

YEARS OF DESTINY: HDD CAPITAL SPENDING AND TECHNOLOGY DEVELOPMENTS FROM 2012-2016

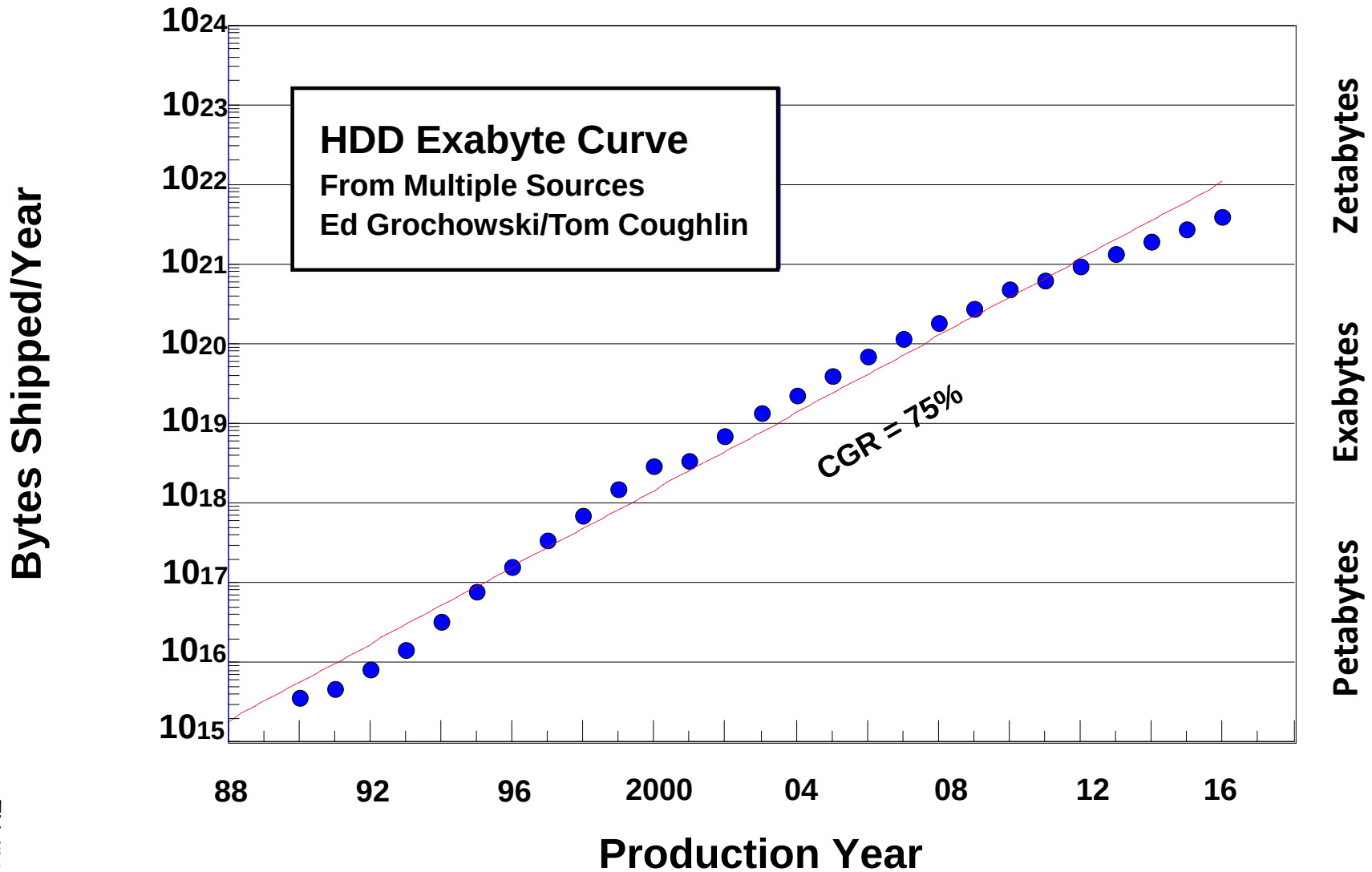
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Ed Grochowski
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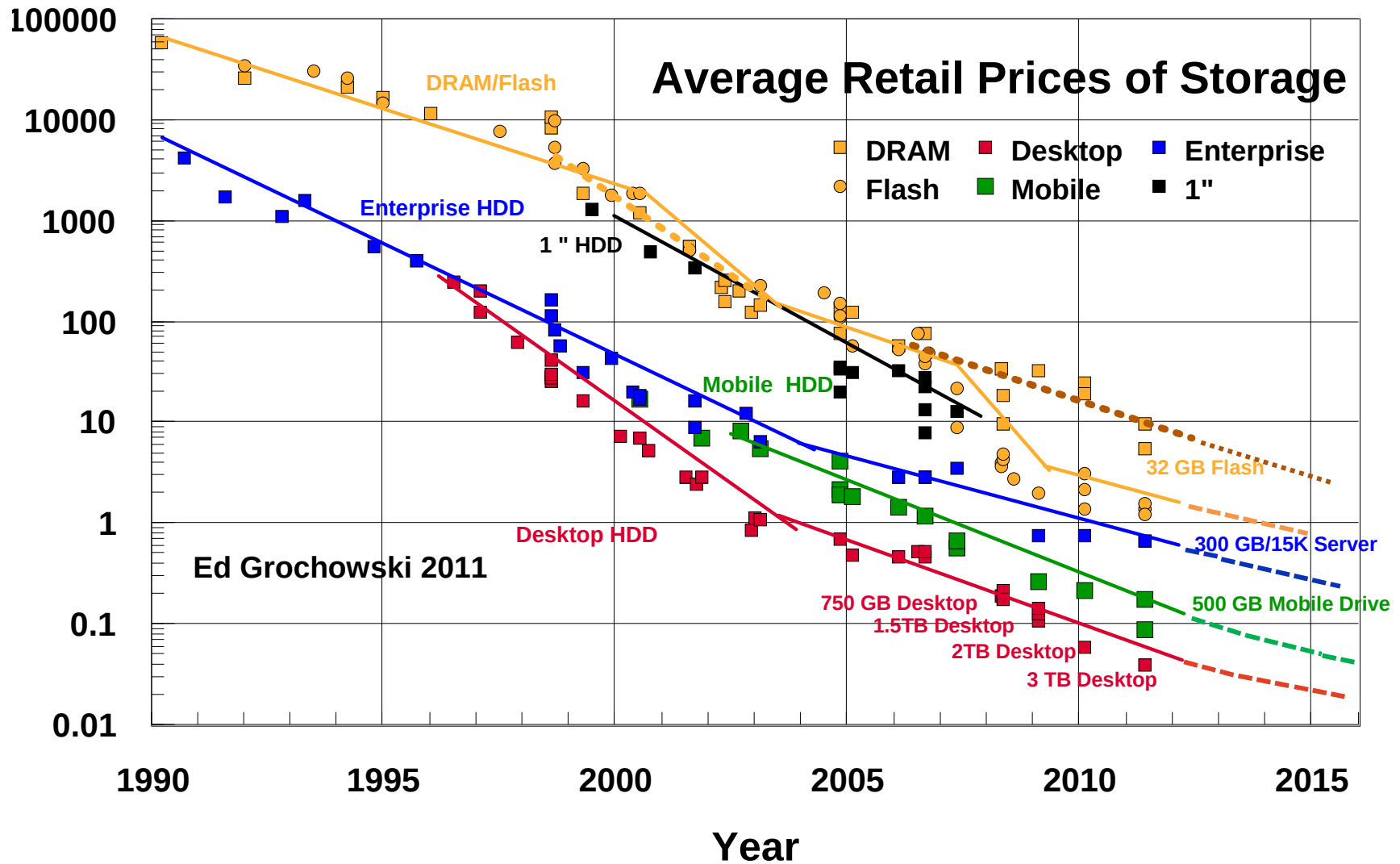
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Presented at IEEE Santa Clara Valley Magnetics Society Meeting, June 19, 2012

