DSI scientist, Professor Lukiyanchuk, was elected for OSA Fellowship

Professor Boris Lukiyanchuk, a senior scientist at DSI, was recently elected a Fellow of the prestigious Optical Society of America (OSA). He was recognized for his outstanding contributions in the theories of laser-matter interactions, including laser thermochemistry, laser cleaning, laser ablation and plasmonics.

Prof Lukiyanchuk has published pioneers papers in optics and photonics with notable achievements. He has also published five monographs and above 10 book chapters, as well as 180 original papers in high impact journals, e.g. Nature Photonics, Nature Materials, Chemical Reviews, Physical Review Letters etc. His papers were cited more than two thousand times. Of particular note is his recent paper in Nature Materials August 2010 issue, which highlighted his investigations on Fano resonance in plasmonics materials and metamaterials.

Prof Lukiyanchuk is the second scientist from Singapore to be elected as a fellow of OSA. The OSA is amongst the most prestigious scientific Societies which bring together optics and photonics scientists, engineers, educators, and business leaders from over 100 countries. It has over 30 Nobel Laureates within its ranks and besides publishing peer review journals, it also manages many world recognized scientific conferences and meetings.
Longitudinally Polarized Light and its applications in HAMR

By Wang Haifeng
Advanced Concepts Group

Longitudinally Polarized Light and its applications in HAMR

In heat assisted magnetic recording (HAMR), effective delivery of light energy onto the magnetic disk is essential for enabling this technology. Cutting edge research in light waves has allowed researchers at DSI to experimentally generate a longitudinally polarized laser beam, which was once thought to not exist. With the discovery of this type of light, and an improved media design, enhancing optical efficiency and improving areal density beyond 1Tb/in² could become a possibility in the future.

Light wave is described as a transversal wave by Maxwell equations; however, a tightly focused laser beam has a longitudinal component, which only takes about 8% of the maximum light energy density if the focusing lens has a numerical aperture of 0.85. In the early development of electromagnetism there were some suggestions that longitudinal electromagnetic waves existed in a vacuum. After Oliver Heaviside's attempts to generalize Maxwell's equations however, he eventually came to the conclusion that electromagnetic waves were not to be found as longitudinal waves in free space.

Researchers at DSI have theoretically modeled and experimentally generated a needle of longitudinally polarized laser beam. Longitudinally polarized laser beam has a lot of applications, like particle acceleration fluorescent imaging, second-harmonic generation, Raman spectroscopy and Heat Assisted Magnetic Recording (HAMR).

Fig.1 a) Schematic

Fig.1 b) Experimental setup for generating a needle of longitudinally polarized beam

Fig.2 a) 3D nano-scanner

Fig.2 b) Intensity beam spot

In HAMR, effective delivery of light energy to the magnetic disk within the scale of sub 30-nm is essential for enabling this technology. Longitudinal field component has been used by researchers in Seagate to localize light spot by using phase shifted grating and lollipop shape transducer, and the recording of 36-nm bit length with 70-nm tracks width was realized, with achievable optical efficiency of about 1%. To further enhance the optical efficiency and increase the density beyond 1Tb/in², high purity longitudinally polarized beam and improved media design need to be used.

When a longitudinal polarized light is incident onto a nano-rod, strong resonance and field localization happens between the ends of the rod. When this localized nano-source interacts with the recording media, the disk may behave like a capacitor, because the electric field is perpendicular to the disk surface.

Fig.3 a) Longitudinally polarized light incident onto optical antenna, the field is enhanced and localized below this antenna, onto the magnetic disk with fine pattern

Fig.3 b) Comparative electric circuit of the diagram in Fig.3 a). The inductance of parallel inductors is smaller than that of a single inductor, and the parallel capacitors add up to form a larger effective capacitor. Now it can be seen that both the gap capacitor and the domain capacitor will affect the resonance of the optical antenna, because the current going through the optical antenna will also go through the gap capacitor and domain capacitor. Thus in the design of the longitudinal optical antenna, the gap between antenna and disk, and the interval between magnetic layer and heat sink layer should all be taken into consideration. Each bit is parallel in the circuit; therefore the current through one bit is less likely to affect its neighboring bits. Since strong field localization always happen in the capacitor (interval between metals) in this design, strong field localization and enhancement will happen between the antenna and the recording media; it will also occur between the recording media and the heat sink layer, with local intensity maximum on both sides of the recording media, i.e. the recording media is heated from both top and bottom side, which results in higher optical efficiency.
and the principle of applying it to HAMR is presented in this article. The use of longitudinally polarized light can heat the media from both top and bottom side, which will result in higher optical efficiency, and the resonance of one bit is independent of its neighboring bits, which will reduce the cross-talk. Furthermore, in this design the disk's multi-layer should be taken as part of the resonant antenna. Higher total optical efficiency of 10% or beyond is expected if the general resonant structure is optimized.

