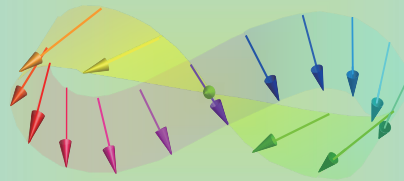


Information Storage and Spintronics

06



Atsufumi Hirohata

Department of Electronic Engineering

THE UNIVERSITY of York

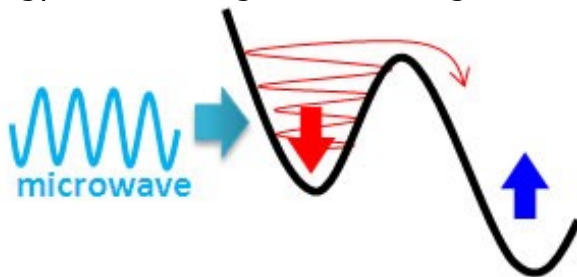


14:00 Monday, 17/October/2022 (SLB 101)

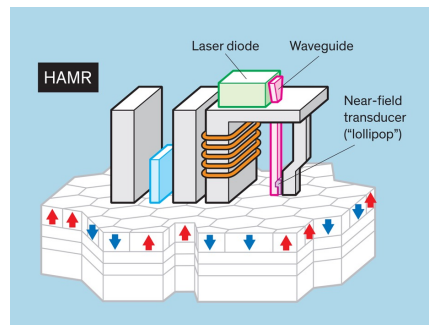


Quick Review over the Last Lecture

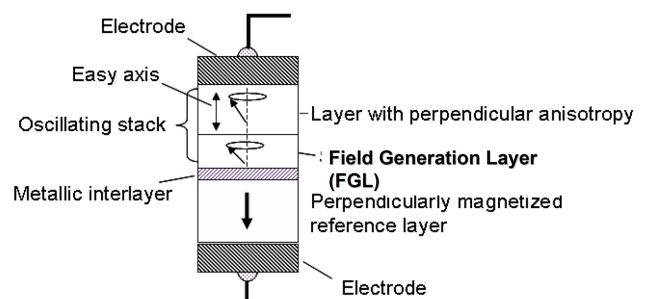
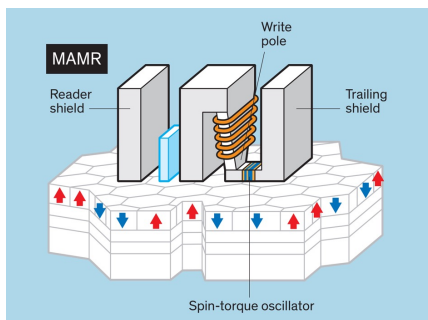
Energy assisted magnetic recording : *



HAMR (heat-assisted magnetic recording) : **



MAMR (microwave-assisted magnetic recording) : **



* http://www.tagen.tohoku.ac.jp/labo/kitakami/JJ/research_j/research_j.html;

** <https://spectrum.ieee.org/computing/hardware/lasers-vs-microwaves-the-billiondollar-bet-on-the-future-of-magnetic-storage.amp.html>;

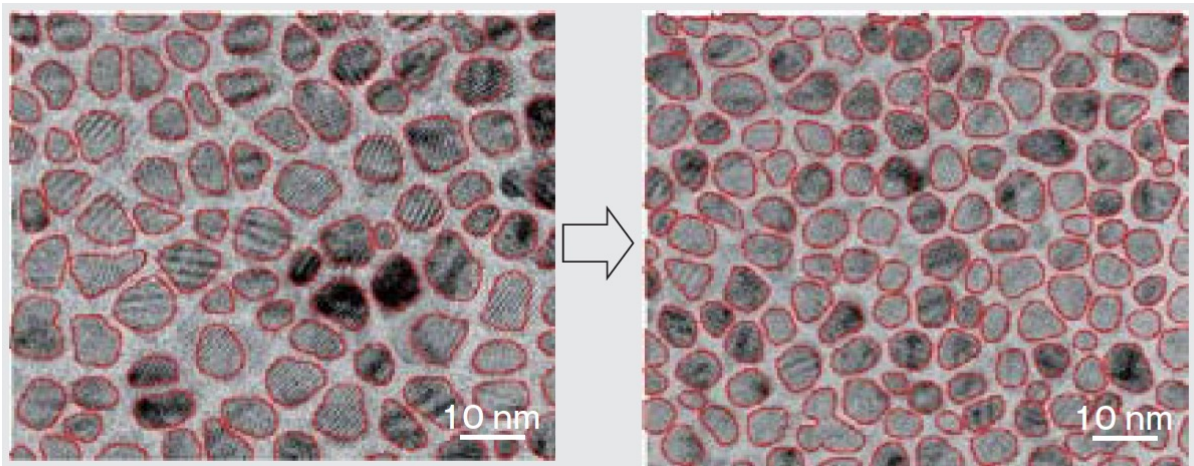
06 HDD Media

- Grain-size control
- 2-dimensional magnetic recording
 - Shingled write recording
 - Bit patterned media
 - Other efforts



Precise Grain-Size Control

Grain-size reduction from 7 ~ 8 nm down to ~ 5 nm :

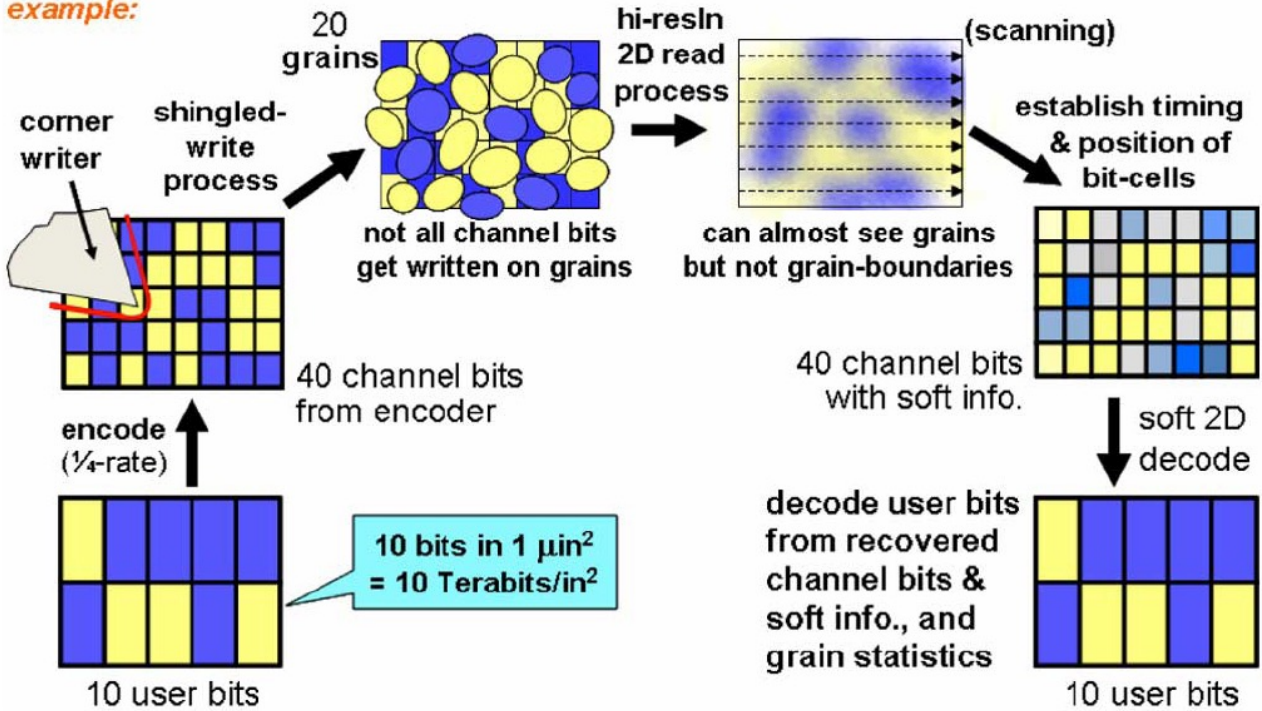


2-Dimensional Recording



In 2008, Roger Wood *et al.* proposed 2-dimensional magnetic recording (TDMR) : *

example:

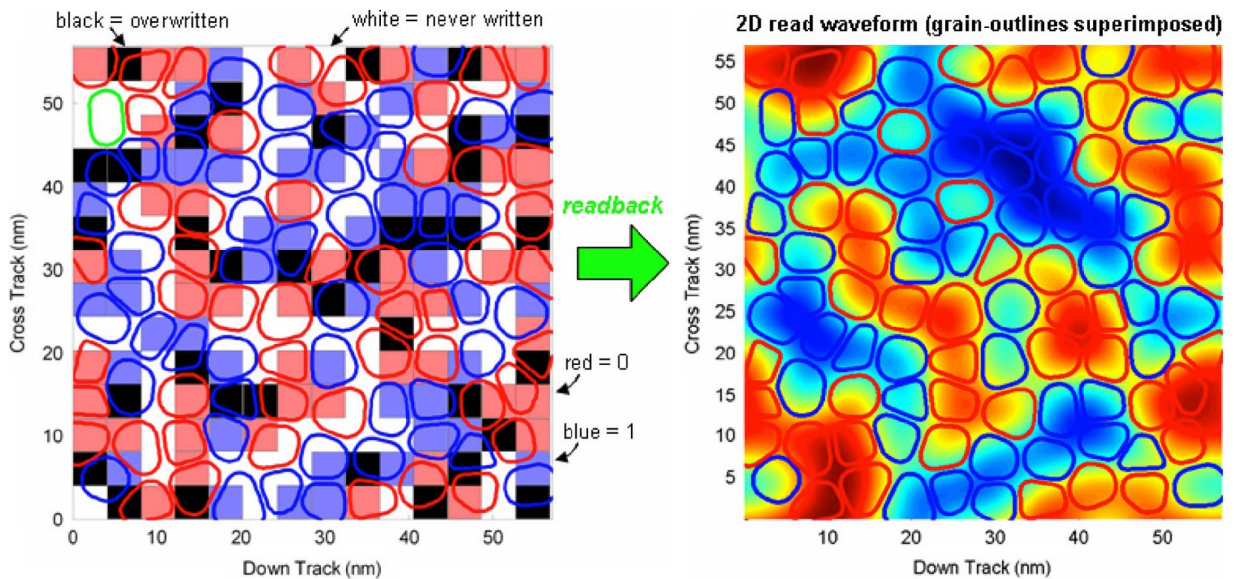


* R. Wood *et al.*, *IEEE Trans. Magn.* **45**, 917 (2009).

2-Dimensional Magnetic Recording (TDMR)



TDMR simulations : *



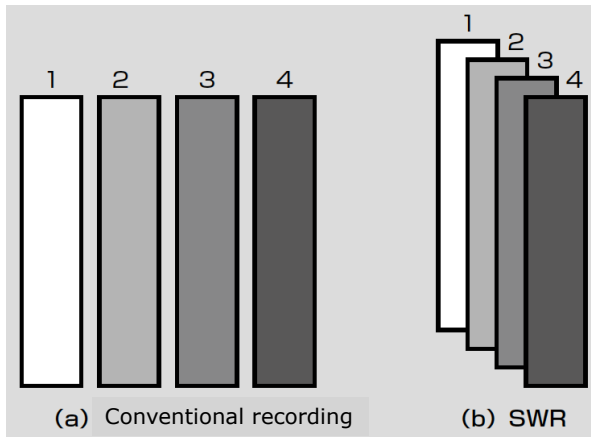
* R. Wood *et al.*, *IEEE Trans. Magn.* **45**, 917 (2009).



Shingled Write Recording (SWR)

Toshiba has been developing shingled write recording : *

- Writing :
- Reading :

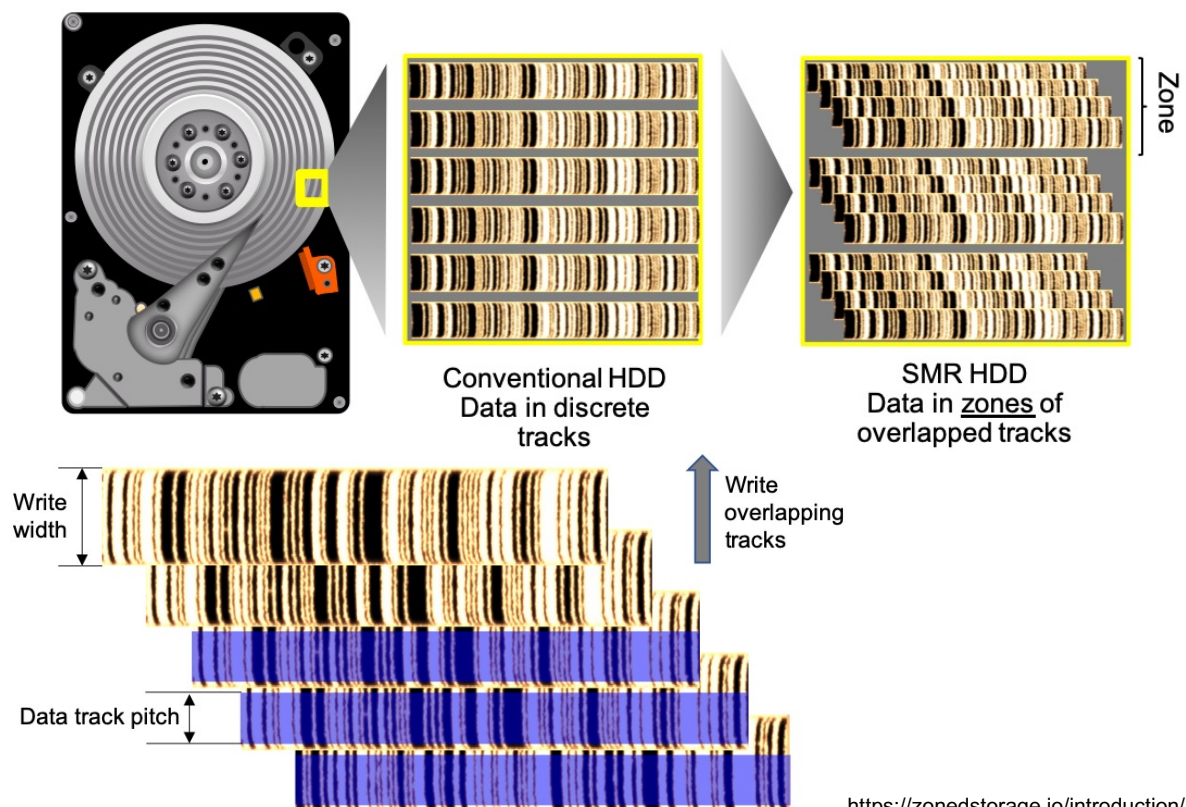


- ✓ Large track width
- ✓ Large writing field
- ✓ Higher areal density (~ 30 %)
- ✓ No cross-talk between tracks
- ✗ Write-in / read-out time
- ✗ Data re-write mechanism
- ✗ No improvement in TPI
- ✗ No improvement in SNR

* S. Matsuo, H. Uwazumi and N. Hara, *Fujidenki Gihou* **85**, 316 (2012).