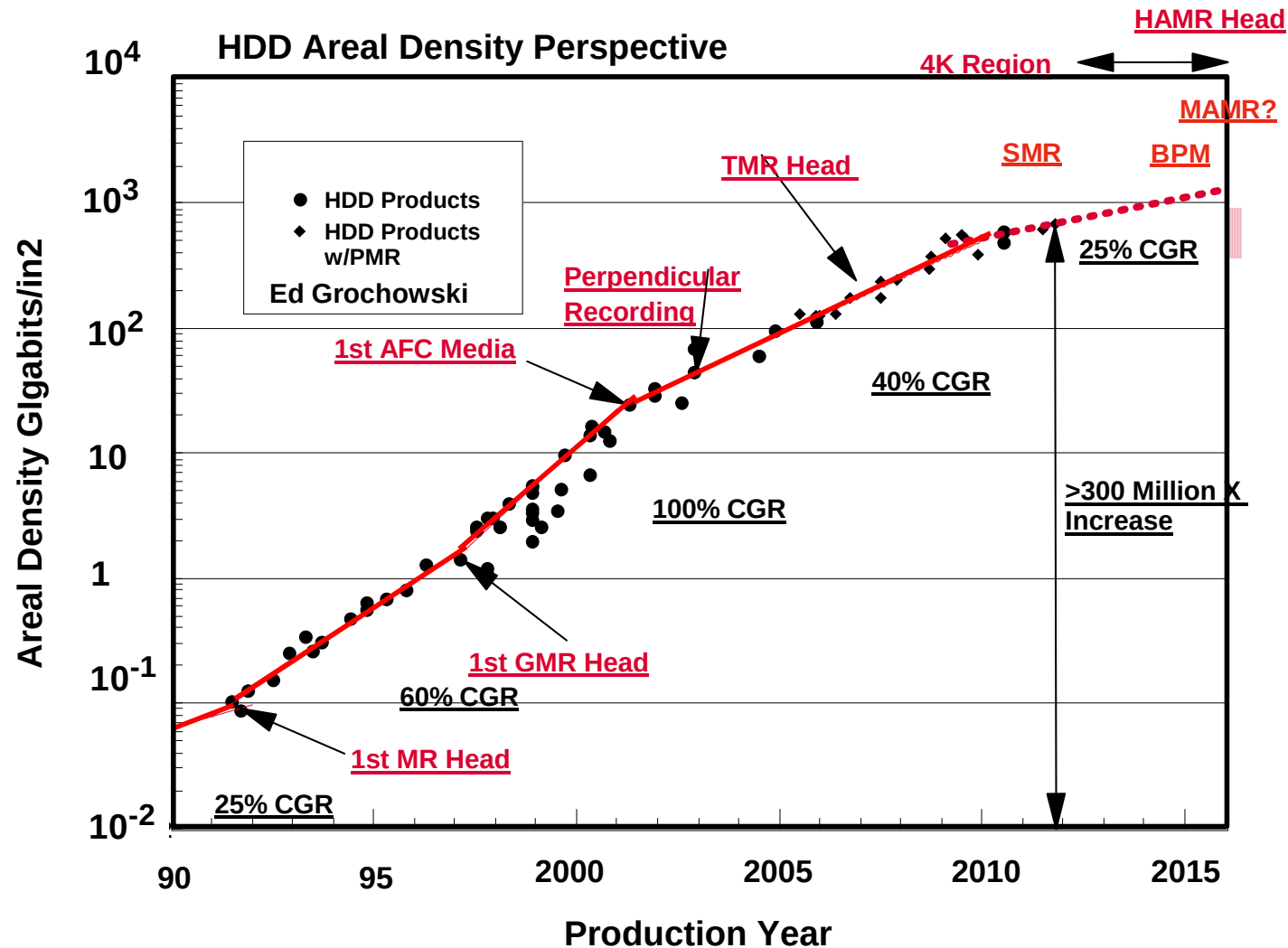
WW DISK CAPACITY SHIPMENTS (1999 THROUGH 2016).