REFERENCES

FePt-X thin films with small grain size and high anisotropy energy for energy assisted magnetic recording

The achievable recording density for conventional granular media is limited by the available head field which is about 0.75Bs (Bs is the saturation magnetization of head materials). Including overwrite criterion, the maximum switching field of a medium which is writable using conventional heads is about 0.65Bs. Given that the highest Bs in the world is 2.4 Tesla, the allowed highest switching field based on S-W model is about 15000 Oe, which is very close to the Hc of current perpendicular media – CoCrPt-TiO2 or CoCrPt-TiO2.

The ultimate recording density that conventional granular media can support is also limited by the achievable grain size at which magnetic grains are thermally stable. The scaling law of recording density versus grain size requires smaller and smaller grains. At the same time, in order to keep magnetic grains thermally stable, high anisotropy energy materials are needed. Iron platinum or FePt-X thin films is a promising material for overcoming the thermal stability issue. Ultrasmall, well isolated and thermally stable magnetic grains are very important attributes for heat assisted magnetic recording (HAMR). This article discusses some of the research done at DSI on FePt-X thin films.

Editorial

Recording on conventional granular media is limited by the achievable grain size at which magnetic grains are thermally stable. In order for recording density to increase, grain sizes must decrease. At the same time, in order to keep magnetic grains thermally stable, high anisotropy energy materials are needed. Iron platinum or FePt-X thin films is a promising material for overcoming the thermal stability issue. Ultra-small, well isolated and thermally stable magnetic grains are very important attributes for heat assisted magnetic recording (HAMR). This article discusses some of the research done at DSI on FePt-X thin films.

FePt-X thin films with small grain size and high anisotropy energy for energy assisted magnetic recording

By Zhou Tiejun
Spritonics, Media & Interface Division

The achievable recording density for conventional granular media is limited by the available head field which is about 0.75Bs (Bs is the saturation magnetization of head materials). Including overwrite criterion, the maximum switching field of a medium which is writable using conventional heads is about 0.65Bs. Given that the highest Bs in the world is 2.4 Tesla, the allowed highest switching field based on S-W model is about 15000 Oe, which is very close to the Hc of current perpendicular media – CoCrPt-TiO2 or CoCrPt-TiO2.

The ultimate recording density that conventional granular media can support is also limited by the achievable grain size at which magnetic grains are thermally stable. The scaling law of recording density versus grain size requires smaller and smaller grains. At the same time, in order to keep the magnetic grains thermally stable, high anisotropy energy materials are needed. (001) textured L12 FePt medium with anisotropy energy of about 6-10 MJ/m3 and high chemical stability is the most promising candidate to overcome the thermal stability issue. The FePt medium has grains of 8-10 nm with acceptable magnetic properties, which is comparable to the current commercial perpendicular media using CoCrPt alloy with the grains of 8-10 nm. The advantages of FePt over conventional CoCrPt alloy media can only be realized if Fept media with 5-6 nm FePt columnar grains, which are (001) oriented, magnetically isolated, and has high enough anisotropy energy, can be fabricated by conventional sputter. On the other hand, due to its high anisotropy energy (and therefore high switching field), FePt medium is not writable using conventional heads. The fabrication of FePt media with the desired microstructure and magnetics at relatively low temperature and making FePt media writable using conventional heads still remain as big challenges.

Over the past years, DSI’s researchers have been working on FePt thin film media for energy assisted magnetic recording with a focus on the control of microstructure, tuning of magnetic and improvement of write-ability. Various approaches have been utilized to control the microstructure and to tune the magnetic of FePt media:

- By optimization of interlayer materials and processes, including development of double-layered granular interlayer, exploration of new interlayer materials, and optimization of new interlayer processes etc.
- By introducing different nucleation layer materials to control the nucleation processes for the reduction of grain size and magnetic isolation of grains.
- By doping different materials which is immiscible with FePt, like C, Ag, TiO2, SiO2, Ta, etc and by optimization of the sputter processes to further reduce grain size and better isolate grains.