Shingled Magnetic Recording (SMR)





Shingled Write Recording in HDD

Western Digital Continues Enterprise-Capacity HDD Leadership

New 15TB Ultrastar DC HC620 HDD Leverages SMR Technology to Improve Areal Density and Lower TCO for Scale-out Cloud and Enterprise Data Center Customers



Western Digital 15TB Ultrastar DC HC620 host-managed SMR Hard Disk Drive (Photo: Business Wire)

* <https://www.businesswire.com/news/home/20181024005162/en/Western-Digital-Continues-Enterprise-Capacity-HDD-Leadership>



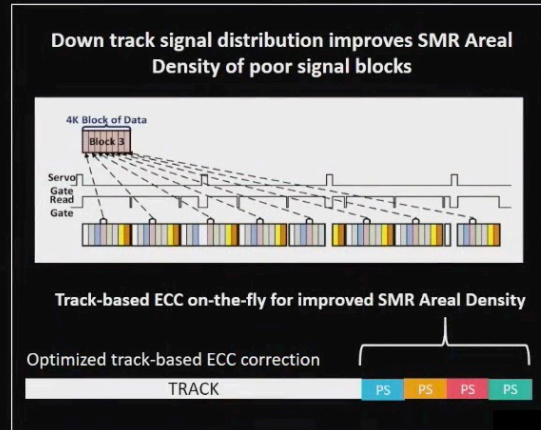
Shingled Recording Projection

Shingled recording technology : *

SMR Innovation to Optimize Shingled Format for Improved Areal Density

- Track-based writes for optimal Areal Density
- SMR Areal Density improved by using signal format optimized for track-based sequential operations

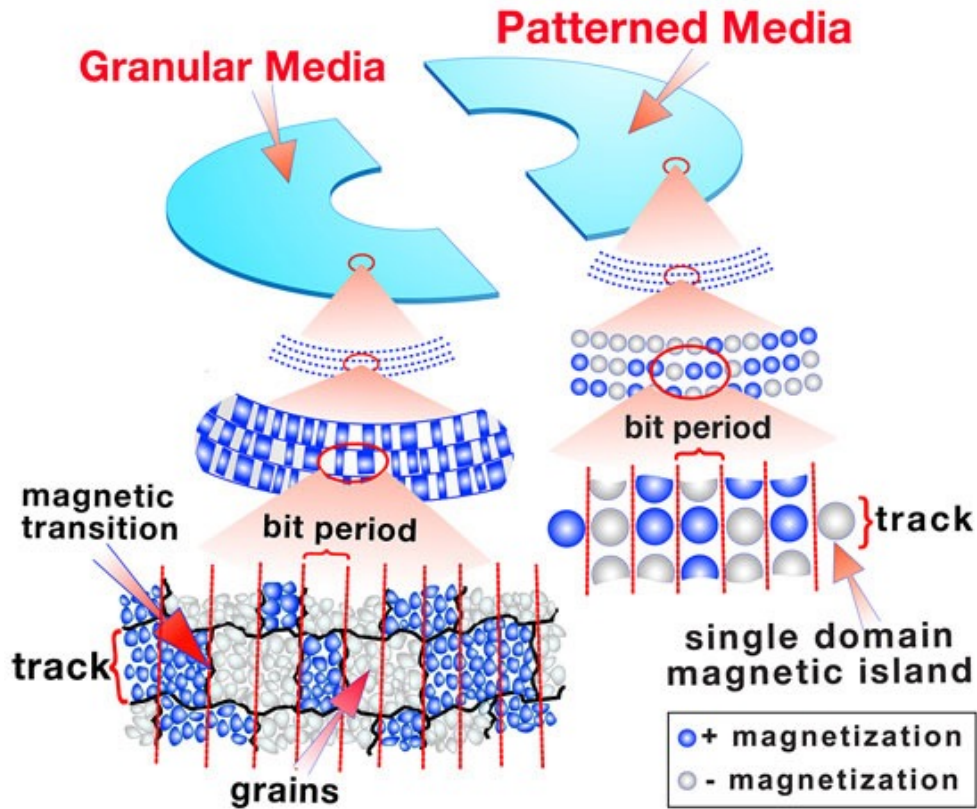
Western Digital SMR Projected Capacity Gain by Generation



* <https://blocksandfiles.com/2020/01/28/western-digital-gives-hdd-technology-roadmap-lesson/>



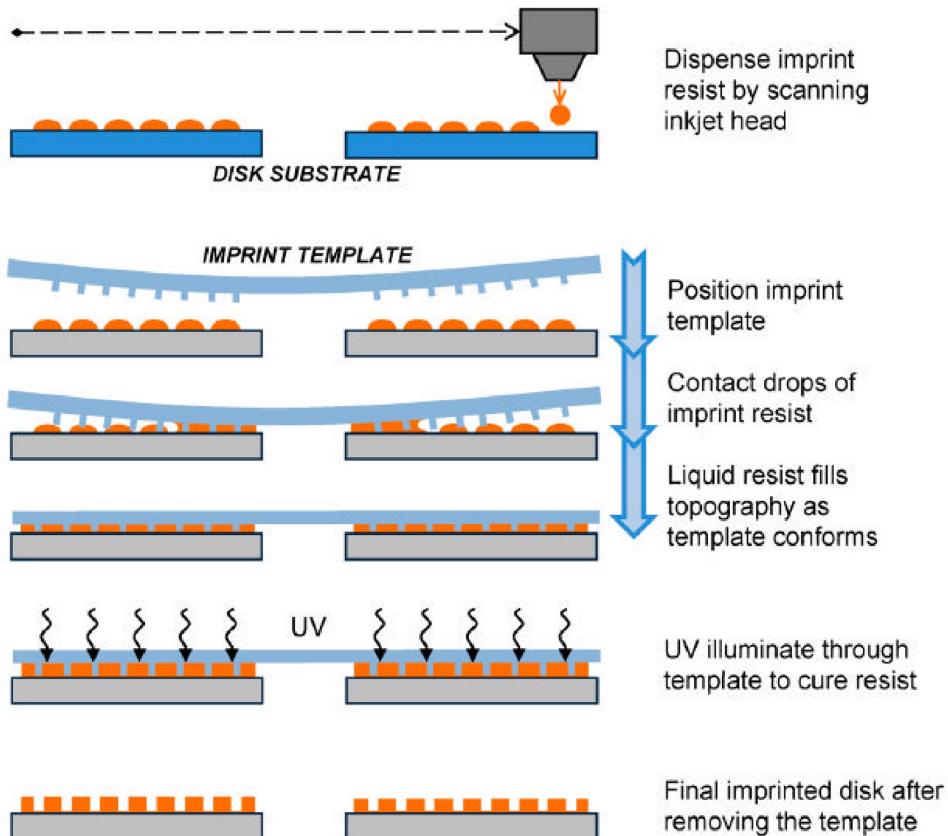
Bit Patterned Media (BPM)



* http://news.cnet.com/2300-1008_3-6108692.html



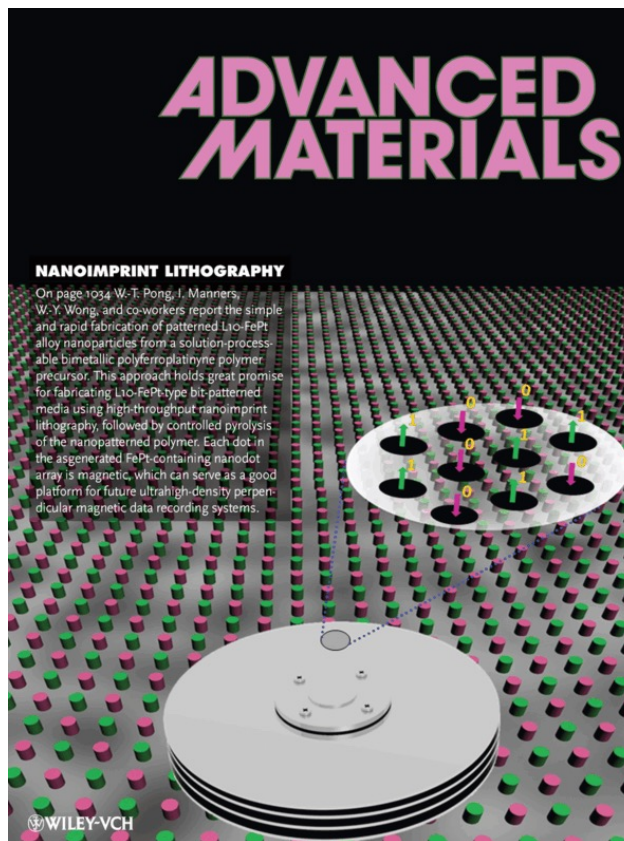
Patterning Process



* <http://spie.org/x33843.xml>



Bit Patterned Media (BPM)