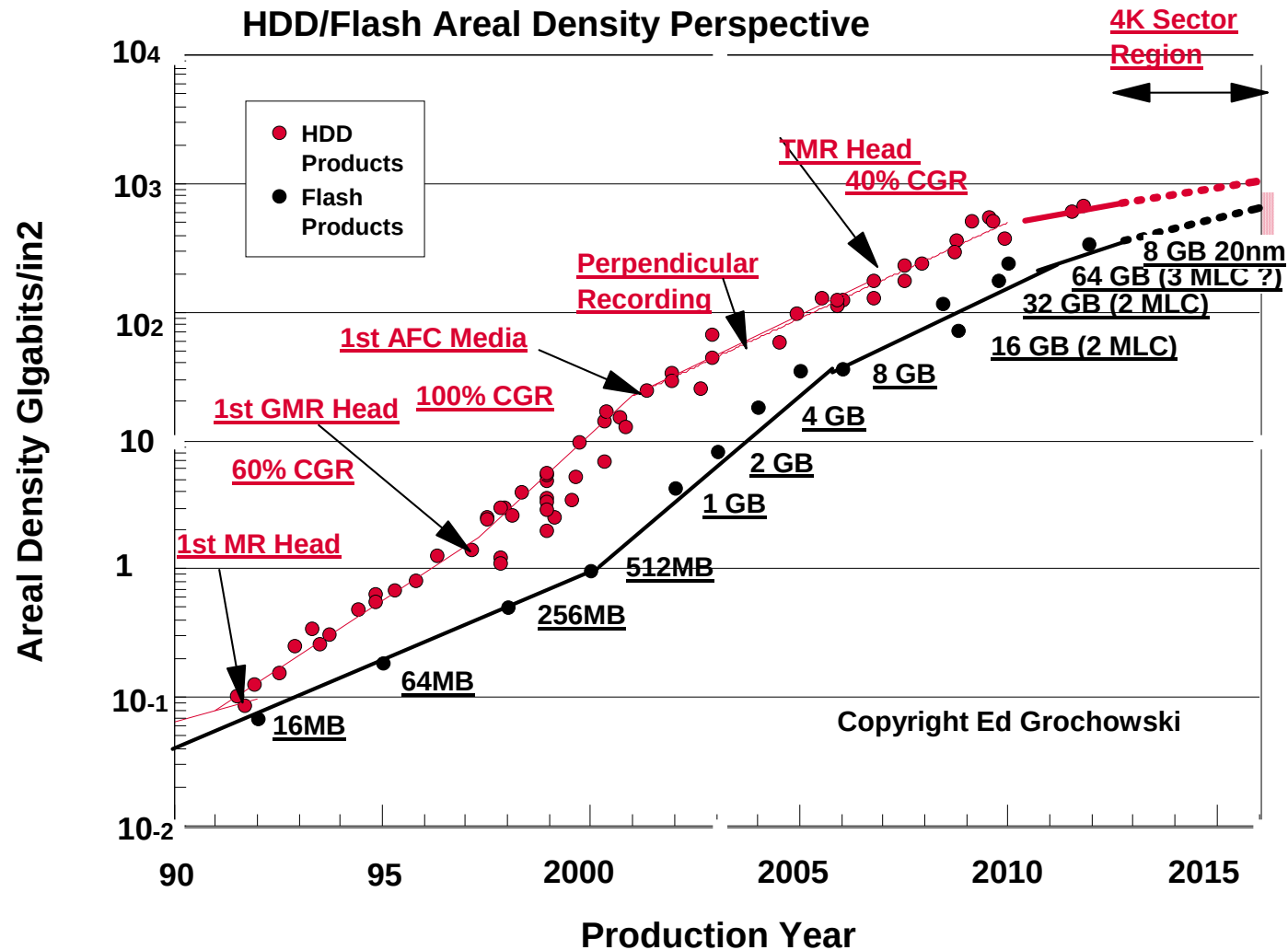
AVERAGE \$/GB FOR HDDS AND FLASH



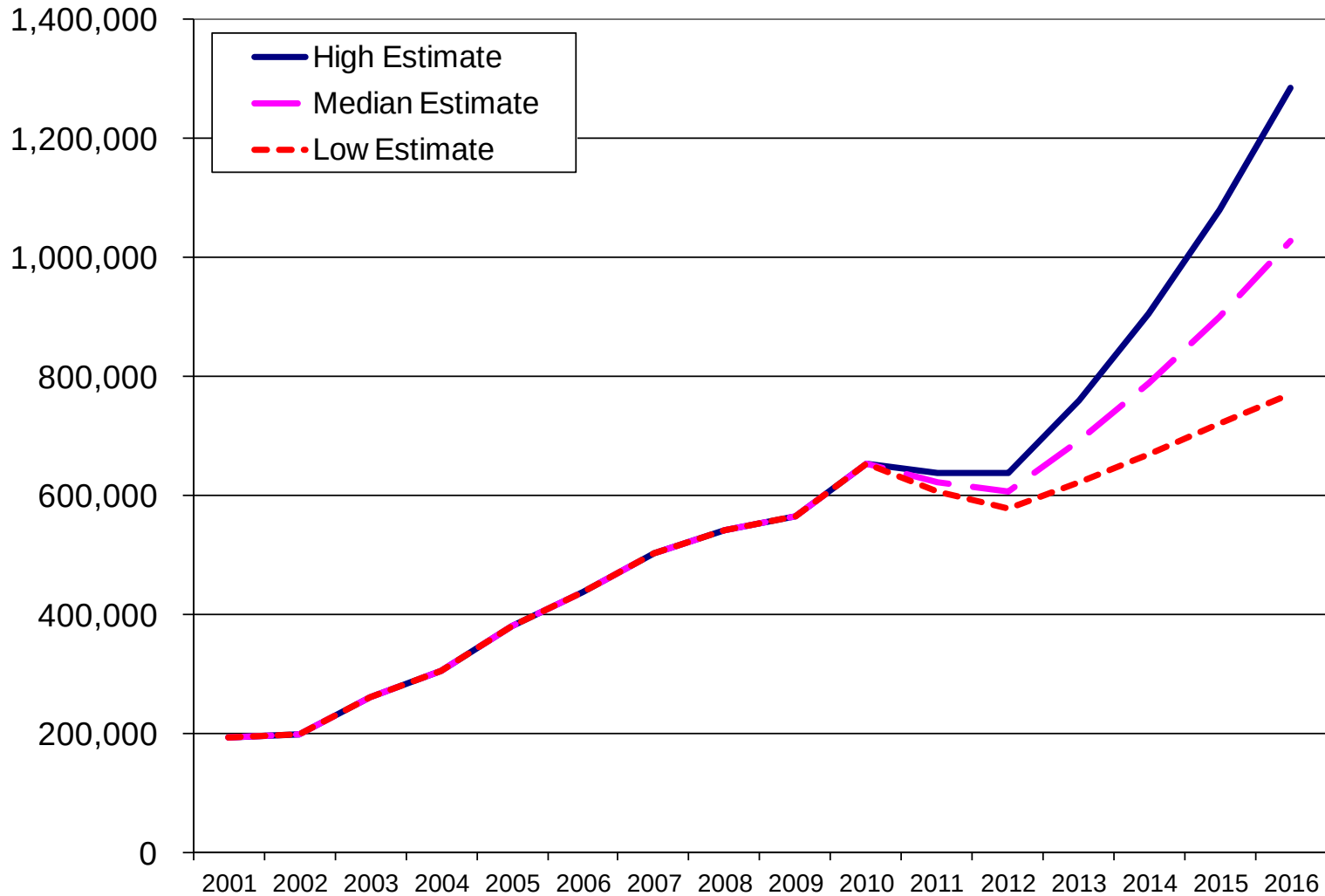
HDD AREAL DENSITY GROWTH AND



AREAL DENSITY GROWTH OF HDDS AND FLASH MEMORY

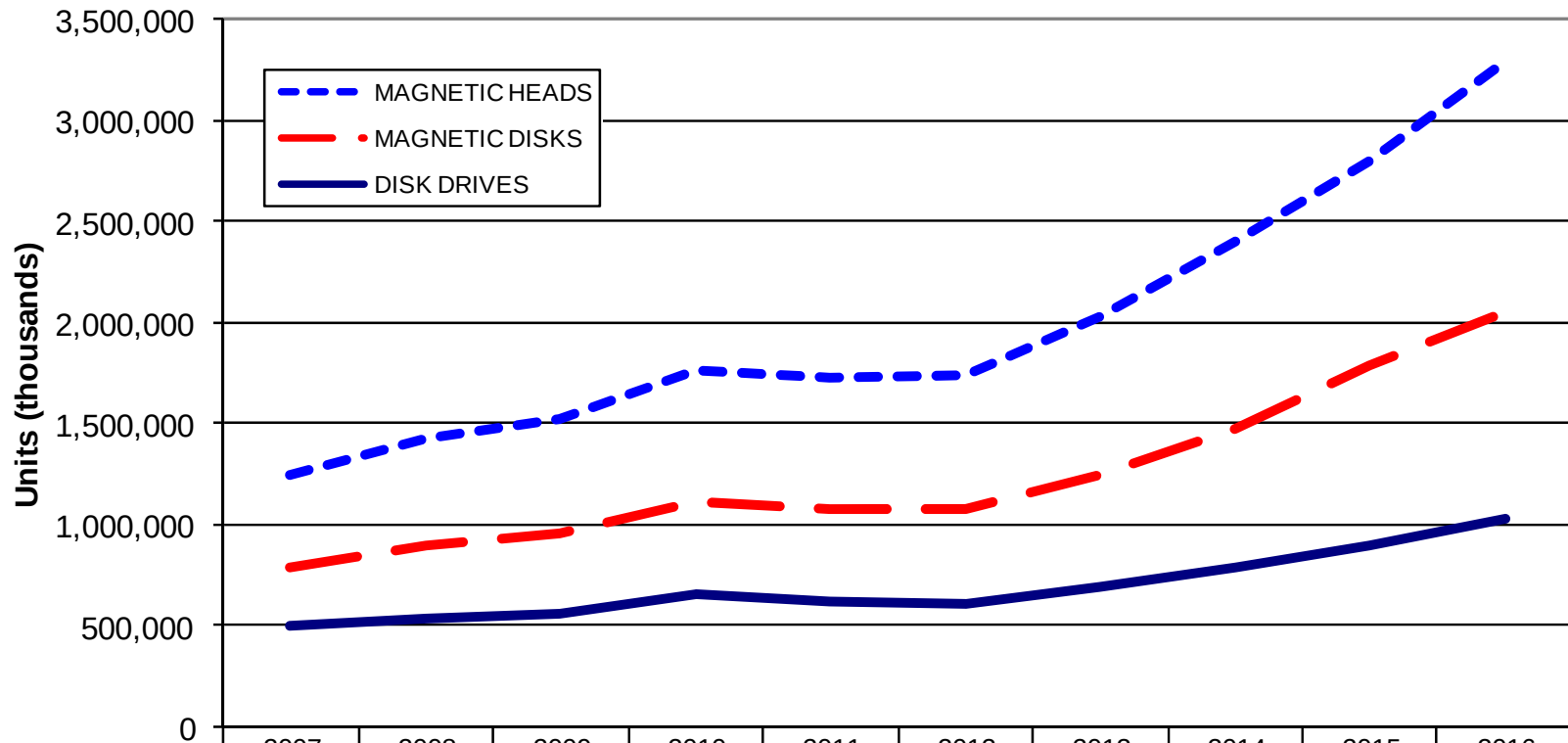


BANDED HDD UNIT VOLUME ESTIMATES.