It has been found that with TiO2 as a doping material into FePt layer under optimized sputtering conditions for seedlayer, interlayer and magnetic layer, a good (001) texture was maintained with TiO2 volume fraction up to 30%. The grain size can be effectively reduced down to about 5.3±1.1 nm which is also magnetically well isolated. Fig. 1 shows the typical TEM image and grain size distribution. Such media have desired magnetic properties with coercivity of 14000 Oe (Fig. 2). The anisotropy energy of such media was measured by using the Miyajima method with applied angle at
45 degree with respect to the film plane. The Ku value reached about 3.5 MJ/m\(^3\), which makes the 5.3 nm grains thermally stable.

For improving the write-ability of FePt media, DSI researchers have been working on exchange-coupled composite (ECC) media consisting of a magnetically hard layer coupled with a magnetically softer layer. The merit for ECC media is that the write-ability and thermal stability can be independently engineered. Therefore with ECC media, the switching field can be significantly reduced while maintaining similar thermal stability. Theoretically, the thermal stability to switching energy ratio \( \xi = 2E/H_{\text{sw}}M_s \) (called figure of merit) could be reaching 2 for ECC media. That is the Hk can be reduced to half of Hk with the same thermal stability. The DSI research team carried out experiments by optimizing the layer structure and the composition in order to make the gain as high as possible. Fig. 3 shows how the figure of merit changes with soft layer thickness (3a) and with MgO thickness inserted between the hard and soft layers. Under optimized soft layer thickness and inter-layer exchange coupling, a figure of merit of 1.7 was achieved, which is lower than the theoretical value of 2.

In order to understand why the experimental value is smaller than the theoretical one, detailed microstructure characterization of ECC FePt media was carried out. Fig. 4 shows the cross-sectional TEM image for the ECC FePt media. Two layer structure can be clearly seen: the bottom layer with larger and isolated grains is magnetically hard and the top layer with small and also isolated grains is magnetically soft. The few soft grains sitting on top of a single hard grain, is somewhat different from the original proposed ECC media, which theorized one magnetically soft grain sitting on top of one magnetically hard grain. Hence, this could be one of the possible reasons for the observed lower value of figure of merit under optimized soft layer thickness and interlayer coupling.

In order to further reduce the switching field, graded FePt media consisting of a multilayer FePt film with gradually reduced anisotropy energy was proposed. The reversal in graded media involves nucleation and propagation of a domain wall from top soft layers into the hard layer. The coercive field is proportional to the gradient in the wall energy density. The energy barrier is equal to the energy of a domain wall in the hard storage layer. With graded FePt media, DSI has demonstrated a figure of merit of 2.0, which is higher than the ECC media.

The key point for the development of FePt media is for energy assisted magnetic recording, specifically for heat assisted magnetic recording (HAMR). For HAMR, thermal profile dominates the recording performance. Therefore proper thermal design with a heat sink layer is necessary for the improvement of performance. DSI researchers experimented on different materials that could be used as the heat sink layer. One of the most optimal materials is Ag with its high thermal conductivity. The effects of the Ag sink layer on the microstructure and magnetics of FePt media was studied. It was found that the (001) orientation, ordering degree (Fig. 5a) and magnetics (Fig. 5b) can be greatly improve by using Ag.

With the Ag heat sink layer, well isolated grains with a size of about 6 nm has also been obtained, which is in favor of high density magnetic recording.

In summary, DSI researchers have successfully fabricated FePt media with good (001) orientation, well isolated grains of size of 5.5 nm and good magnetic properties. Our study also showed that Ag is a promising candidate to be used as a heat sink layer for heat assisted magnetic recording.
DSI hosted Swiss film crew

In December 2010, NZZ Television from Switzerland came to DSI to film the institute's facilities for a 30 minute documentary programme entitled, 'Is Singapore the better Switzerland?'. This programme gives a broad overview of the economic strategies shaping Singapore's economy and society as well as mapping Singapore's progress vis-à-vis Switzerland's, and will be aired in Europe in early 2011.

DSI was given the opportunity to appear in a segment of the programme as an illustration of one of A*STAR's success stories. When Singapore moved from producing disk drives to high-end enterprise drives, it was DSI's expertise that helped the local industry to upgrade itself to manufacture the high-end enterprise drives.

