PY5021 - 7 Imaging

J. M. D. Coey

School of Physics and CRANN, Trinity College Dublin

Ireland.

1. Magnetic recording
2. Scanning probe methods
2. Medical imaging

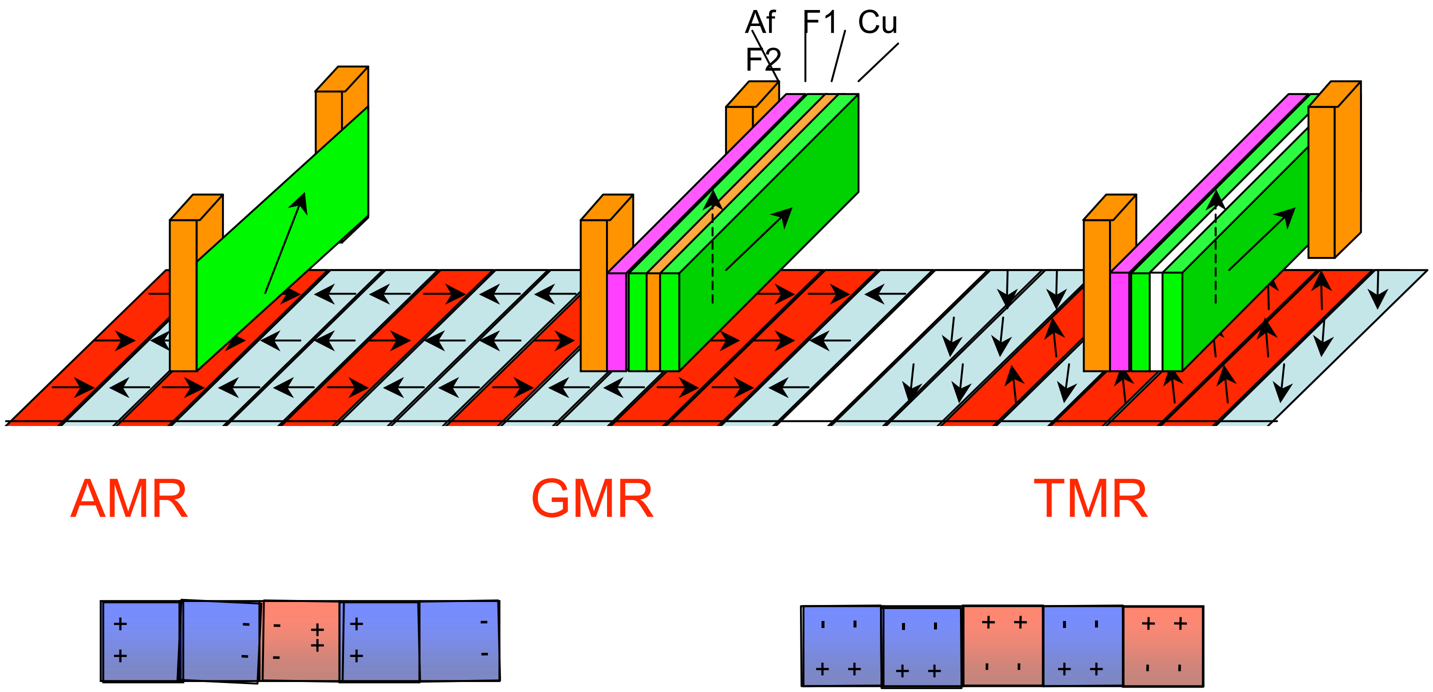
Comments and corrections please: jcoey@tcd.ie