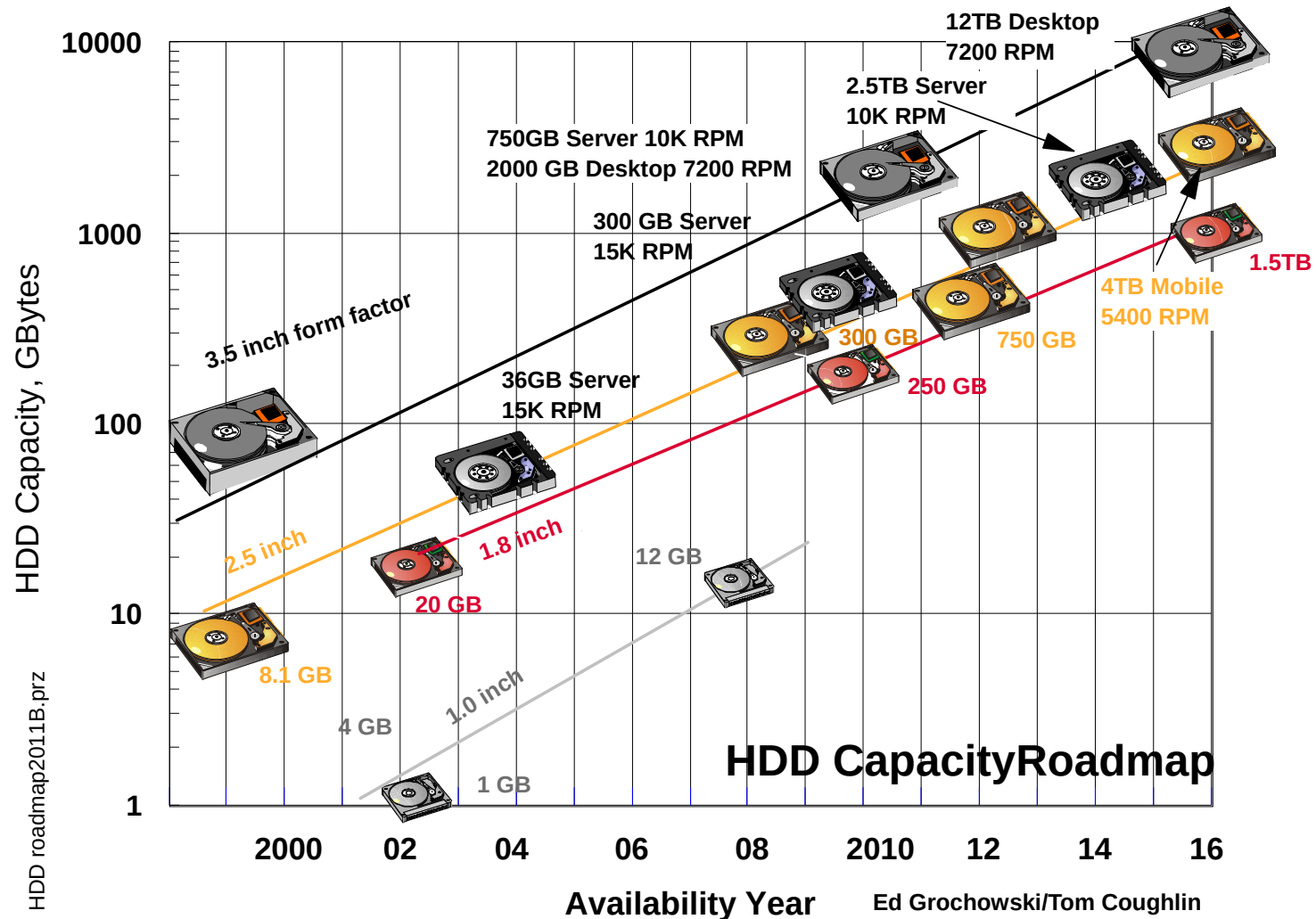
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ESTIMATES OF DRIVE, HEADS AND DISKS TO 2016.

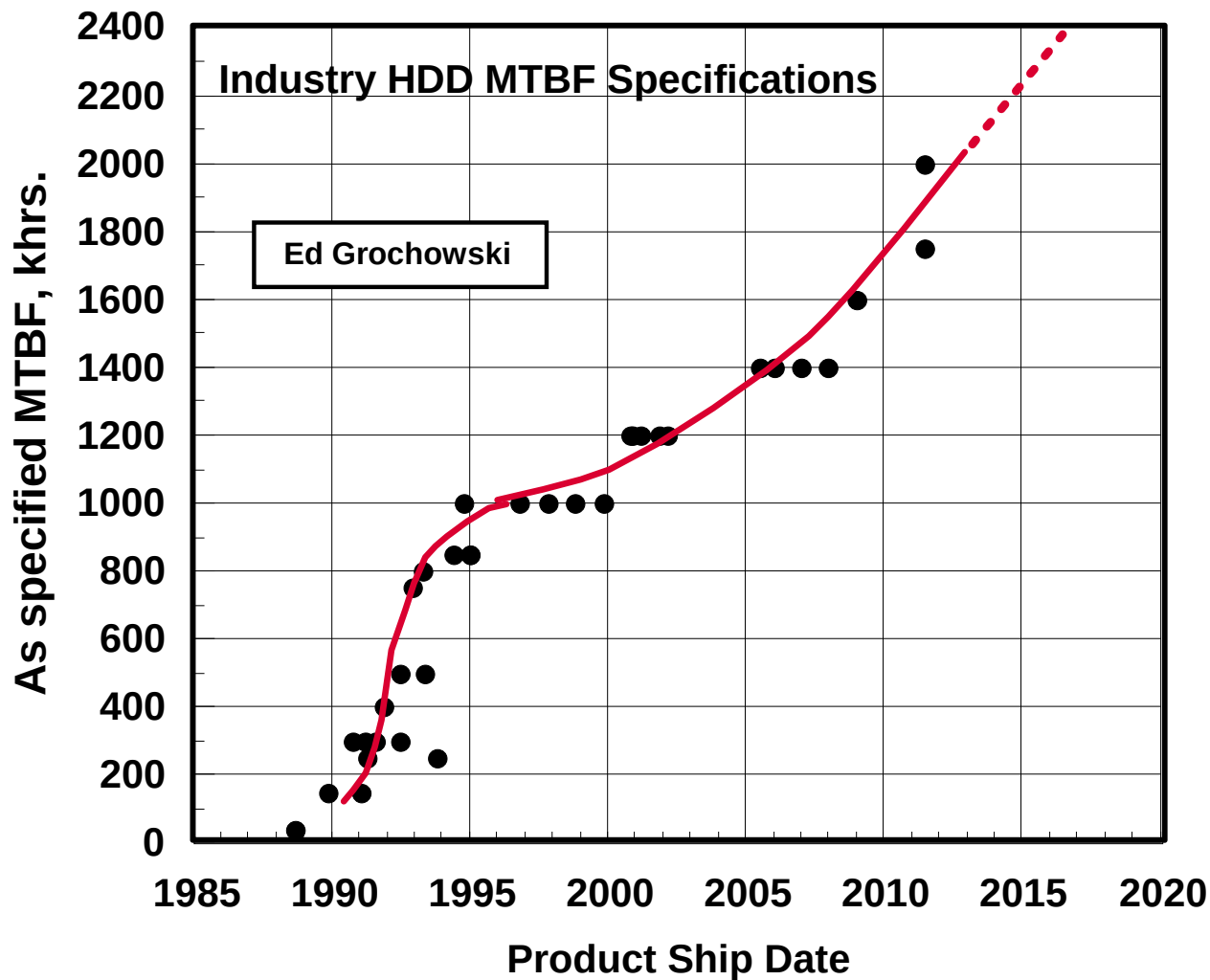


	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
MAGNETIC HEADS	1,241,136	1,424,939	1,521,262	1,764,546	1,720,248	1,741,597	2,027,086	2,403,859	2,792,790	3,291,203
MAGNETIC DISKS	789,104	897,439	955,515	1,109,600	1,070,733	1,080,392	1,239,668	1,471,683	1,782,153	2,046,655
DISK DRIVES	501,400	539,583	563,600	653,604	622,592	606,876	690,789	787,616	899,840	1,026,885

