Chapter 1
From Magnetodynamics to Spin Dynamics in Magnetic Heterosystems

Claus M. Schneider

Abstract The dynamic behavior of magnetic systems covers a broad range of length and time scales and is of both fundamental interest and technological relevance. The particular challenge in magnetic heterosystems is the need to disentangle the responses of the individual magnetic and chemical components. In this contribution we discuss the results of two complementary experimental approaches addressing element-selective magnetization and spin dynamics. Time-resolved X-ray photoemission electron microscopy (TR-XPEEM) is employed to image the temporal evolution of the magnetization in interlayer exchange-coupled trilayers in the picosecond regime with high lateral resolution. In order to address the femtosecond time scale with element selectivity, we developed a novel pump-probe magneto-optical Kerr effect (MOKE) technique involving higher harmonic generation (HHG) in the extreme ultraviolet regime. We are able to map the spin dynamics of the individual constituents in Permalloy ($Ni_{80}Fe_{20}$) with a time resolution of better than 100 fs. Combining PEEM with HHG excitation may pave the way to an element-selective magnetic imaging technique in the lab offering femtosecond time resolution.

1.1 Introduction

The dynamic behavior of magnetic systems involves a wide variety of physical phenomena and covers a broad range of time scales of more than 23 orders of magnitude. Moreover, this enormous dynamic range is also of high technological relevance. The long-term end of the time axis is marked by the data storage retention time defined by the magnetic storage industry. It relates to the thermal stability of a written bit of information for a period of at least 10 years. Another technologically important regime is located between 10^{-9} and 10^{-12} s and governs fast magnetic

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B. Aktaş, F. Mikailzade (eds.), *Nanostructured Materials for Magnetoelectronics*,
Springer Series in Materials Science 175, DOI: 10.1007/978-3-642-34958-4_1,

Magnetoelectronics And Magnetic Materialsnovel Phenomena And Advanced Characterization Proceedings

Shufeng Zhang

Magnetoelectronics And Magnetic Materialsnovel Phenomena And Advanced Characterization Proceedings: Magnetoelectronics and Magnetic Materials - Novel Phenomena and Advanced Characterization: Volume 746 Shufeng Zhang,2003-04 This book combines the proceedings of Symposium Q Magnetoelectronics Novel Magnetic Phenomena in Nanostructures and Symposium R Advanced Characterization of Artificially Structured Magnetic Materials both from the 2002 MRS Fall Meeting in Boston The common focus is on artificially engineered nanostructured magnetic systems The two symposia address new phenomena in magnetoelectronic applications their preparation and advanced methodology for characterization Interest in nanomagnetism has been catalyzed by advances in two fields of research 1 Advances in materials synthesis of structures whose length scales transcend magnetic length scales and open the possibility for creating materials with new magnetic properties Such structures include interfaces superlattices tunneling devices nanostructures and single molecule magnets 2 Advances in sample characterization techniques for nano magnetism which allow detailed exploration of structure property relationships in nanostructured magnetic systems The volume highlights current trends in both fields and offers an outlook for further advances and new capabilities **Handbook of Less-Common Nanostructures** Boris I. Kharisov,Oxana Vasilievna Kharissova,Ubaldo Ortiz-Mendez,2012-03-19 As nanotechnology has developed over the last two decades some nanostructures such as nanotubes nanowires and nanoparticles have become very popular However recent research has led to the discovery of other less common nanoforms which often serve as building blocks for more complex structures In an effort to organize the field the Handbook of Less Common Nanostructures presents an informal classification based mainly on the less common nanostructures A small nanotechnological encyclopedia this book Describes a range of little known nanostructures Offers a unifying vision of the synthesis of nanostructures and the generalization of rare nanoforms Includes downloadable resources with color versions of more than 100 nanostructures Explores the fabrication of rare nanostructures including modern physical chemical and biological synthesis techniques The Handbook of Less Common Nanostructures discusses a classification system not directly related to the dimensionality and chemical composition of nanostructure forming compounds or composite Instead it is based mainly on the less common nanostructures Possessing unusual shapes and high surface areas these structures are potentially very useful for catalytic medical electronic and many other applications **Spatially Resolved Characterization of Local Phenomena in Materials and Nanostructures: Volume 738** Javier Piqueras,2003-03-27 A primary driver of progress in nanoscience and technology is the continuing advances in the ability to measure structure and particularly properties at spatially localized scales From the point of view of characterization it is worth mentioning advances in the interpretation of processes in semiconductors the ability to observe and manipulate metal carbon and silicon nanowires and nanodots and studies in molecular self assembly The papers in this book fall into two categories those addressing classes of characterization techniques that emphasize how the combination of theoretical experimental and instrumentational

developments lead to new capabilities in nanoscale characterization and those focused on the use of various spatially localized approaches on a single phenomenon or materials issue Topics include characterization with electron optics novel measurements of nanoscale properties size dependent behavior of nanoparticles biological systems at the nanoscale processing and properties of nanowires and heterostructures and local phenomena in materials and microstructures