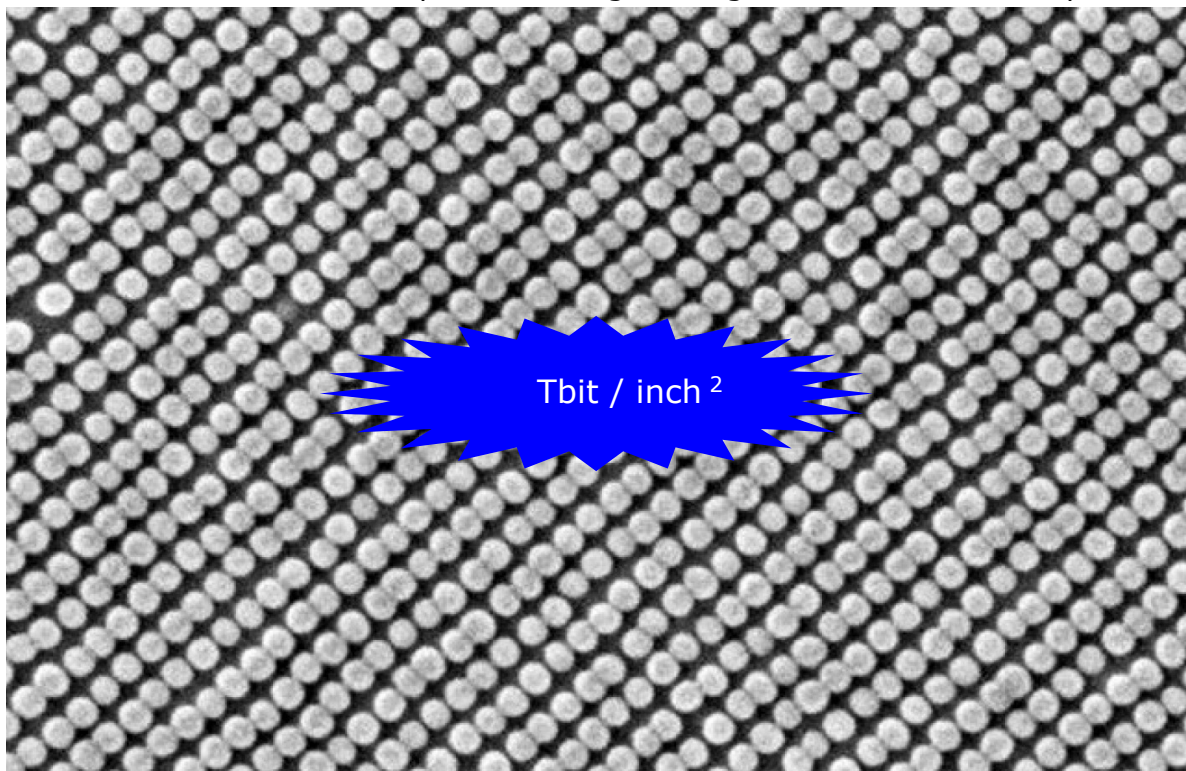


* <http://onlinelibrary.wiley.com/doi/10.1002/adma.201290034/abstract>



Bit Patterned Media (BPM)

HGST demonstrated 10-nm bit patterns using self-organisation and nano-imprint : *

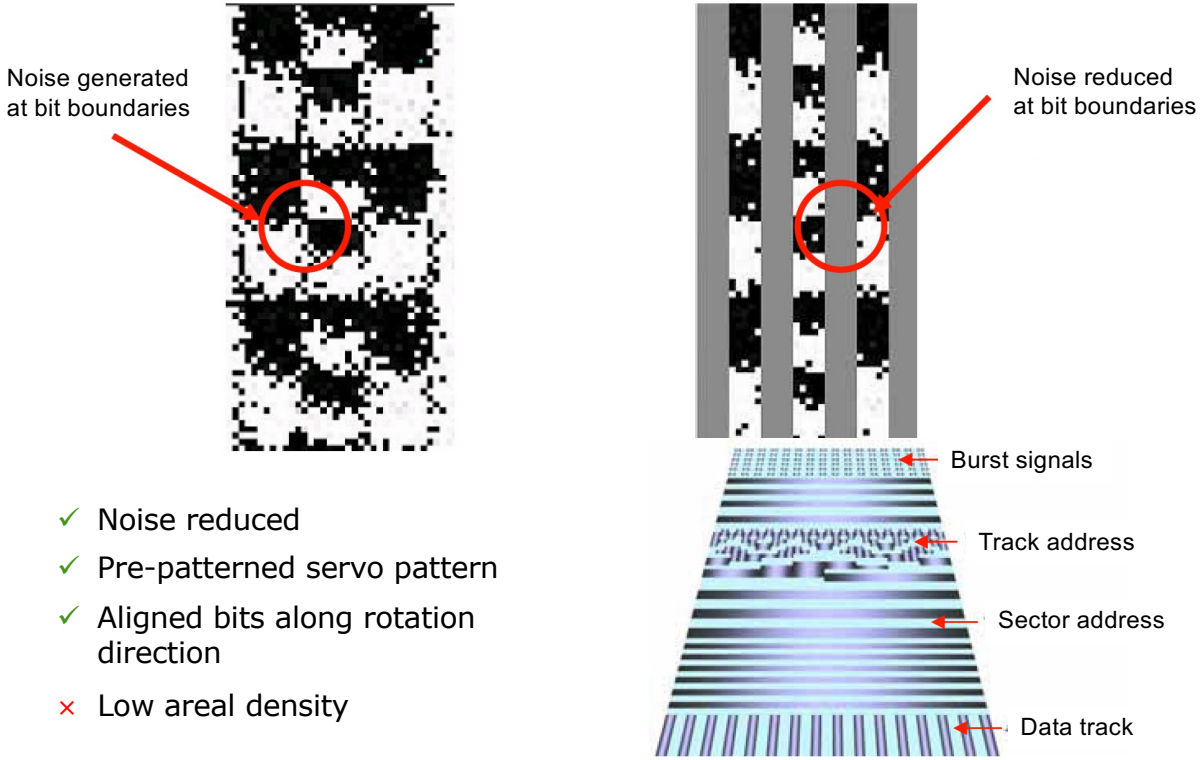


* <http://www.hgst.com/>



Discrete Track Media

Tracks can be confined to reduce noise at bit boundaries : *

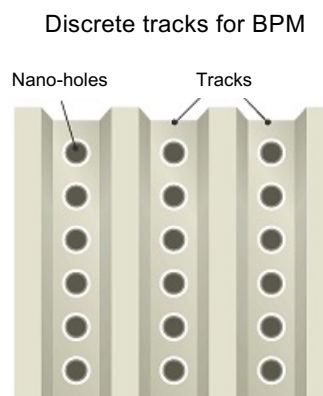
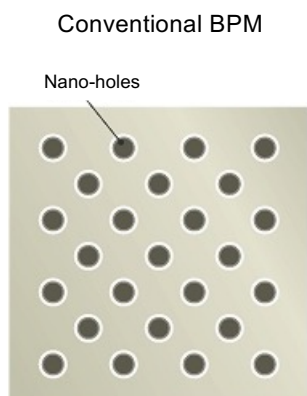
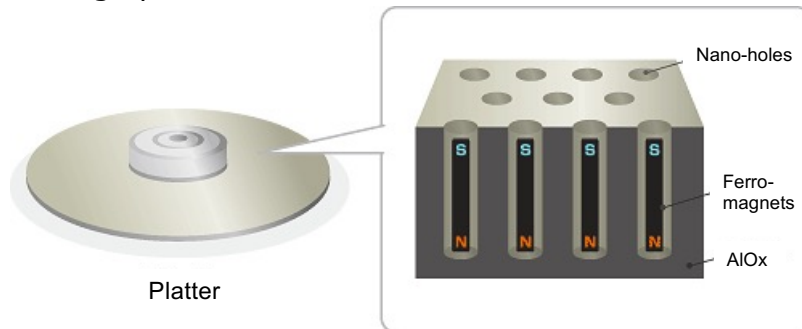