PROJECTIONS FOR HDD CAPACITIES AT VARIOUS FORM FACTORS

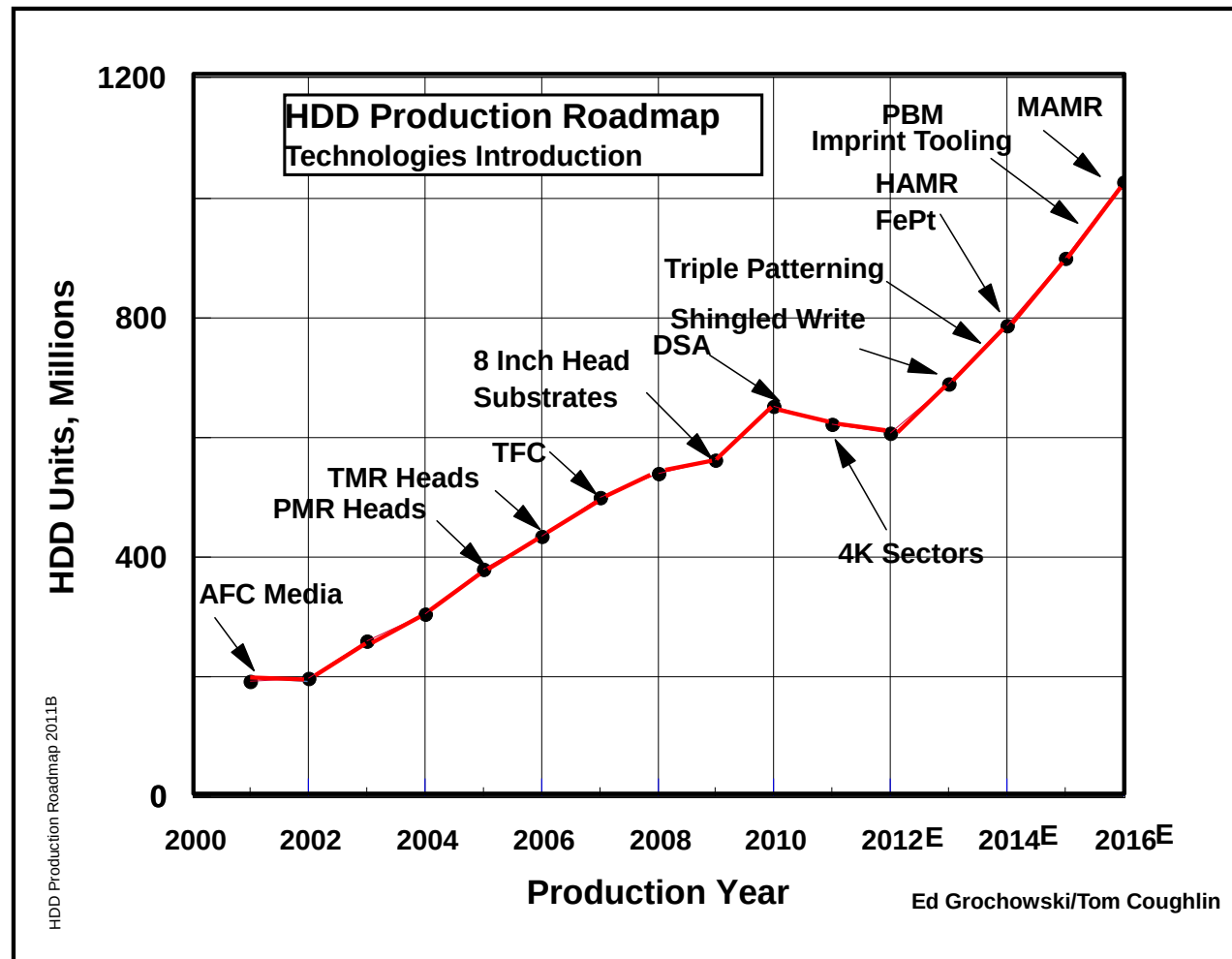


INDUSTRY HDD MTBF SPECIFICATIONS.



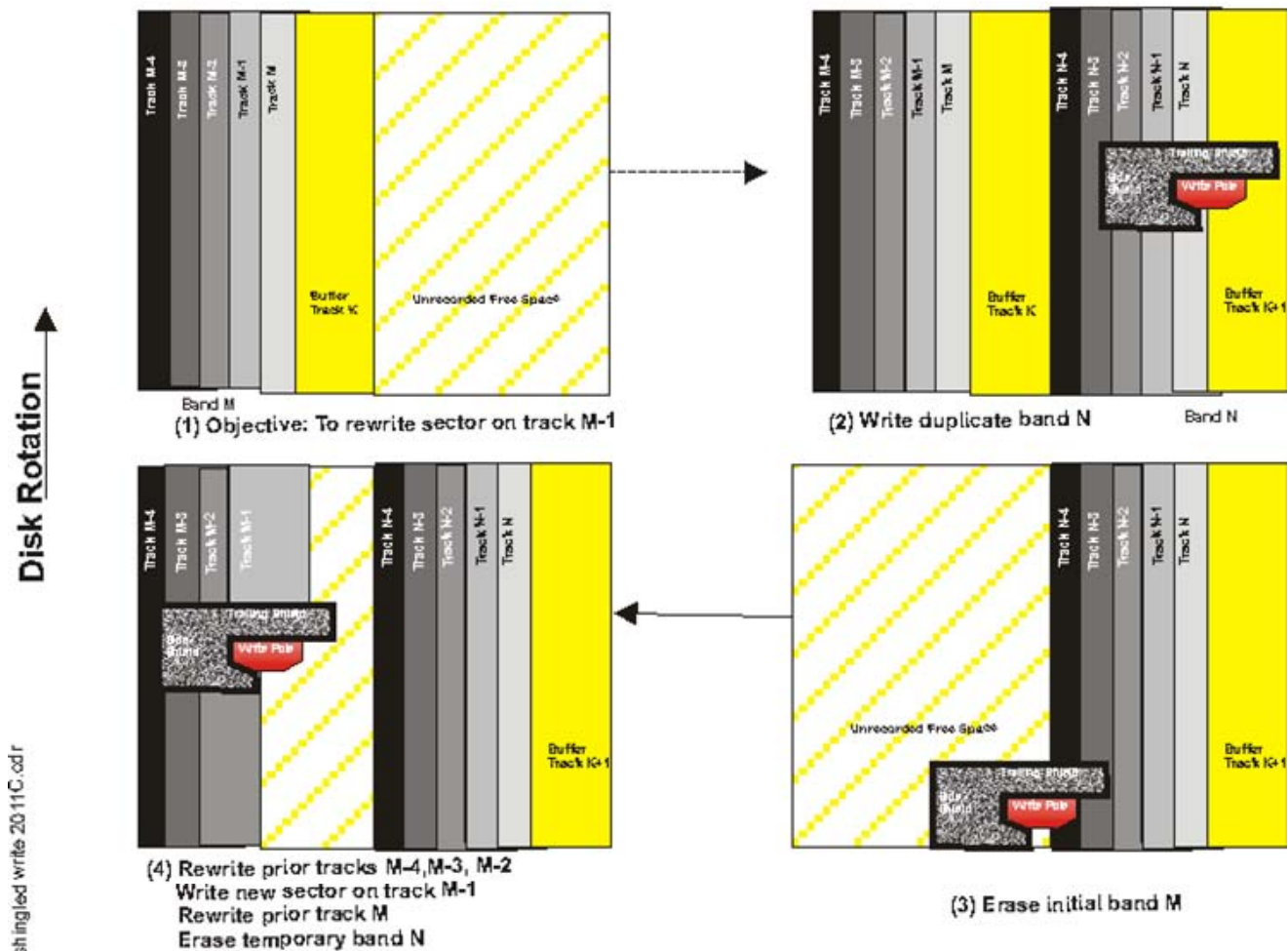
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HDD TECHNOLOGY INTRODUCTION WITH UNIT VOLUME GROWTH.

