TECHNISCHE UNIVERSITÄT CHEMNITZ

Guest Lecture „Magnetic Functional Materials“ within the AFM module„Facets of Materials“

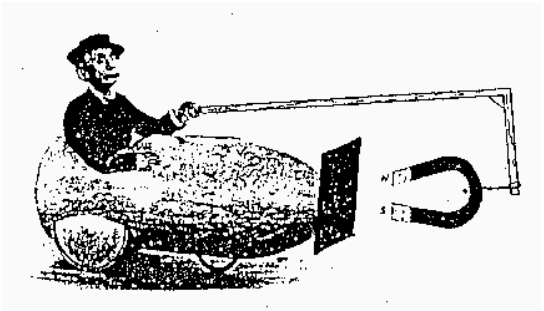
Feedback Session II (applications)

Prof. Dr. Olav Hellwig

Lehrstuhl für Magnetische Funktionsmaterialien

Sommersemester 2021

Fridays
9:15 – 10:45 Uhr



Content

Ferromagnetic (Functional) Materials

- Introduction
- Energies und energy densities of a ferromagnetic sample
  - Exchange Interaction
  - Stray field or demagnetization energy, shape anisotropy
  - Additional anisotropy energies (except for shape anisotropy = demagnetization energy)
  - Zeemann energy, external fields
- Mutual competition between the different magnetic energy terms
- Hysteresis-effects, Stoner-Wohlfarth model, basis for binary magn. data storage)
- **Magnetic functional materials for data storage**
  - **Development of the hard disk drive: from magnetic Micro-systems to Nano-systemes**
  - **GMR (Giant magnetoresisance) and TMR effects for high sensitivity magnetic read heads**
  - **Future hard disk drive technologies**
  - **New effects in the magnetic nano-world: Spin tranfer torque in Nano-contacts**
  - **Separation of charge and spin currents: Spin orbit torque in thin films systems**
  - **New applications Magnetic Random Access Memory (MRAM)**
  - **Spin waves as new information carriers (HZDR-movie)**

Inhalt

Ferromagnetische (Funktionale) Materialien

- Guest-lecture “Komplexe Materialien” part 1: FM functional materials for data storage (some basics) (1:36:31)
- **Guest-lecture “Komplexe Materialien” part 2: FM functional materials for data storage (applications) (1:32:24)**

- Total lecture time 3:08:55

Lecture Review

- Some Questions and joint discussion …

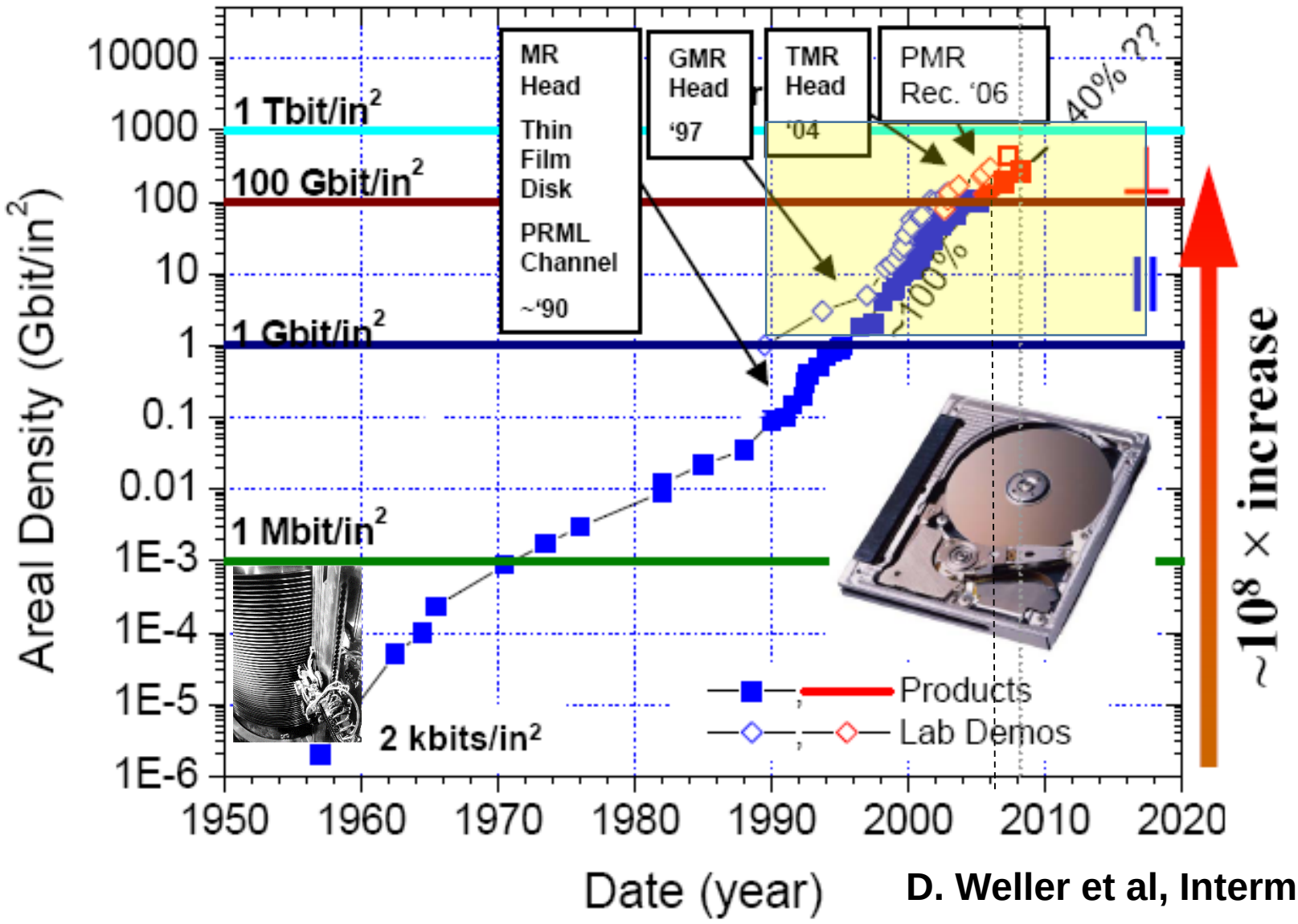
Do you remember?