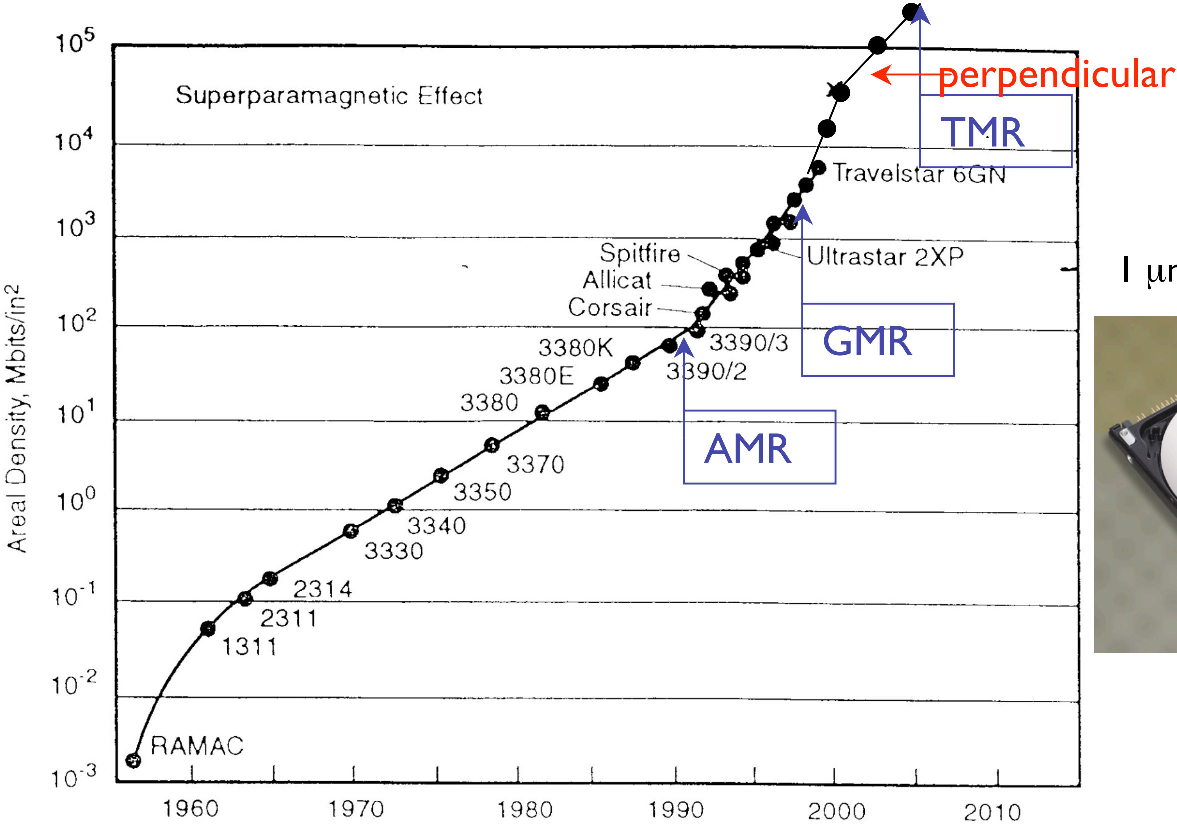
www.tcd.ie/Physics/Magnetism

Sensor	Principle	Detects	Frequency	Field (T)	Noise	Comments
Coil	Faraday's law	dΦ/dt	10^{-3} - 10^{9}	10^{-10} - 10^{2}	100 nT	bulky ,absolute
Fluxgate	saturation	H	dc - 10^{3}	10^{-10} -10^{-3}	10 pT	bulky
Hall probe	Lorentz f'ce	B	dc - 10^{5}	10^{-5} - 10	100 nT	thin film
MR	Lorentz f'ce	B^2	dc - 10^{5}	10^{-2} -10	10 nT	thin film
AMR	spin-orbit int	H	dc - 10^{7}	10^{-9} -10^{-3}	10 nT	thin film
GMR	spin accum.n	H	dc - 10^{9}	10^{-9} -10^{-3}	10 nT	thin film
TMR	tunelling	H	dc - 10^{9}	10^{-9} -10^{-3}	1 nT	thin film
GMI	permability	H	dc - 10^{4}	10^{-9} -10^{-2}		wire
MO	Kerr/Faraday	M	dc - 10^{5}	10^{-9} -10^{2}	1 pT	bulky
SQUID lt	flux quanta	Φ	dc - 10^{9}	10^{-15} -10^{-2}	1 fT	cryogenic
SQUID ht	flux quanta	Φ	dc - 10^{4}	10^{-15} -10^{-2}	30 fT	cryogenic
NMR	resonance	B	dc - 10^{3}	10^{-10} -10	1 nT	Very precise

7.1 Magnetic recording

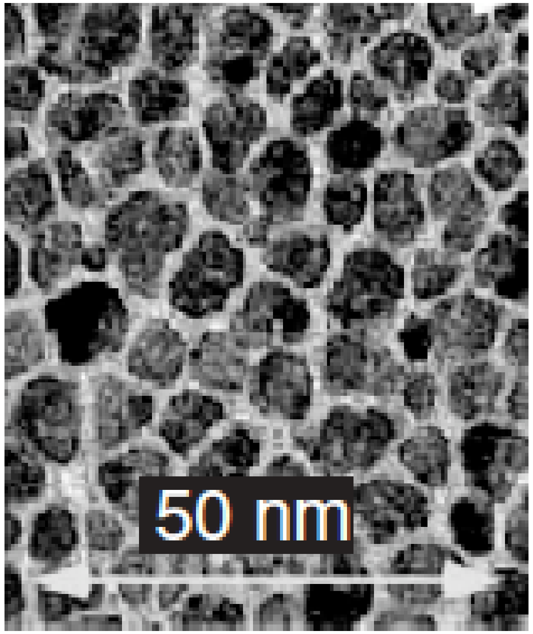
The reading of magnetic records depends on sensing the stray fields from magnetized regions on the hard disc.
The stray field can be calculated from the magnetic charge density, as indicated in the last lectures.