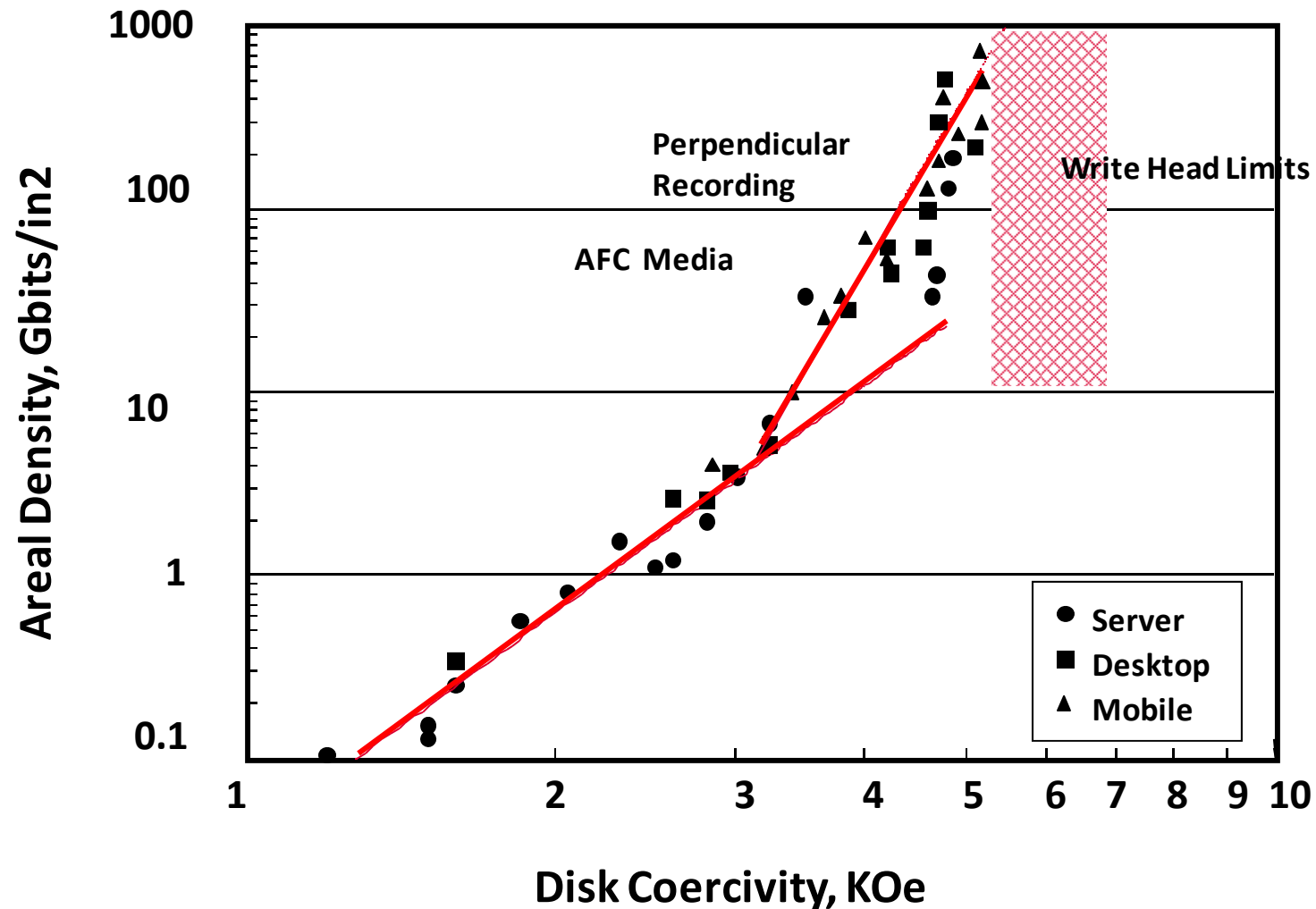


BLOCK OVERWRITING PROCESS IN SMR

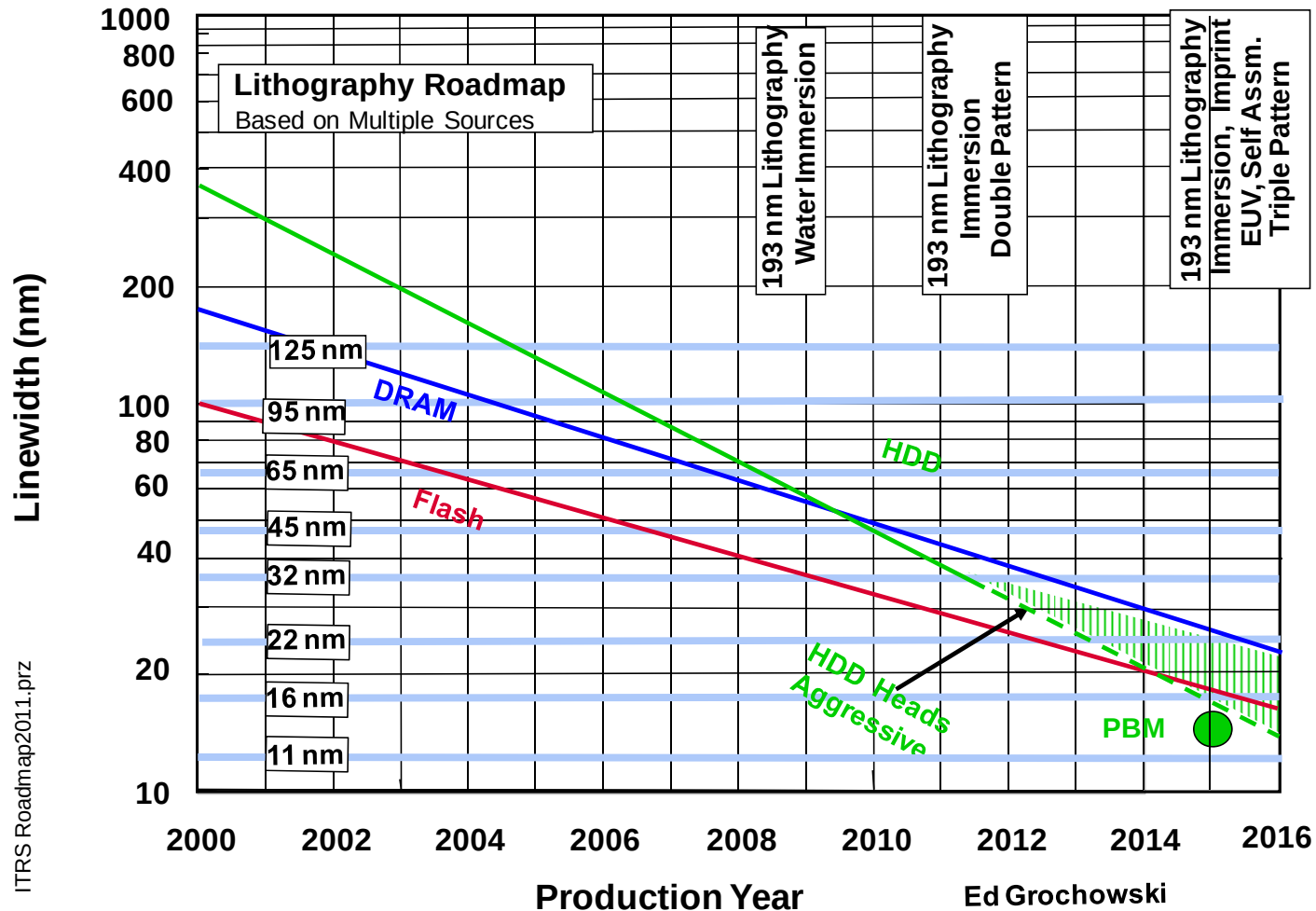
Shingled Rewrite Dynamics



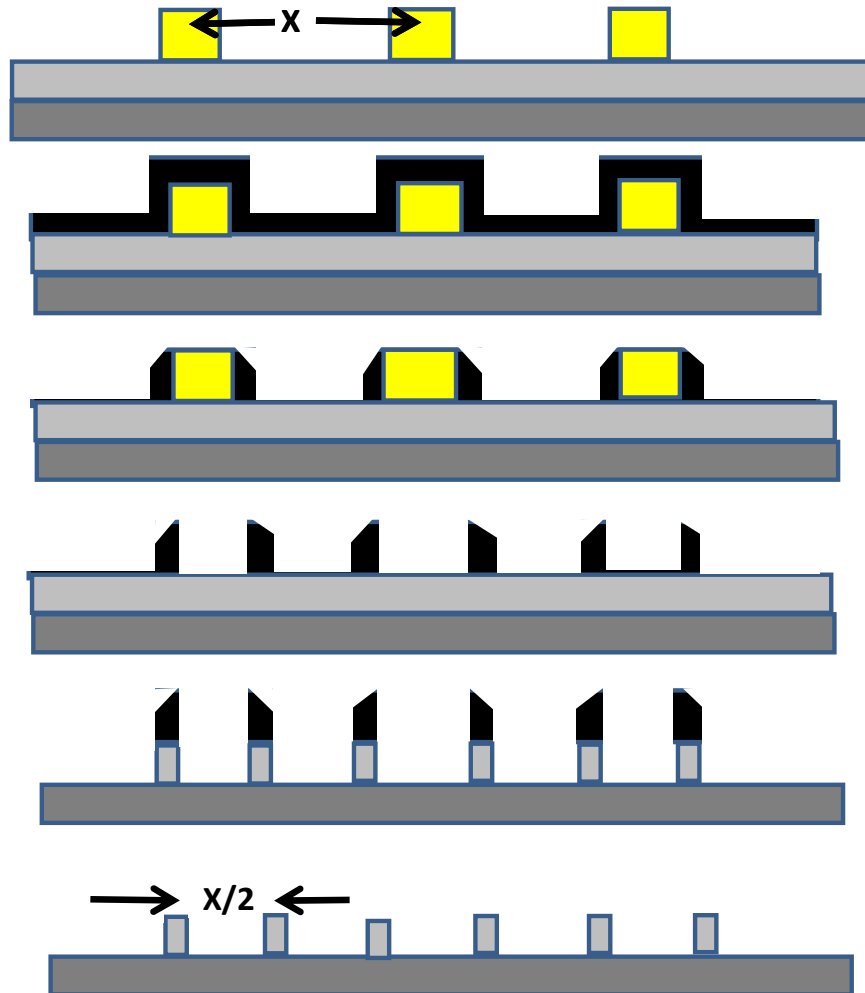
AREAL DENSITY AND DISK COERCIVITY EVOLUTION.



LITHOGRAPHY ROADMAP SHOWING HDD HEAD AND BPM/BPM TRENDS VS. ITRS SEMICONDUCTOR REQUIREMENTS.