Question 1

How many orders of magnitude did the areal storage density increase from the first HDD in 1956 until today?

A: 3
B: 6
C: 9
D: 12
E: 15

HDD areal density progress



D. Weller et al, Intermag 2008

Question 2

How many a typical PMA media nano- or micro-structure in today's hard disk drives look like?

A: like a homogeneous continuous thin film

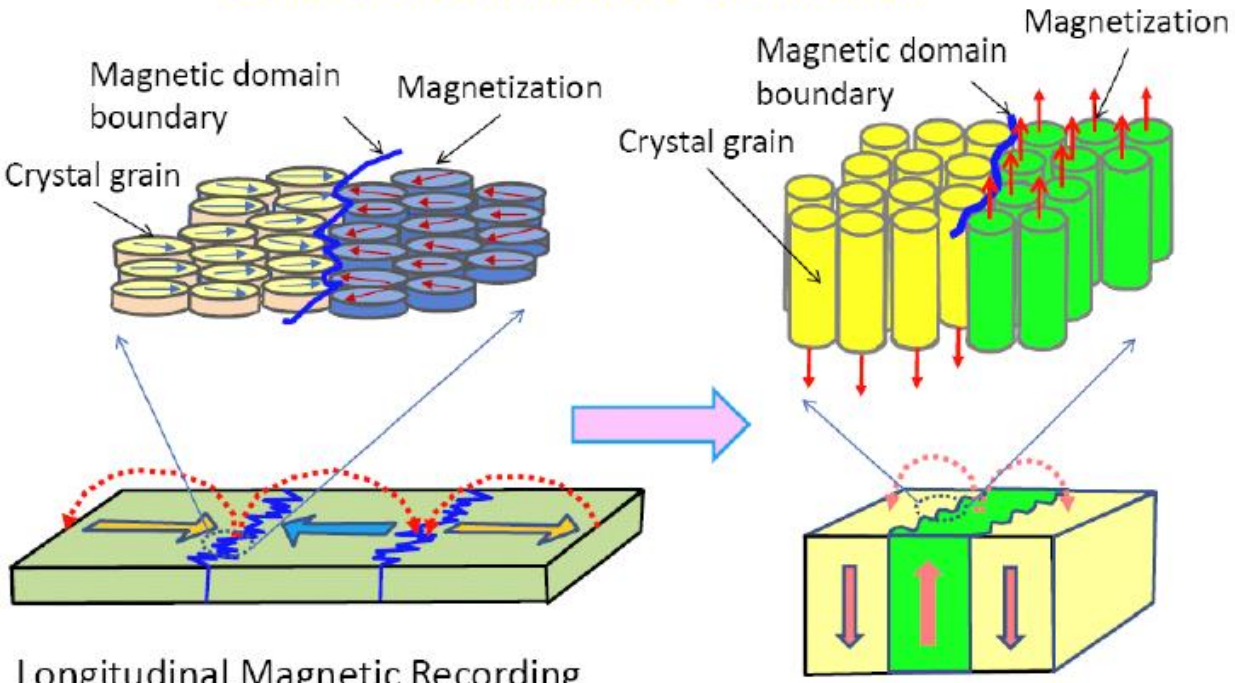
B: like a homogeneous granular thin film, where grains are directly in contact with each other