Novel Materials and Processes for Advanced CMOS: Volume 745 Mark I. Gardner,Materials Research Society,2003-03-25 Progress in MOS integrated circuit technology is largely driven by the ability to dimensionally scale the constituent components of individual devices and their associated interconnections Given a set of materials with fixed properties this scaling is finite and its predicted limits are rapidly approaching The International Technology Roadmap for Semiconductors establishes the pace at which this scaling occurs and identifies many of the technological challenges ahead This volume assembles representatives from the fields of materials science physics electrical and chemical engineering to provide an insightful review of current technology and understanding Specifically the intent is to discuss materials issues stemming from device scaling to sub 100nm technology nodes Topics include high k characterization atomic layer deposition gate metal materials and integration contacts and ultrashallow junction formation theory and modeling and crystalline oxides for gate dielectrics **Multiscale Phenomena in Materials - Experiments and Modeling Related to Mechanical Behavior: Volume 779** Materials Research Society. Meeting,2003-09-05 The MRS Symposium Proceeding series is an internationally recognised reference suitable for researchers and practitioners This 2003 volume focuses on experimentally validated multiscale modeling of ductile metals and alloys **CMOS Front-End Materials and Process Technology: Volume 765** Materials Research Society. Meeting,2003-09-12 In the future because fundamental materials and process limits are being approached continued transistor scaling will not be as straightforward Future complementary metal oxide semiconductor MOS transistors will require high permittivity high k gate dielectrics and metal gate electrodes as well as low resistance ultrashallow junctions in order to meet the stringent specifications of the International Technology Roadmap for Semiconductors Techniques to improve transconductance and drive current may also be required Process integration issues must be solved and reliability must be assured before any new material or processing technique can be used in IC manufacture A further complication is that the key challenges will differ according to application This book reports research results from industry government labs and academia covering a wide scope of front end process issues for future CMOS technologies Topics include advanced materials and structures high k dielectrics advanced gate stack materials heterogeneous integration and strained Si technologies ultrashallow junction technology strained Si and source drain technology and laser annealing and silicide processes *Organic and Polymetric Materials and Devices* Materials Research Society. Meeting,2003 The field of organic semiconductors has seen much development in the past years Displays based on light emitting diodes made of small organic molecules as well as polymers have recently been commercialized Other

applications such as electronic circuits for tagging efficient photovoltaic devices and biosensors have already been demonstrated This volume brings together a wish list of leading researchers in the fields of chemistry physics and technology of organic devices Novel device concepts such as charge generation layers metal complexes and the use of heterojunctions are presented and should lead to further improvement in the efficiency of organic light emitting diodes In the field of organic transistors major progress is reported on the charge transport properties of organic semiconductors mobilities up to 5cm2 Vs are reported for pentacene based transistors High mobility n type materials which enable the development of ambipolar organic electronic circuits are also discussed And new approaches to fully printable displays on substrates such as textiles and paper are presented These may lead the way to new applications of organic optoelectronic devices *Optoelectronics of Group-IV-based Materials* Materials Research Society. Meeting,2003 Elemental semiconductors feature fundamental advantages when compared to II VI and III V compounds This is best illustrated by the success of silicon technology and also by the superior purity of germanium and MOCVD diamond However in contrast to electronic the optical properties of these materials are inferior and therefore their applications remain electronic rather than photonic Nevertheless an effort toward optoelectronics continues In the case of silicon and silicon based media this is motivated by the almost unlimited possibilities offered by VLSI technology Among other methods quantum confinement in low dimensional structures optical doping development of inhomogeneous media and applications of microcavities are being vigorously explored as ways to improve emission When brought to maturity these approaches could lead to widespread applications ranging from telecommunications to chemical and biological sensing For silicon a full on chip integration of electronic and photonic elements could be realized This volume brings together researchers from academic industry and government laboratories around the world to review progress in the field identify the most promising targets point out possible bottlenecks and assess future perspectives A cross fertilization of ideas from the fields of materials science spectroscopy solid state physics and chemistry as well as device physics are presented *Advanced Optical Processing of Materials* Materials Research Society. Meeting,2003 Since the inauguration of the MRS symposium series on advanced optical processing of materials back in 1990 the number of optical based techniques applied to process materials and the capabilities of optical systems has continued to expand and improve beyond simple pulsed laser deposition of thin films In turn the scope of materials being investigated has also increased from oxide ceramics to include alloys polymers and bio materials Many of the most exciting areas presented in this interdisciplinary forum include current and future applications in engineering materials at the mesoscopic to nanometer scale optoelectronics biomaterials sensors and electronics Advanced optical processing of materials now includes laser interactions with materials that are specially designed to optimize the beneficial qualities of laser modification However femtosecond processing of materials emerged as the dominant theme this year and several papers on this topic are featured Another hot topic is one connected with biomedical applications the controlled delivery of drugs to increase their efficacy by