SELF-ALIGNING DOUBLE PATTERN LITHOGRAPHY



First Pattern Photoresist
On Hardmask layer

Deposition

Spacer Formation
By Etching

First Pattern
Removal

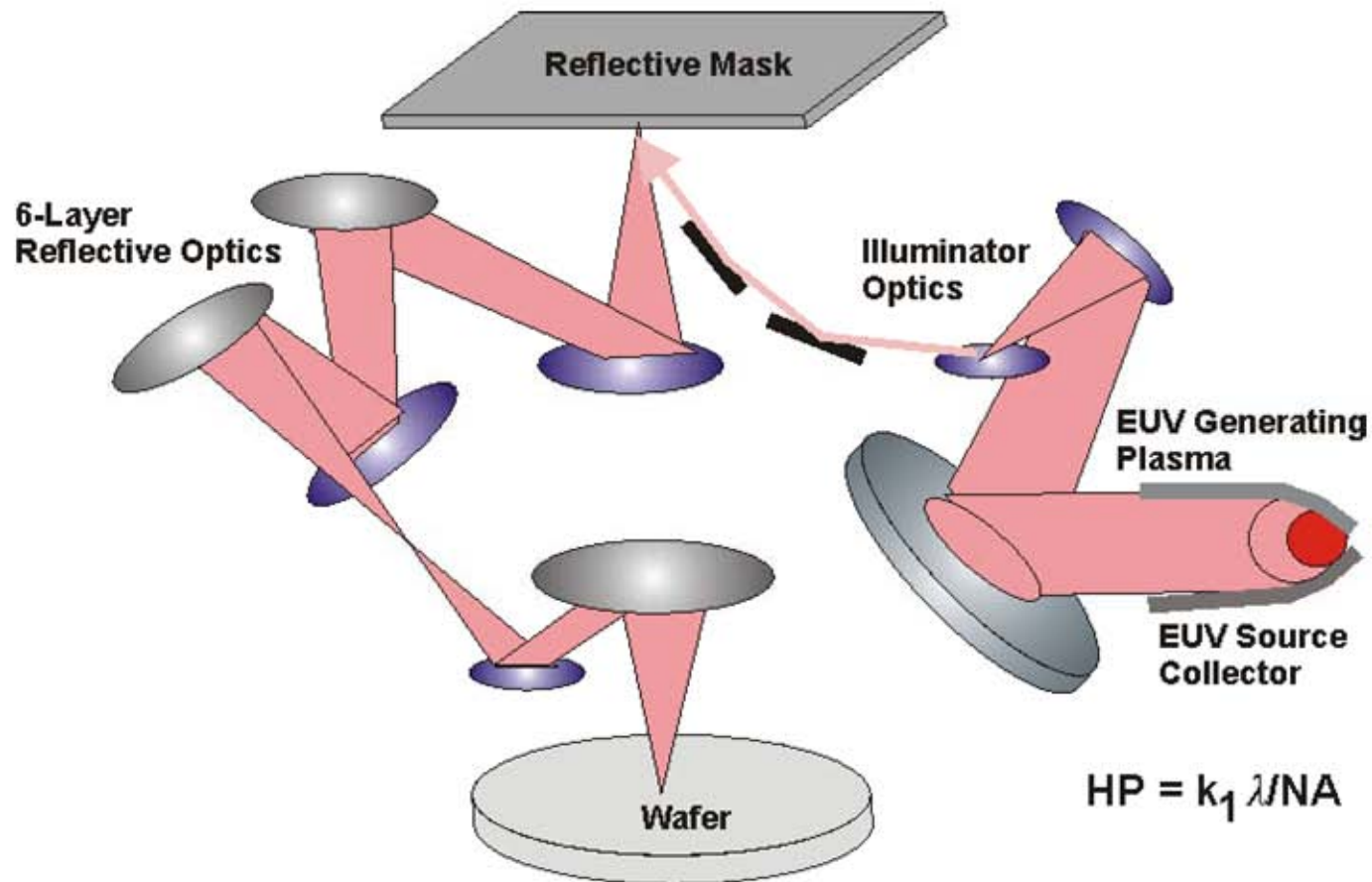
Etching With
Spacer Mask

Final Pattern
Trim Mask Required

Ed Grochowski

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EXPERIMENTAL EUV EXPOSURE TOOL