C: like a heterogeneous granular film with FM grains in a non magnetic matrix

D: like a lithographically patterned film

From Longitudinal to Perpendicular Media

Shift from LMR to PMR



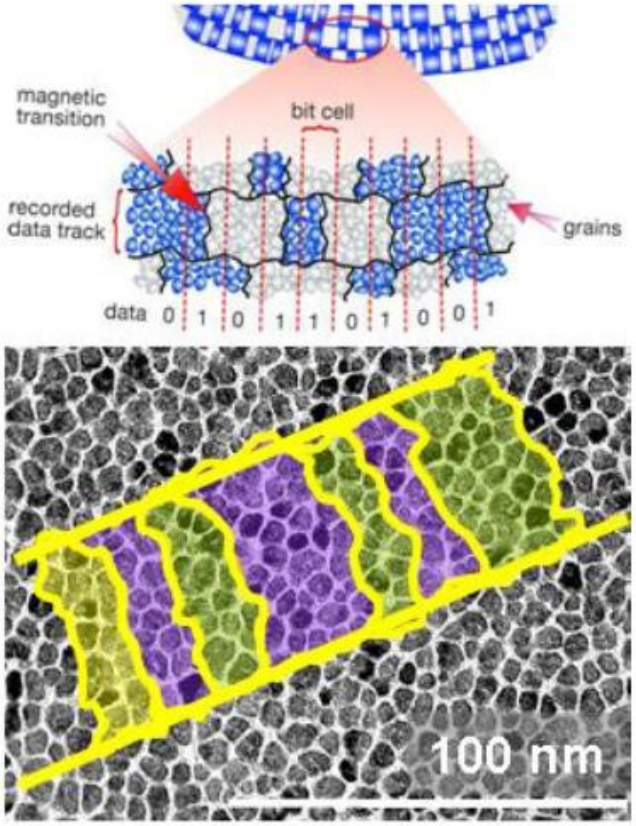
Longitudinal Magnetic Recording (LMR)

Perpendicular Magnetic Recording (PMR)

highest demag fields at bit transitions

highest demag fields in bit center
➔ intergranular exchange counteracts demag fields

Conventional granular media



Question 3

What is the crystal structure of the grains in a current PMR hard disk drive media?

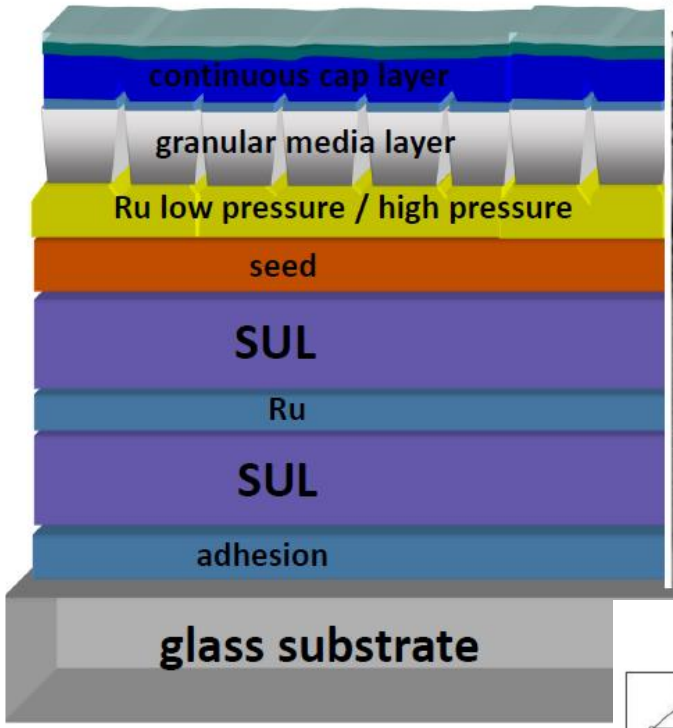
A: grains are all oriented the same way like a single crystal

