Outline for Heat Assisted Magnetic Recording

– Introduction
– HAMR systems
– Integrated head
  • Challenge #1: Delivering the Light
  • Challenge #2: Delivering the Field
– HAMR media and HDI
– HAMR recording results
– Future prospects
– Conclusion
Introduction
Insatiable demand for Digital Storage

Storage has become personal...

- Digital Imaging
- Game Consoles
- Personal Computer
- Handheld / Portable
- Home Media Server
- Digital Video Recorder
- HDTV w/ built-in DVR
- Automobile
Areal Density Growth

- Areal density growth calls for media with higher anisotropy and smaller grains

- Writability limitation due to limited $B_S$ from write pole materials

Dieter Weller

YCo$_5$
Heat Assisted Magnetic Recording

Lower $K_u$ by temporarily raising Temperature

![Diagram showing the process of Heat Assisted Magnetic Recording]
HDD Recording Subsystem Components

Seagate Barracuda ATA II

Major Elements of HAMR HDD

- Recording Head
  - Optical Delivery
  - Magnetic Field Source
  - Magneto-Resistive Reader
- Media
  - Lubricant
  - Overcoat
  - Recording Layer
  - Heatsink/Soft Underlayer
  - Disk Substrate
- Mechanical Integration
- Servo
- Preamp
- Data Channel
Integrated HAMR head:

Challenge #1: Delivering the Light

Challenge #2: Delivering the field
Recording Head - Optical Light Delivery
Planar Solid Immersion Mirror

W. Challener et al., Optics Express 2005;13(18):7189-7197

Front View

100 µm

Coupling Grating

Side View

Cladding

Core

Media

W. Challener et al., Optics Express 2005;13(18):7189-7197
Optical Components

Coupling
Grating

Optical Waveguide
Alumina Spacer
Tantala Core
Bottom Cladding Alumina

Sidewall Mirror

Optical Waveguide

Sidewall Reflectivity

Bill Challener

W3 Q44 TE 10 deg

Fresnel

Reflectivity

Angle of Incidence (°)
Completed Optical Heads

- Grating
- Control SIM
- Near Field Transducer
- Channel Waveguide

Completed Optical Heads
200 μm
PSIM Near-field Intensity

- SNOM scans over focal plane at ABS.
- PSIM with tantala core layer sandwiched between two alumina cladding layers.
- At blue light (413 nm), FWHM focused spot size = 90 nm.
Integrated HAMR head:

Challenge #1: Delivering the Light

Challenge #2: Delivering the field
Implementation of Ring head

Gratings

Coils

WG Core       WG Cladding

Magnetic Poles

Substrate

PSIM

ABS

Cladding

Core

Cladding

Coils

WG Core

WG Cladding

Magnetic Poles

Substrate
Built Integrated HAMR Head: ABS View

PSIM

Top Pole(s)

WG Core

WG Cladding

Return Pole

Reader

Jerry Baltzer
Optical Image & SNOM of ABS

SIM Only Head

FWHM = 124 nm

With a Top Pole & Aperture

FWHM = 140 nm
Integrated HAMR Head Cross-section

ABS (after lapping)

Main Pole

Return Pole

Coils (x5)

Core

Bottom Cladding

Top Cladding

Back Via

Write Location

Light intensity and direction

Coils (x5) by Kathy Trumbull
HAMR Media

High anisotropy media

Thermal management via heat sink to obtain rapid cooling after writing doable; 100-500 ps thermal relaxation times observed (J. Hohlfeld, G. Ju-Seagate)

Specially designed heat sink and SUL

Overcoat and lubricant materials

Lubricant/Overcoat
Recording Layer
Interlayer
Heat Sink /SUL

Recording at or near Curie Temperature
HDI Issue: >770K interface temperatures
Reducing Tc by doping, e.g. with Ni also reduces Ku
(e.g. J.Thiele, JAP 91, 6995 (2002))
HAMR Media with thermal design

- High anisotropy
- Optimize thermal design
  - Vertical thermal flow
  - Lateral thermal diffusion
- Reduced $T_c \sim 650$K

Measuring Lateral Temperature Profiles

- Pump induced thermal profile measured as reflectivity changes by the XY scanning probe
- Signal is convolution of media thermal profile and probe profile
- Focus servo to ensure repeatable pump focusing and ability to spin disk
- Probe/Pump spot size ~280/380 nm
- Pump frequency up to 100 MHz (10 ns)
- Capable of supporting disks instead of samples

Incident angle

532 nm

405 nm

Medium
Interlayer
SUL/Heat sink
Substrate

Scanning pump-probe spin-stand (D. Karns)
Effects of HS thickness for model media

- **Velocity ~ 0 m/s**
  - No HS
  - With HS

- **Velocity ~ 11 m/s**
  - With HS

**Media motion**

- **Proper thermally designed heat sink prevents preheating effects, very confined T-profiles**

- **Note the different scale**

D. Karns, B. Lu, G. Ju

M. Re and G. Ju

Status and Prospect on HAMR
HAMR HDI

• Zdol2000 won’t work
HAMR recording and MFM
Spin Stand with Light Delivery

Mirror

Detector

BS

Lens

Optical Fiber

Steering Mirror

Disk

HAMR
HGA

Slider

Steering Mirror

Mirror

Detector

BS

Lens

Optical Fiber

Steering Mirror

Disk

HAMR
HGA

Slider

Steering Mirror

Mirror
Magnetic Field – Optical Spot Registration

Blue PSIM Optical Spot with FWHM = 90 nm
Rapid Cooling Limits Thermal Spread, FWHM_{thermal} ~ 130 nm
Power Chosen for Tmax = 650 K
Optical Spot and Media Short-time Coercivity
Recording Point

How to optimize recording point which is a function of
• Magnetic field (pole position, writer design, write current)
• Thermal spot (optical spot, power, media thermal properties)
• Media magnetic properties (Hc, Curie temperature)

- Pole 75 nm from center of optical spot
- Write gradient (thermal and magnetic field) is not optimum
- Recording point is under the pole => Light Blocked?
Wrote and read back data

HAMR data was written and read back using an integrated HAMR read write head.

The written track width was less than 150 nm.

The physical magnetic pole width was ~300 nm.

HAMR writing dominated by the thermal spot.
MFM of Non-HAMR & HAMR Tracks

Fully Integrated HAMR Head

HAMR Unique Media
- High Anisotropy
- Proper Heatsinking

Tim Rausch, Xiaobin Zhu
MFM images of recorded tracks

Fully Integrated HAMR Head

HAMR Unique Media
  • High Anisotropy
  • Proper Heatsinking

Both single tone and PRBS have been recorded

Thermally dominated regime

Xiaobin Zhu, Tim Rausch
Future prospects
What is next: Near Field Transducers

NFT to reduce the optical spot size.

- Aperture, bowtie, ridge WG, beaked antenna, ...

- Nano-Holes

- Rectangular Aperture

- Bowtie

- Hitachi - Beaked Antenna

- Sharp - Smash Head

- Sony - SIL + Single Pole Head
HAMR + Bit Patterned Media

Cross-sectional View

Non-Magnetic Filler

Magnetic Nano-particle(s)
Conclusion

- Fabricated a thin film integrated HAMR head containing a reader, a magnetic writer, and an efficient blue light delivery system
- Optical FWHM is $\approx \lambda/4$
- Created high anisotropy media with rapid cooling design
- Built a spin stand with light delivery system
- HAMR Recording was achieved
- For productization, Near Field Transducer needs to be integrated.
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