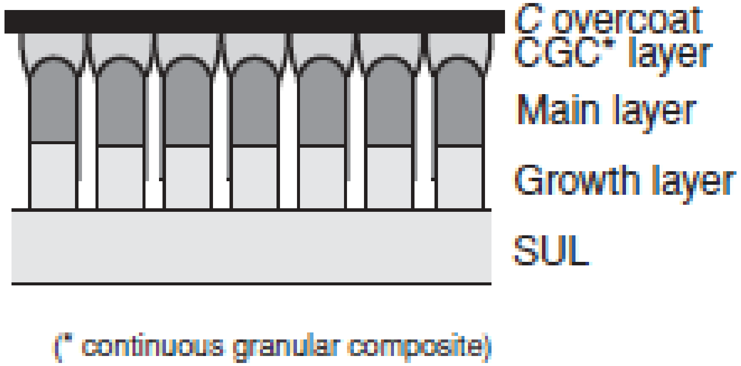


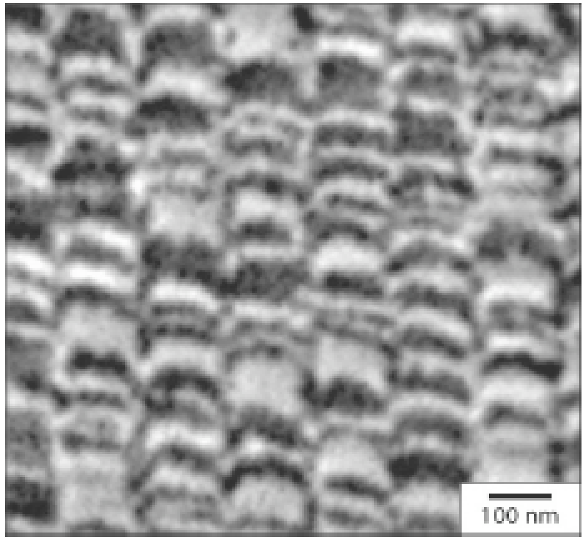


Superparamagnetic Effect
perpendicular
TMR
Travelstar 6GN
Ultrastar 2XP
Spitfire
Allicat
Corsair
GMR
3390/3
3390/2
3380K
3380E
3380
AMR
3370
3350
3340
3330
2314
2311
1311
RAMAC
Areal Density, Mbits/in2
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
1960
1970
1980
1990
2000
2010

1 μm²





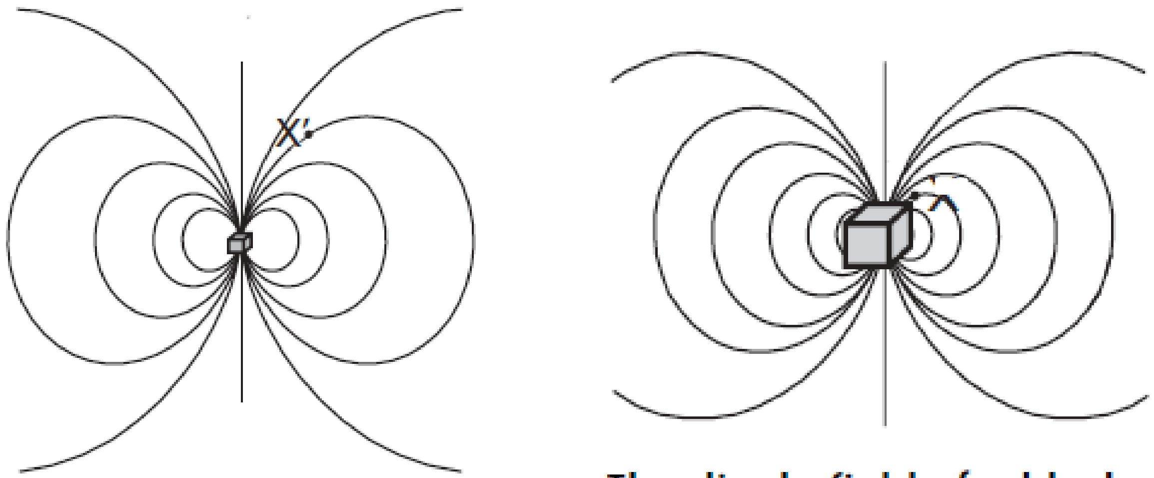


Perpendicular tracks on a hard disc imaged by high-resolution magnetic force microscopy. The width of the tracts is determined by the width of the write head. The recording density here is 300 bits μm^{-2} or 250 Gbit/square inch. (Courtesy of Nanoscan AG.)

Tracks are not infinitely wide

Scaling

X



The dipole field of a block of magnetic material is scale-independent. Fields at X and X′ are the same.

7.2 Scanning probe methods

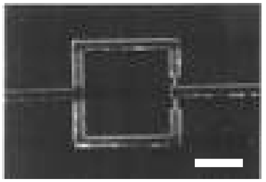
Magnetic force microscopy
Measures $B\nabla B$ *via* the force on a resonant cantilever.

Scanning Hall probe microscopy
Measures B in a sensitive high-mobility semiconductor plate.

Scanning SQUID microscopy
Measures Φ in a small superconducting loop.

7.3 Medical imaging

SQUID sensors for magnetometers, nondestructive testing, geophysical prospection… incluing high-T_{sc} SQUIDS and microsquids



SQUID sensor arrays for magnetocardiography and magnetoencelography (MEG)