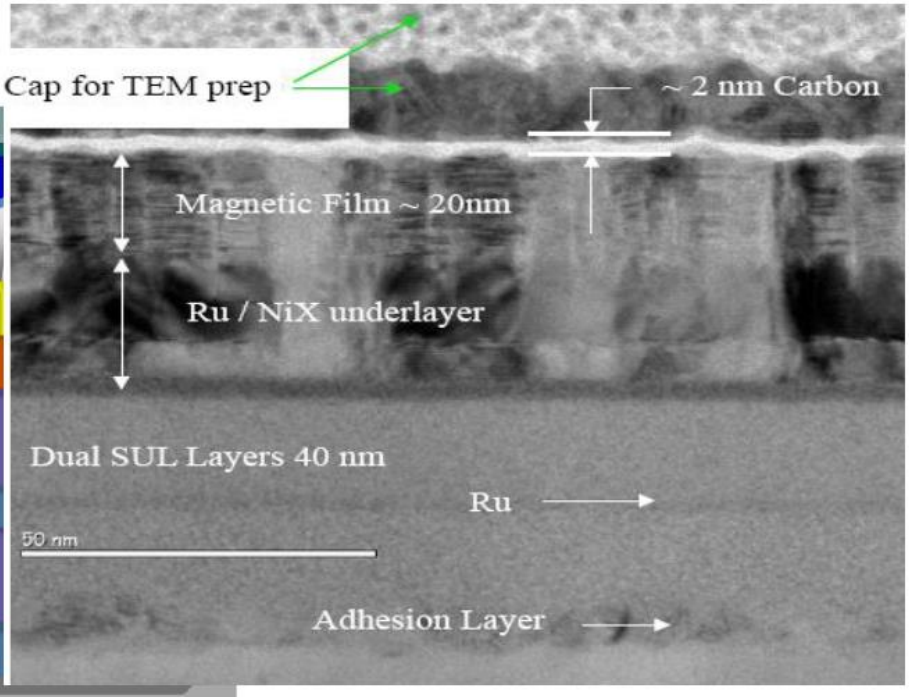
B: grains are polycrystalline, i.e. 3d randomly oriented

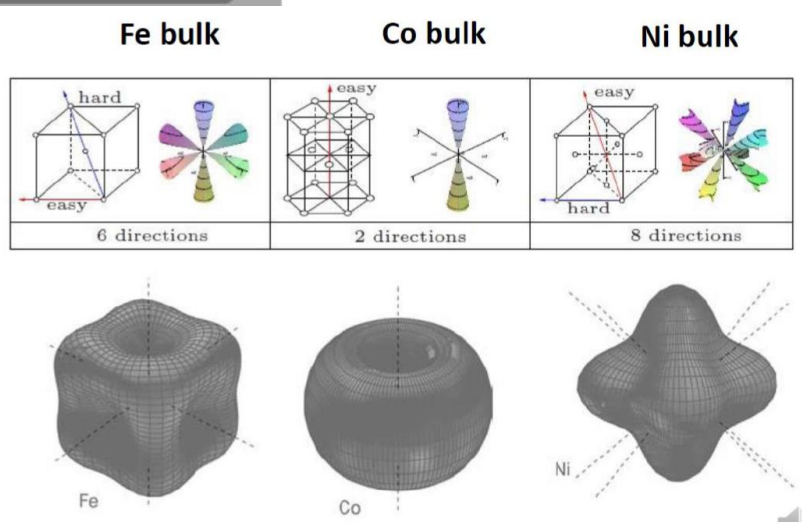
C: grains are amorphous with no long range ordered crystalline structure

D: grains are out-of-plane textured with a well defined crystal direction and in the plane 2D randomly oriented.

Basic PMR Media structure







Question 4

What is the magnetic layer structure in a GMR element?