* <http://www.tdk.co.jp/>



Discrete Tracks for BPM

Defined tracks can align patterned bits : *

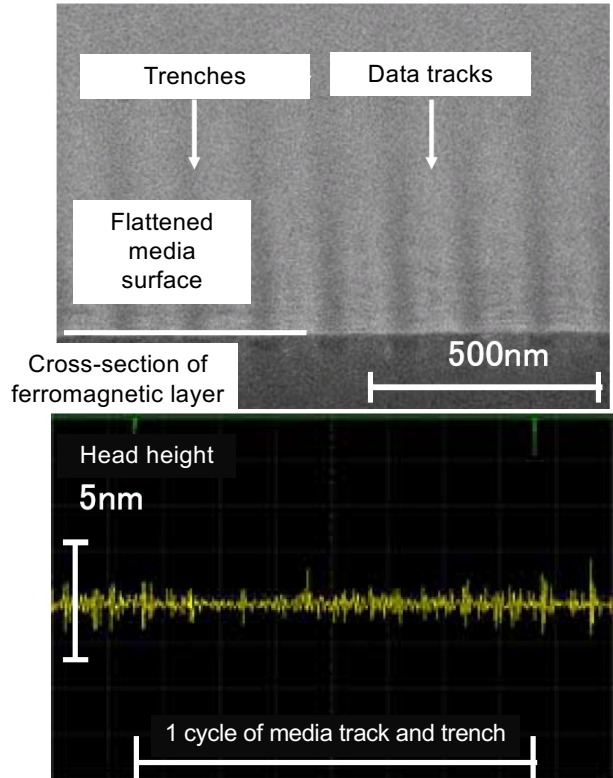
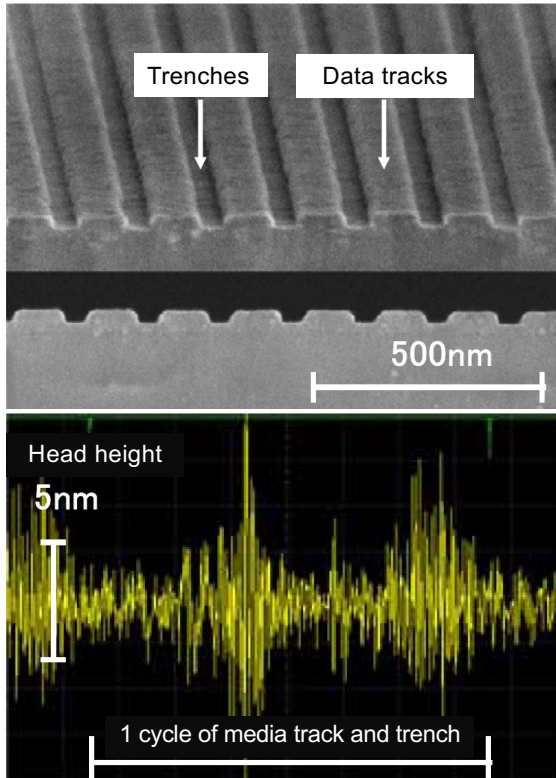


* <http://www.tdk.co.jp/>



Fabrication of Discrete Tracks

Discrete tracks are flattened by sputtering and dry etching processes : *

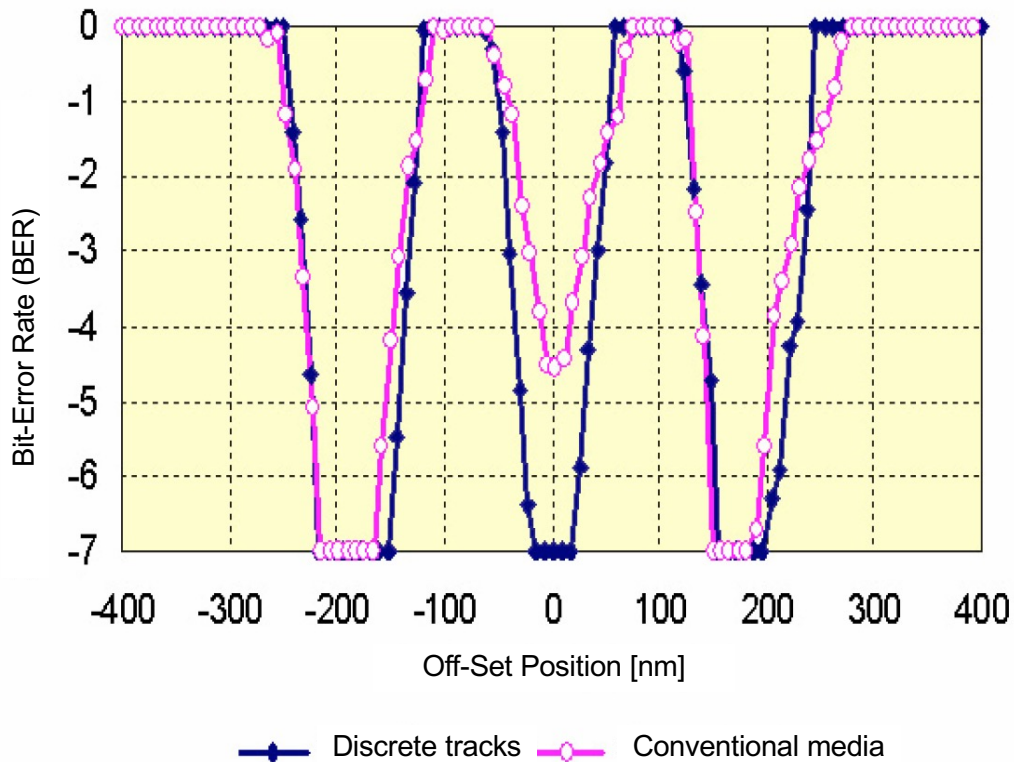


* <http://www.tdk.co.jp/>



Bit-Error Rate with Discrete Tracks in BPM

Significant improvement in bit-error rates : *

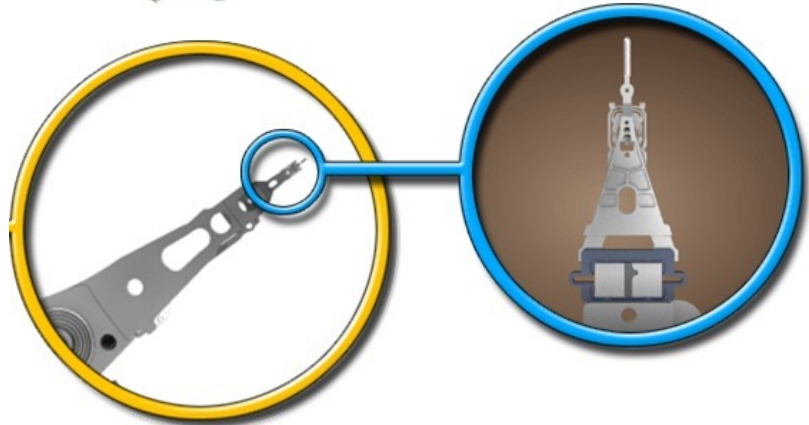
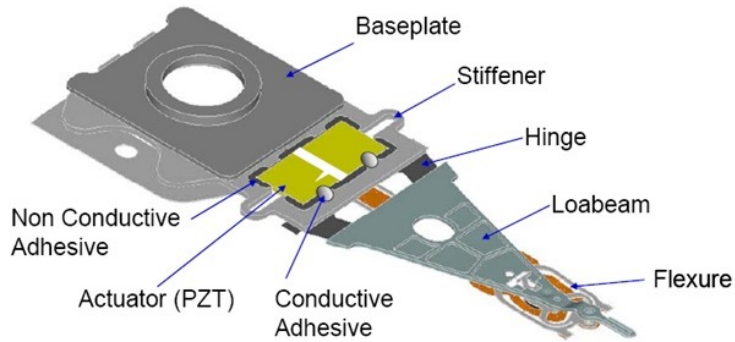


