication Location:
Article Title: Advances in Nanostructured Permanent Magnets Research,
Authors:
Keywords: Nanostructured Permanent Magnets
Abstract: This is a review article on recent progress in nanostructured permanent magnets by N. Poudyal and J. P. Liu, published in J. of Physics D: Applied Physics, 46 (2013) 043001 (23pp).
Distribution Statement: 1-Approved for public release; distribution is unlimited.
Acknowledged Federal Support:

RPPR Final Report
as of 04-Oct-2018

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published
Journal: Applied Physics Letters
Publication Identifier Type: Publication Identifier:
Volume: 0 Issue: 0 First Page #: 0
Date Submitted: Date Published:
Publication Location:
Article Title: 173. High temperature magnetic properties of SmCo5/?-Fe(Co) bulk nanocomposite magnets
Authors:
Keywords: bulk nanocomposite magnets
Abstract: High temperature magnetic properties of SmCo5/?-Fe(Co) bulk nanocomposite magnets, Chuanbing Rong, Narayan Poudyal, Xubo Liu, Ying Zhang, M. J. Kramer, and J. Ping Liu, Appl. Phys. Lett., 101, 152401 (2012).
Distribution Statement: 1-Approved for public release; distribution is unlimited.
Acknowledged Federal Support:

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published
Journal:
Publication Identifier Type: Publication Identifier:
Volume: 0 Issue: 0 First Page #: 0
Date Submitted: Date Published:
Publication Location:
Article Title: 176. Effect of selective Co addition on magnetic properties of Nd2(FeCo)14B/?-Fe nanocomposite magnets
Authors:
Keywords: Nanocomposite magnets
Abstract: 176. Effect of selective Co addition on magnetic properties of Nd2(FeCo)14B/?-Fe nanocomposite magnets, C. Bing Rong, Dapeng Wang, Vuong Van Nguyen, Maria Daniil, Matthew A. Willard, Ying Zhang, M. J. Kramer, and J. Ping Liu, J. Phys. D: Appl. Phys., 46 (2013) 045001 (5pp).
Distribution Statement: 1-Approved for public release; distribution is unlimited.
Acknowledged Federal Support:

Publication Type: Journal Article Peer Reviewed: N **Publication Status:** 1-Published
Journal: Nanotechnology
Publication Identifier Type: Publication Identifier:
Volume: 0 Issue: 0 First Page #: 0
Date Submitted: Date Published:
Publication Location:
Article Title: Synthesis of monodisperse FeCo nanoparticles by reductive salt-matrix annealing
Authors:
Keywords: magnetic nanoparticles
Abstract: Synthesis of monodisperse FeCo nanoparticles by reductive salt-matrix annealing, Narayan Poudyal, Girija S Chaubey, Chuan-Bing Rong, Jun Cui and J Ping Liu, Nanotechnology, 24 (2013) 345605 (6pp).
Distribution Statement: 1-Approved for public release; distribution is unlimited.
Acknowledged Federal Support:

RPPR Final Report
as of 04-Oct-2018

Nothing to report in the uploaded pdf (see accomplishments). The last submitted report was the summary of the project (the project ended two years ago though a no-cost extension was made for closing paperwork).