coating a fluidized bed of drug powders with biodegradable polymers was realized by conventional pulsed laser deposition PLD and matrix assisted pulsed laser evaporation MAPLE or by microencapsulation *Materials, Technology, and Reliability for Advanced Interconnects and Low-k Dielectrics* ,2003 *Materials, Technology and Reliability for Advanced Interconnects and Low-k Dielectrics, 2003* Materials Research Society. Meeting,2003 **Mechanical Properties Derived from Nanostructuring Materials** David F. Bahr,2003 **Defect Properties and Related Phenomena in Intermetallic Alloys: Volume 753** Materials Research Society. Meeting,2003-06-25 Defects such as dislocations antiphase domains and grain boundaries interstitials substitutionals and vacancies affect many physical and mechanical properties of ordered intermetallics As a result they often play a decisive role in determining the macroscopic behavior of not just structural intermetallics but also functional intermetallics such as shape memory alloys and hydrogen storage materials This book follows in the general tradition of the highly successful series of MRS symposia titled High Temperature Ordered Intermetallic Alloys However it also represents a significant departure from its predecessors it includes papers on functional intermetallics in addition to papers on structural intermetallics and focuses on defects and how they affect various properties of interest in structural and functional intermetallics Roughly 30 percent of the papers in the book are on functional intermetallics including materials for hydrogen storage magnetic and shape memory applications The remaining papers deal with structural intermetallics including the still active areas of nickel iron and titanium aluminides as well as the newer materials for ultrahigh temperature applications *Chemical-Mechanical Planarization: Volume 767* Duane S. Boning,2003-08-27 Chemical mechanical planarization CMP has emerged as a critical fabrication technology for advanced integrated circuits Even as the applications of CMP have diversified and we have begun to understand aspects of the physics and chemistry of the process a new generation of CMP innovations is unfolding New slurries and consumables are under development New applications to novel devices continue to appear This book the most recent in a successful series on CMP offers a review of the advances to date and provides a comprehensive discussion of the future challenges that must be overcome Presentations from academia government labs and industry are featured Topics include CMP modeling CMP science CMP slurries and particles for planarization of copper oxide and other materials planarization applications including shallow trench isolation STI copper damascene and novel devices and CMP integration *Flexible Electronics--materials and Device Technology* Norbert Fruehauf,2003 **Integration of Heterogeneous Thin-Films Materials and Devices: Volume 768** Materials Research Society. Meeting,2003-07-28 The MRS Symposium Proceeding series is an internationally recognised reference suitable for researchers and practitioners This book first published in 2003 addresses the science engineering innovations and applications of multimaterial integration Topics range from heteroepitaxy to wafer bonding and layer transfer *Surface Engineering 2002 - Synthesis, Characterization and Applications: Volume 750* A. Kumar,2003-06-02 This book provides a forum for international and interdisciplinary discussion of phenomena where

materials performance may be enhanced through engineered surfaces and interfaces The materials science of hard and wear resistant coatings including nanostructured coatings is a scientifically challenging problem with immediate technological applications in machine and machining tools magnetic recording and other manufacturing industries Hard coating systems designed for use in next generation materials applications must achieve a combination of physical properties The performance and reliability of MEMS devices strongly depend on the near surface properties and many materials issues at the micro and nanoscale remain to be resolved This book reviews key aspects discusses ongoing research and speculates on future trends Topics include nano and micrometer scale characterization and properties synthesis and characterization of nanostructured materials deposition characterization and properties of films and coatings industrial applications of surface engineering atomistic and continuum modeling of materials properties surface engineering issues for bio microelectronics applications and surface engineering issues in MEMS structures and devices **Unconventional Approaches to Nanostructures with Applications in Electronics, Photonics, Information Storage and Sensing: Volume 776** Materials Research Society. Meeting,2003-08-14 The MRS Symposium Proceeding series is an internationally recognised reference suitable for researchers and practitioners **Ferroelectric Thin Films XI** Materials Research Society. Meeting,2003 **Polymer/Metal Interfaces and Defect Mediated Phenomena in Ordered Polymers: Volume 734** Evangelos D. Manias,George G. Malliaras,2003-04-10 The MRS Symposium Proceeding series is an internationally recognised reference suitable for researchers and practitioners

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