* <http://www.hgst.com/>



Dual Stage Actuator

Precise head positioning can be achieved by two-step actuator :

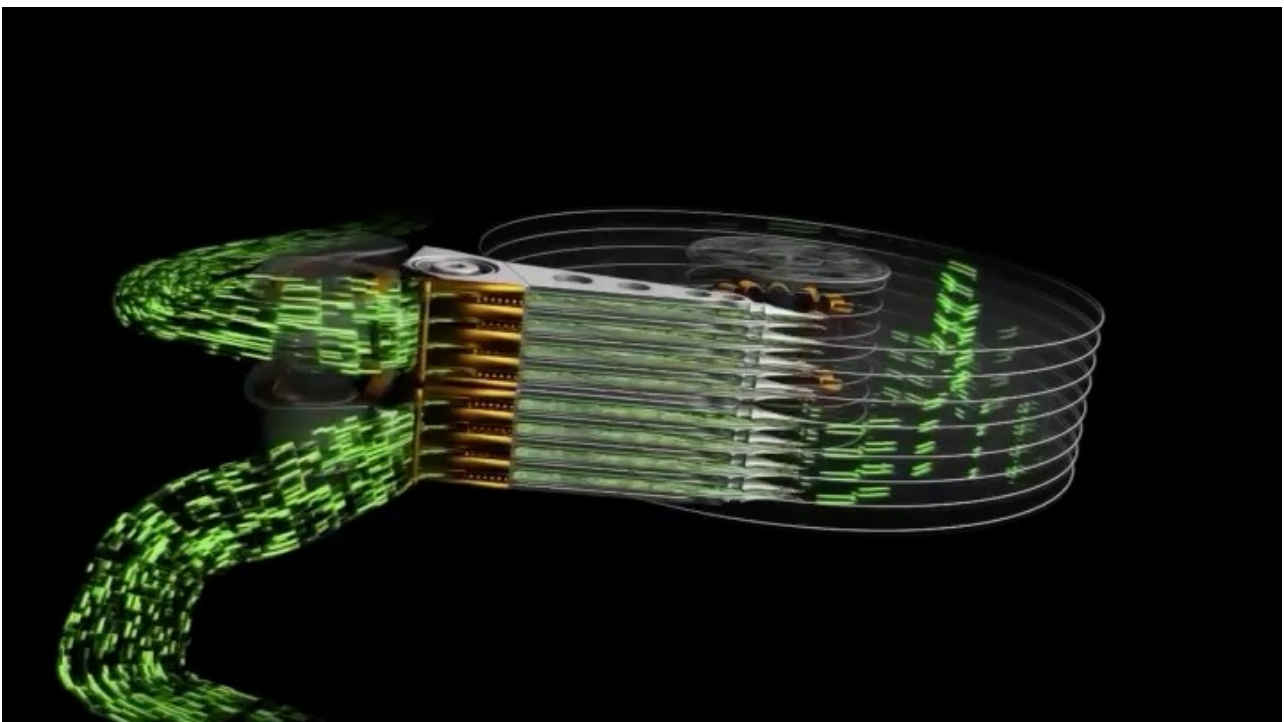


* <http://www.pcper.com/news/Storage/WD-unleashes-nested-actuator-and-anti-disk-tech-two-new-7200RPM-2TB-models>



Multi-Actuator Operation

Seagate plans to introduce a new HDD with multi-actuator technology : *



* <https://blog.seagate.com/craftsman-ship/multi-actuator-technology-a-new-performance-breakthrough/>




Head Suspension Projection





Head suspension technology : *

Suspension Technology Roadmap

TMR Enabler

- Improved suspension dynamics and implementation of PZT actuation has played a significant role in increasing TPI capability by enabling higher servo bandwidth



	Single Stage Shipping → EOL	Dual Stage "Milli" Shipping → EOL	Dual Stage "Micro" Shipping Now	Triple Stage Shipping 1H 2020
Description	VCM control (actuator coil)	VCM control + suspension control (loadbeam moves)	VCM control+ suspension control (slider/gimbal moves)	VCM control + suspension loadbeam + slider/gimbal
Illustration				

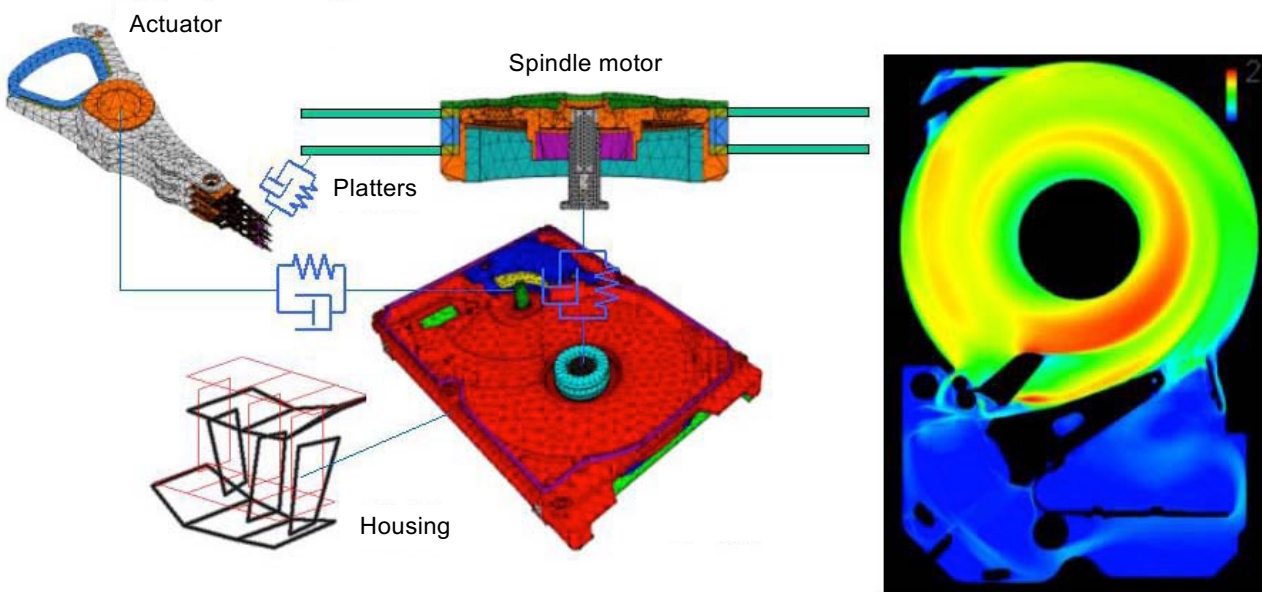
Western Digital © 2020 Western Digital Corporation or its affiliates. All rights reserved. 1/22/2020 8

* <https://blocksandfiles.com/2020/01/28/western-digital-gives-hdd-technology-roadmap-lesson/>



Minimisation of Vibration

Entire HDD is simulated using fluid dynamics modelling :