DSI teams up with KAI Square to commercialize ‘black box’

Local small-medium enterprise (SME) KAI Square Pte Ltd recently signed a licensing agreement with DSI to commercialize a “black box” platform, also known as the In-Vehicle Event Management System (IVEMS), for vehicles. The IVEMS boasts features such as up to 16 video camera input channels, 3G, WiFi, GPS ready, 1 Terabit hard disk drive, proprietary software algorithms and wireless remote monitoring via 3G technology amongst others. Combined with KAI Square’s own central management portal, Juzz4logistics, a total turnkey solution for real-time surveillance needs in the logistics and transportation industries, IVEMS would enable KAI Square to deliver to transportation fleet operators, the highest standards of communication between the fleet operators’ control centres and their vehicles. This combined platform will likely hit the commercial market in late 2011.

Visiting Scientists

PROFESSOR SERGEY KULIK

17-21 DEC 2010

Professor at the Department of Quantum Electronics, Faculty of Physics of Moscow M.V. Lomonosov State University, Moscow, Russia

PROFESSOR MING FENG

15-16 NOV 2010

Professor, School of Mechanical Engineering, University of Science and Technology Beijing

PROFESSOR LIU WENTAI

03-04 NOV 2010

Professor, Electrical Engineering Department, Campus Director and Thrust Leader of the NSF Engineering Research Center on Biomimetic Microelectronic Systems, University of California, Santa Cruz, California, USA

DR TIMUR ISKHAKOV

06-17 DEC 2010

Research Fellow at Max Planck Institute for the Science of Light, Erlangen, Germany

DR JEN-YUAN (JAMES) CHANG

15-16 NOV 2010

Associate Professor, School of Engineering and Advanced Technology, Massey University, New Zealand
Our Invited Papers

The 55th Annual Conference on Magnetism & Magnetic Materials

The 55th Annual Conference on Magnetism & Magnetic Materials was held in Atlanta, Georgia, USA from 14 - 18 November 2010.

Research scientist Dr Rachid Sbiaa was invited to present his paper “Reduction of Switching Current by Spin Transfer Effect in Perpendicular Magnetic Anisotropy Magnetoresistive Devices”. His paper details an investigation on the effect of in-plane polarizer properties in reducing spin-transfer current.

This Conference provides a good platform for worldwide participants to discuss new as well as controversial developments in all areas of magnetism research.

Recent Conferences/Seminars/Workshop Participated By Our Staff

27-29 OCT 2010, Singapore
The 9th International Power and Energy Conference

10-11 NOV 2010, Singapore
Asia-Pacific Magnetic Recording Conference 2010 (APMRC 2010)

13-19 NOV 2010, Louisiana, USA
The International Conference for High Performance Computing, Networking, Storage and Analysis (SC'10)

14-18 NOV 2010, Vancouver, Canada
ASME International Mechanical Engineering Congress Exposition IMECE 2010

14-18 NOV 2010, Georgia, USA
55th Annual Conference on Magnetism & Magnetic Materials

17-20 NOV 2010, Singapore
12th IEEE International Conference on Communication Systems

05-08 DEC 2010, USA
2010 IEEE International Electron Devices Meeting

06-10 DEC 2010, Miami, USA
IEEE Global Communications Conference 2010 (GLOBECOM 2010)

07-10 DEC 2010, Singapore
11th International Conference on Control, Automation, Robotics and Vision

14-16 DEC 2010, Singapore
Photonics Global Conference 2010

14-17 DEC 2010, Singapore
Asia-Pacific Signal and Information Processing Association (APSIPA) Annual Summit and Conference (ASC) 2010

The IEEE Global Communications Conference 2010

The IEEE Global Communications Conference 2010 (GLOBECOM 2010) was held in Miami, Florida, USA from 6 – 10 December 2010.

Research scientist Dr Cai Kui was invited to give a talk on her paper titled, “Modeling, Detection and LDPC Codes for Bit-Patterned Media Recording”. Her paper presented a thorough and comprehensive study for bit-patterned media recording (BPMR), from a signal processing and coding perspective. The work includes a recording-physics-based generic channel model, 2D equalization, advanced detection, as well as low-density parity-check (LDPC) codes for BPMR. In addition, Dr Cai also served as the chairman of the technical session of Signal Processing on Data Storage.

IEEE GLOBECOM 2010 covers the entire range of communications technologies, offering in-depth information on the latest developments in voice, data, image, and multimedia.

Recent Conferences/Seminars/Workshop

03-07 OCT 2010, Gyeongju, Korea
The 5th International Symposium on Practical Surface Analysis

04-07 OCT 2010, Hanover, Germany
Bio-IT World Conference

18-20 OCT 2010, Singapore
Decade of the Mind VI 2010

24-28 OCT 2010, Hualian, Taiwan
International Symposium on Optical Memory 2010