A: NM / FM / NM

B: FM / AFM / FM

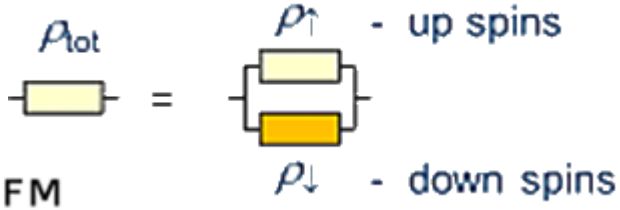
C: AFM / NM / AFM

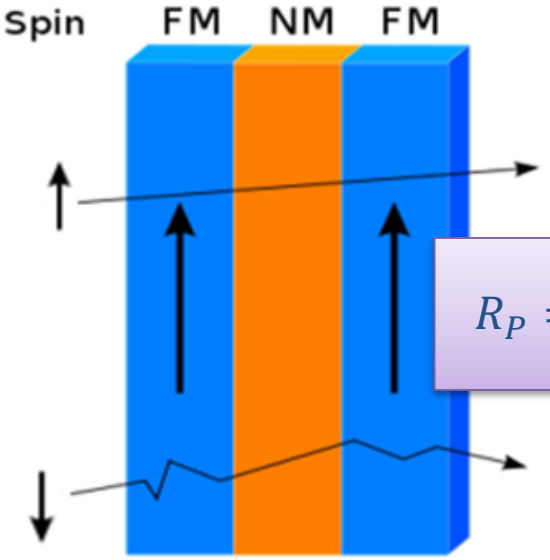
D: FM/ NM / AFM

E: FM / NM / FM

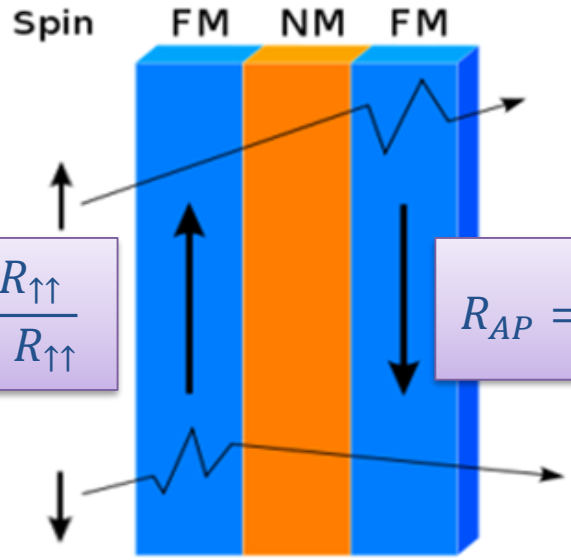
FM=ferromagnetic
AFM=antiferromagnetic
NM=non-magnetic

GMR – equivalent circuits for multilayer





$$R_P = \frac{2R_{\downarrow\uparrow}R_{\uparrow\uparrow}}{R_{\downarrow\uparrow} + R_{\uparrow\uparrow}}$$

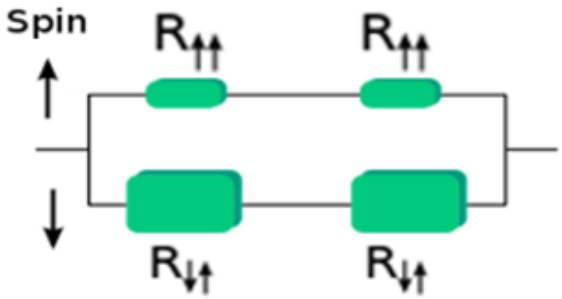


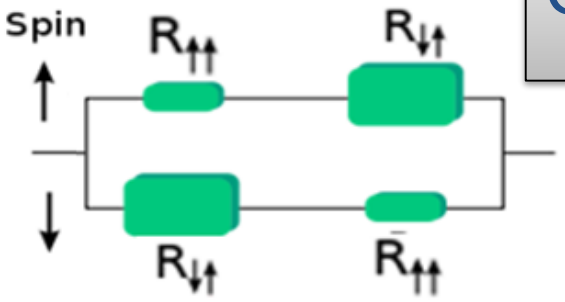
$$R_{AP} = \frac{R_{\downarrow\uparrow} + R_{\uparrow\uparrow}}{2}$$

Low resistance

High resistance

$$GMR = \frac{R_{AP} - R_P}{R_P}$$





Some open questions …

Explain the following abbreviations ?

1. HDD
2. PMR, SUL
3. BPR (or BPM)
4. HAMR or TAR
5. MAMR
6. EAMR
7. MRAM
8. GMR
9. STT
10. SOT

Some open discussion …

Compare magnetic data processing and storage in

A) Magnetic HDDs (read/write, mechanics …)
   a) Coil (read/write)
   b) Coil (write), GMR (read)

B) MRAM
   a) Toggle
   b) STT
   c) SOT

C) Spin Waves / Magnons

Shortly explain how and in which way each technology is superior to the previous one …

Januar 2018

Video des Helmholtz-Zentrums Dresden-Rossendorf zum Thema Datenspeicherung und Datenübertragung.

Ausgezeichnet mit dem PLATINUM Remi Award 2019 in der Kategorie Science & Research auf dem 51. WorldFest-Houston, USA und dem GOLD Green Award 2018 in der Kategorie Innovations and Technological Leaps bei den Deauville Green Awards in Frankreich.

Für weitere Informationen sowie Urheber und Lizenz siehe Originalbeitrag auf YouTube.

For more information, as well as author and license, see the English version on YouTube.

https://www.tu-chemnitz.de/physik/MAGFUN/

Discussion about and feedback on the lecture recordings