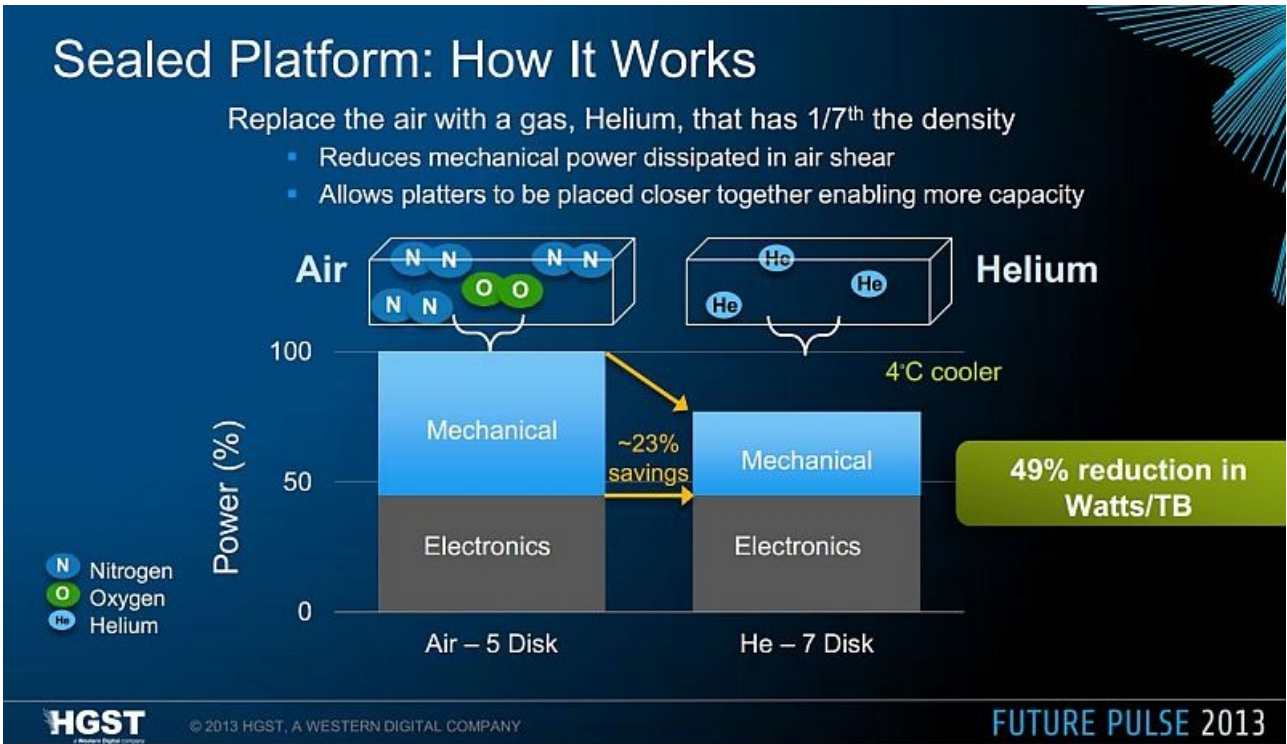


* H. Kataoka, *Knowledge Base: Inst. Electron. Info. Comm. Eng.* 8-2, 1 (2011).



Helium-Sealed HDD

In 2012, HGST introduced a He-sealed HDD to reduce the head-media distance : *

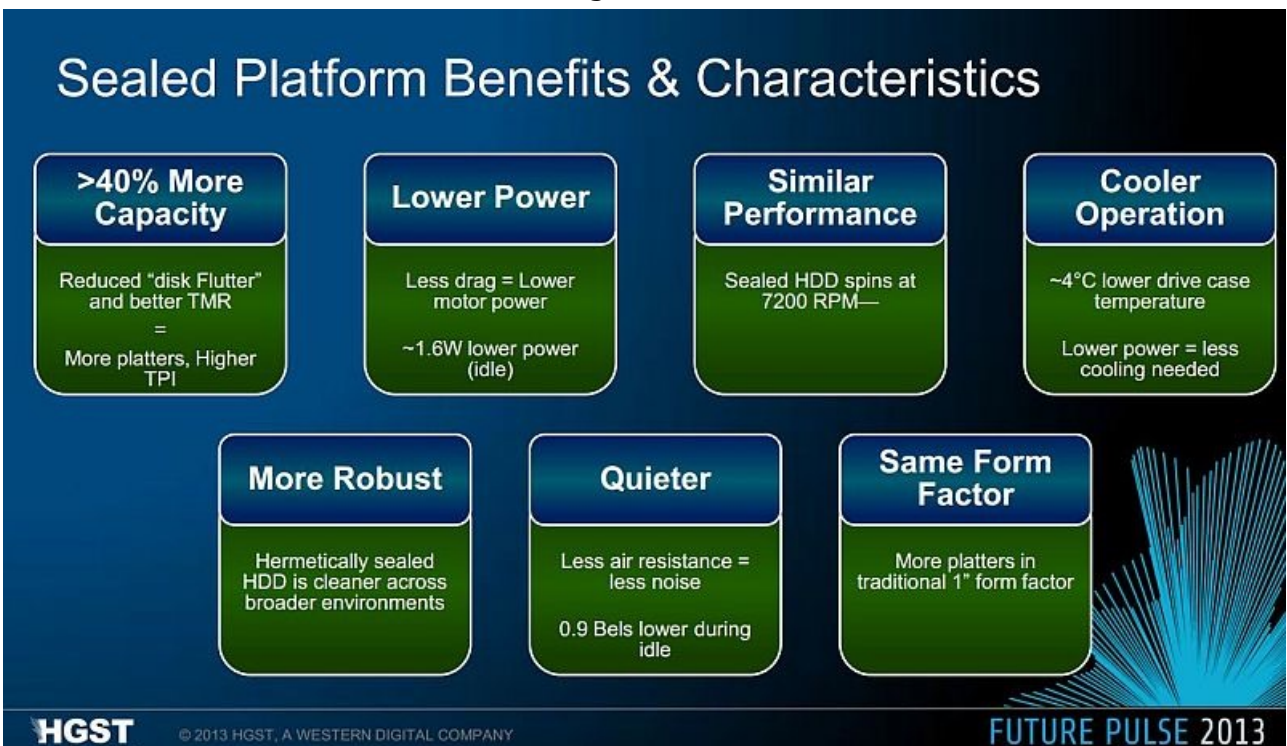


* <http://www.hgst.com/>



Helium-Sealed HDD

He-sealed HDD can achieve the following features : *



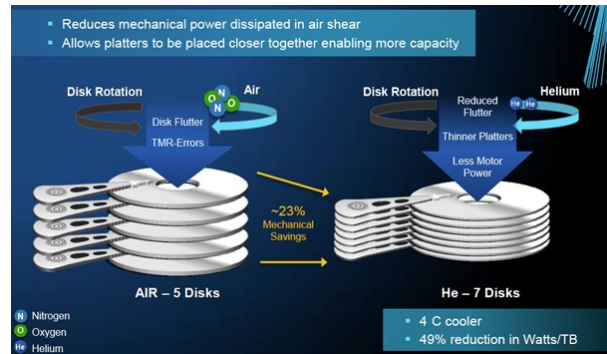
* <http://www.hgst.com/>



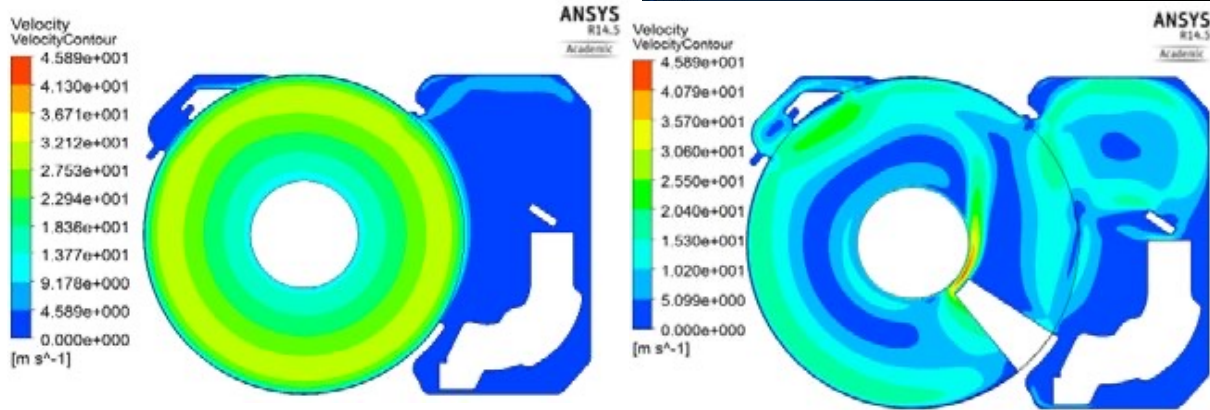
Advantages of He Seal

Comparison between air- and He-sealed HDD : *

Properties	Air	Helium
Density (kg/m ³)	1.2	0.1
Dynamic viscosity (kg/m·s)	1.9608×10 ⁻⁵	2.0939×10 ⁻⁵
Kinematic viscosity (kg/m·s)	1.79947×10 ⁻⁵	1.3844×10 ⁻⁴



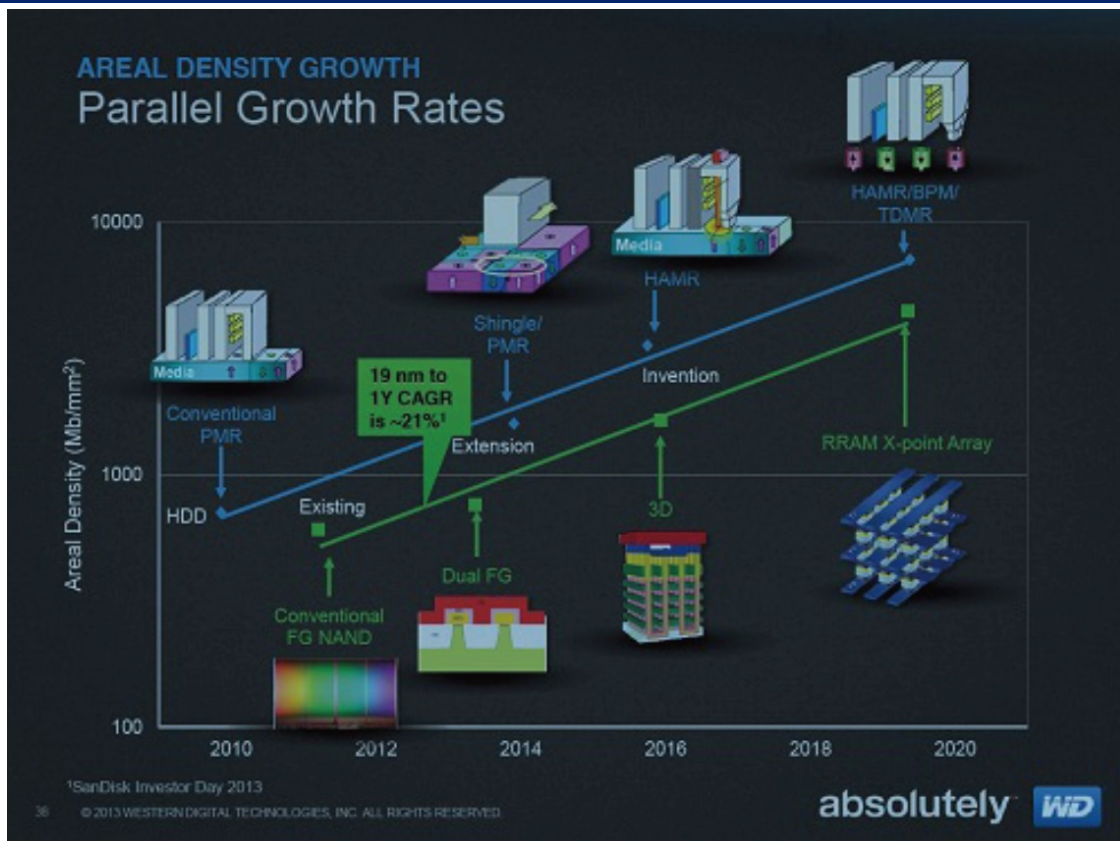
Velocity distribution of He-sealed HDD : *



* S. Tawinprai et al., IOP Conf. Ser.: Earth Environ. Sci. **113**, 012200 (2018).



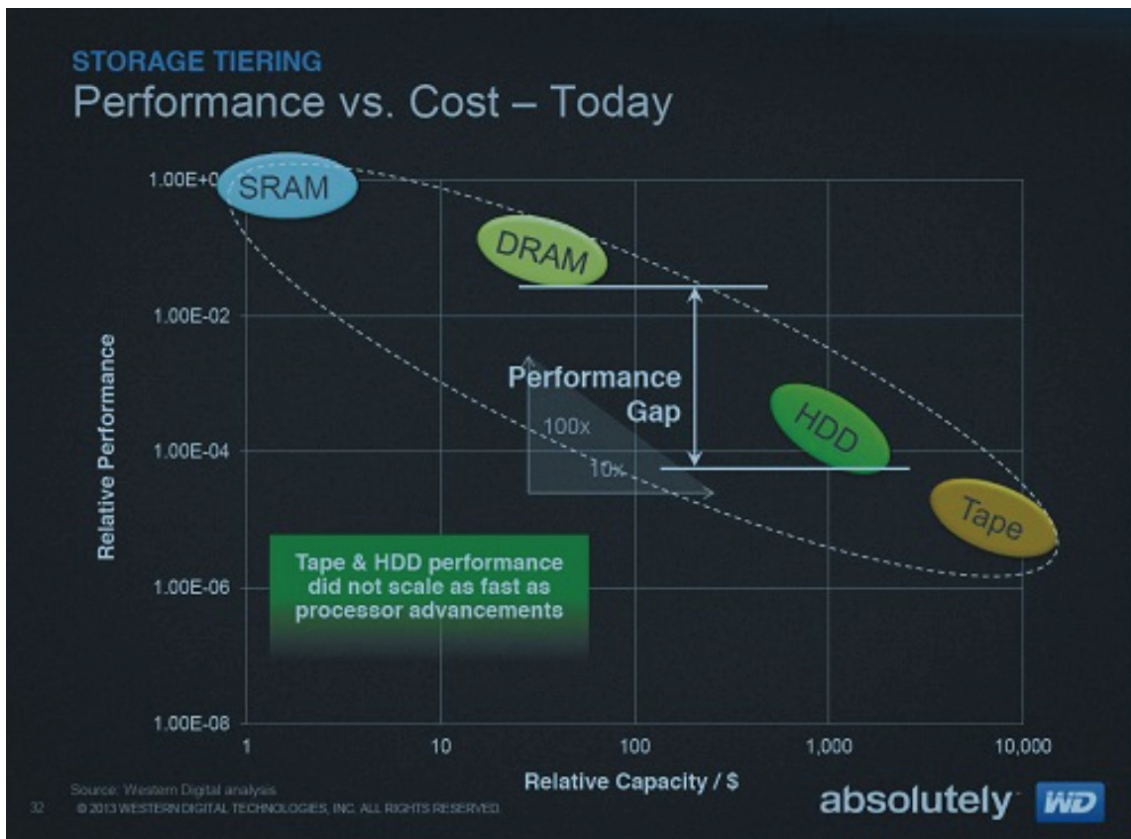
HDD and DRAM



* http://www.theregister.co.uk/2013/06/25/wd_shingles_hamr_roadmap/



Performance Gap between HDD and DRAM



* http://www.theregister.co.uk/2013/06/25/wd_shingles_hamr_roadmap/