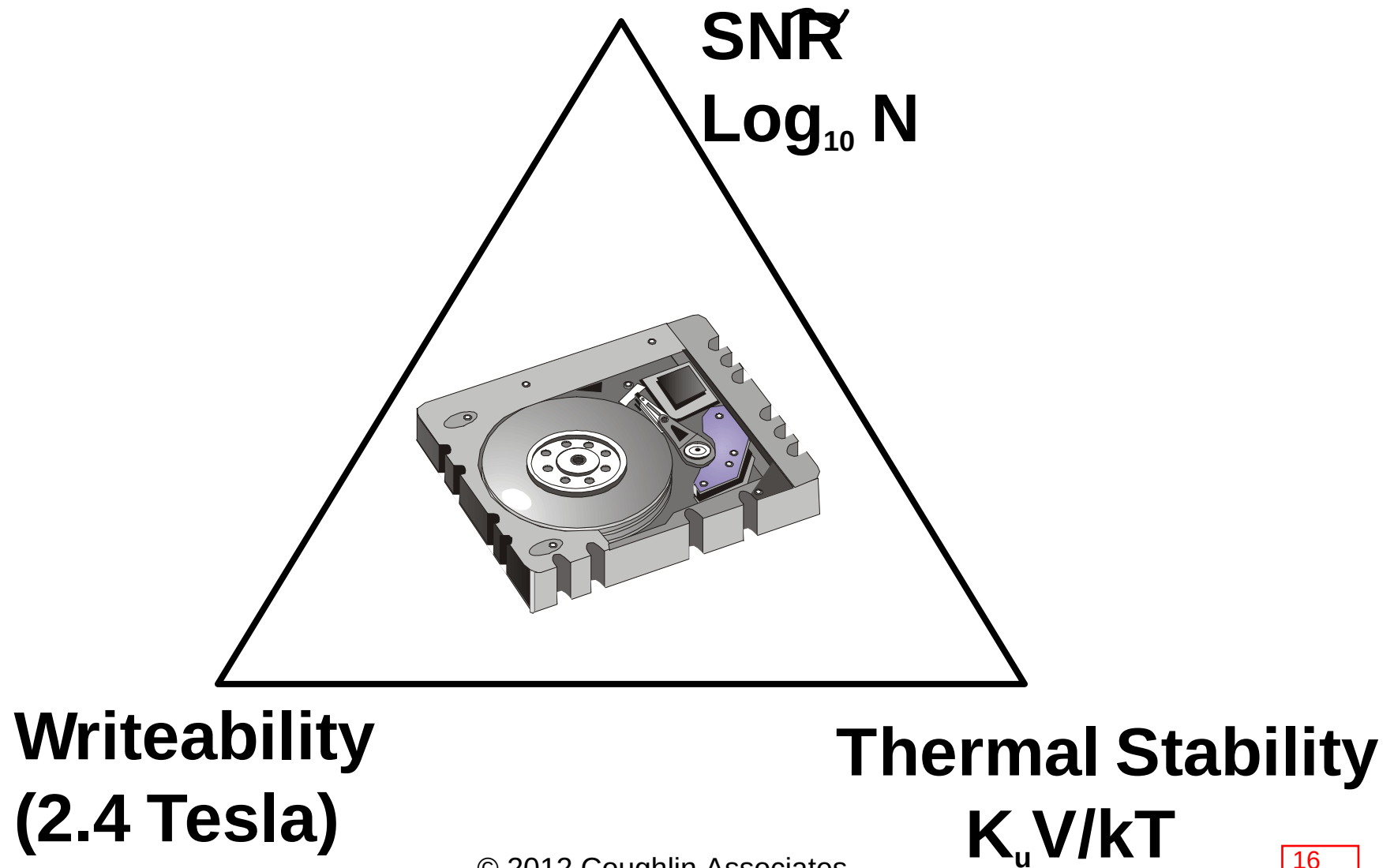


$$HP = k_1 \lambda / NA$$

EUV Exposure Tool

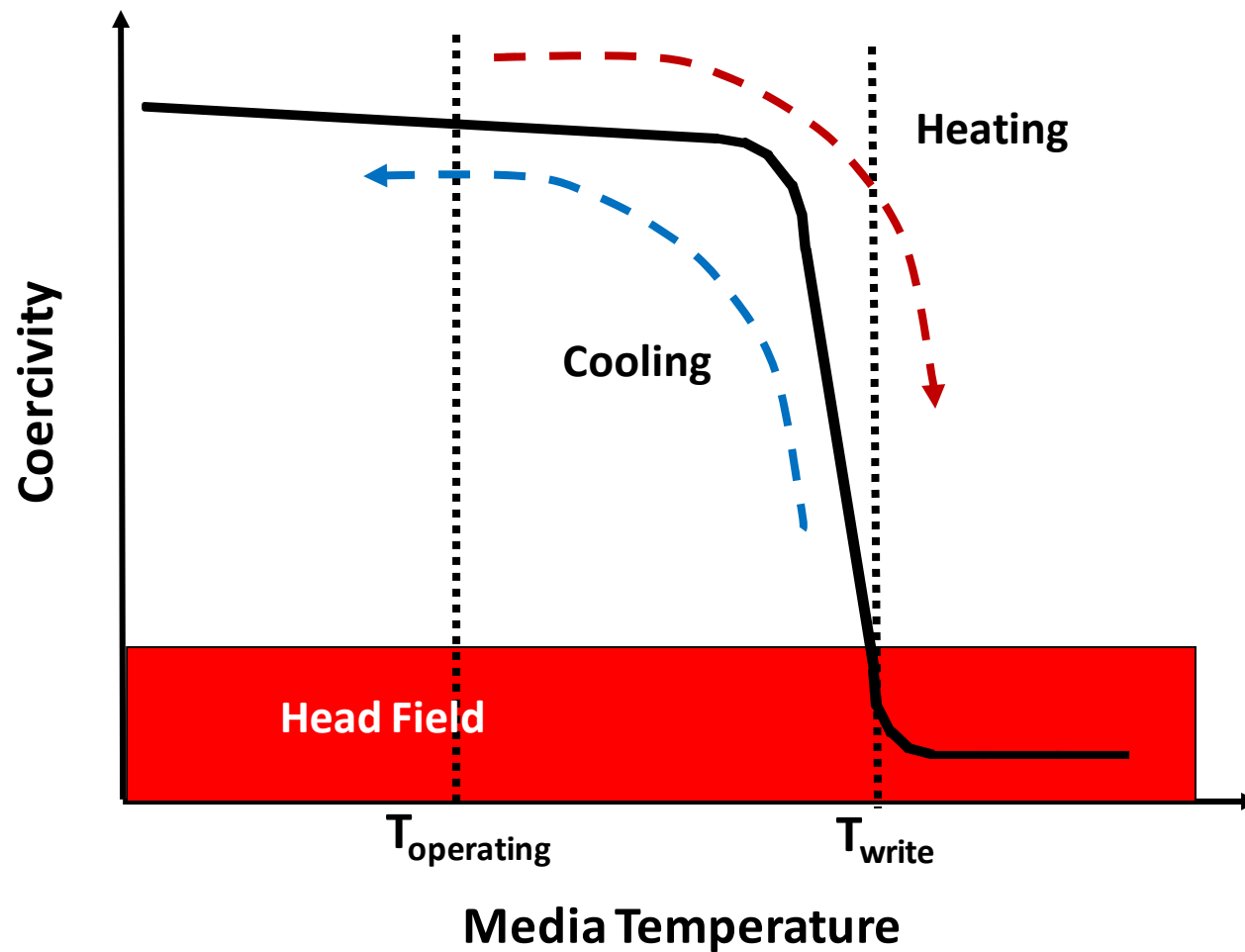
Source O. Wood GLOBALFOUNDRIES

MAGNETIC RECORDING TRILEMMA.



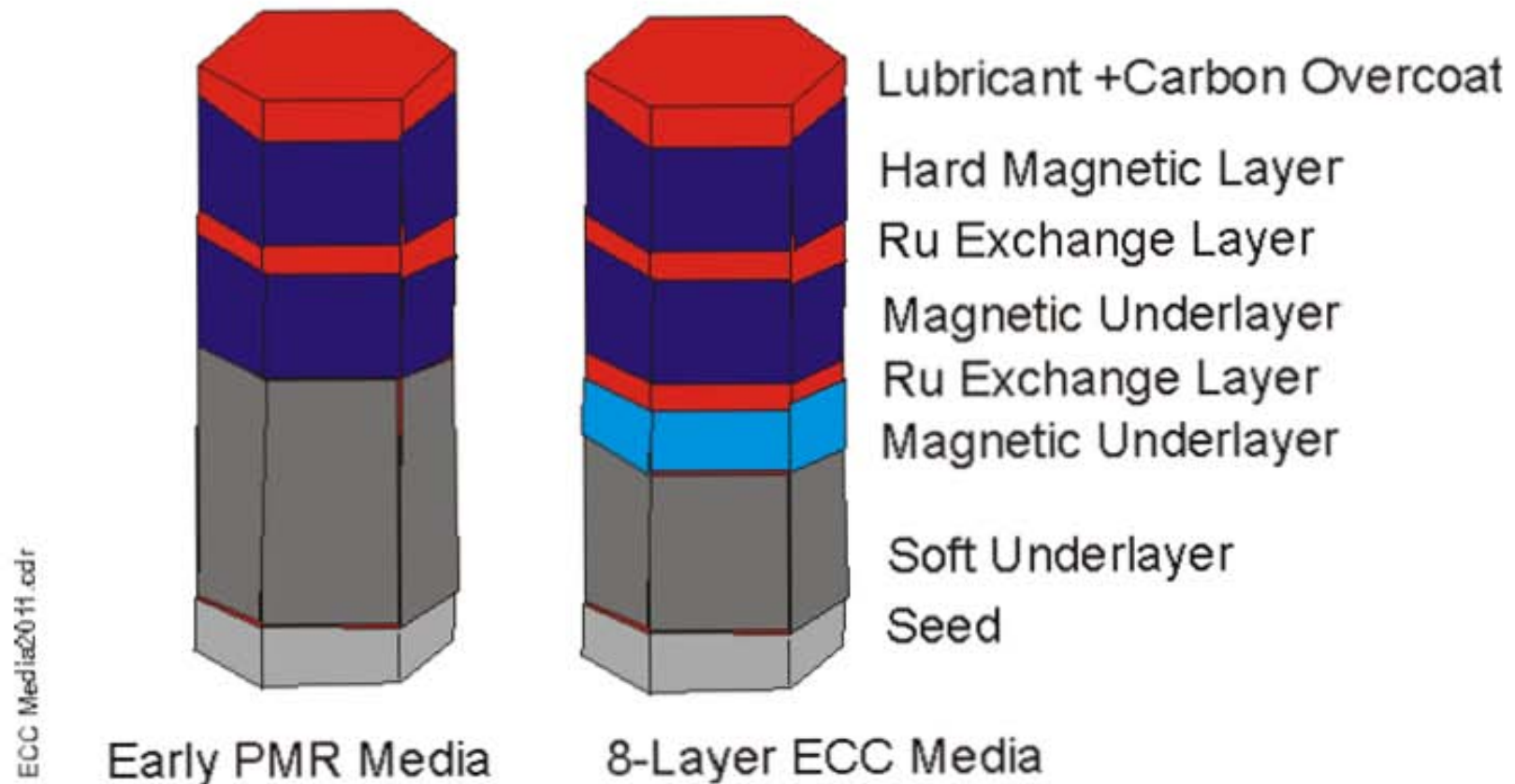
HEAT ASSISTED MAGNETIC RECORDING

Source: Seagate Technology Corp.



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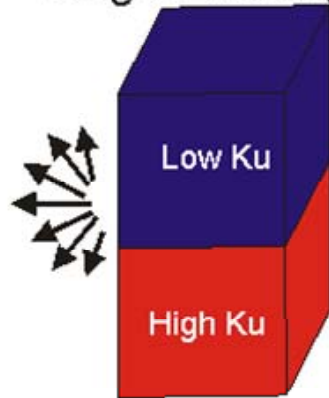
EVOLUTION OF PERPENDICULAR MAGNETIC RECORDING MEDIA.



ADVANCED ECC MAGNETIC MEDIA STRUCTURES

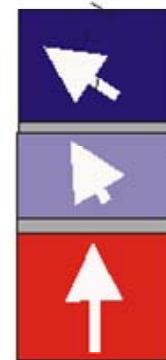
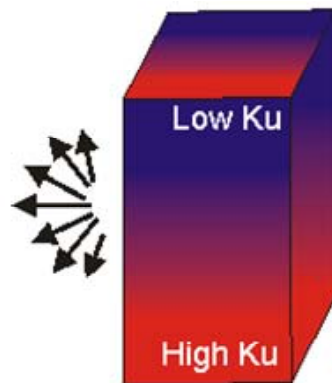
Advanced ECC Media

Single Exchange Break Layer



Two Spin Model

Double Exchange Break Layer

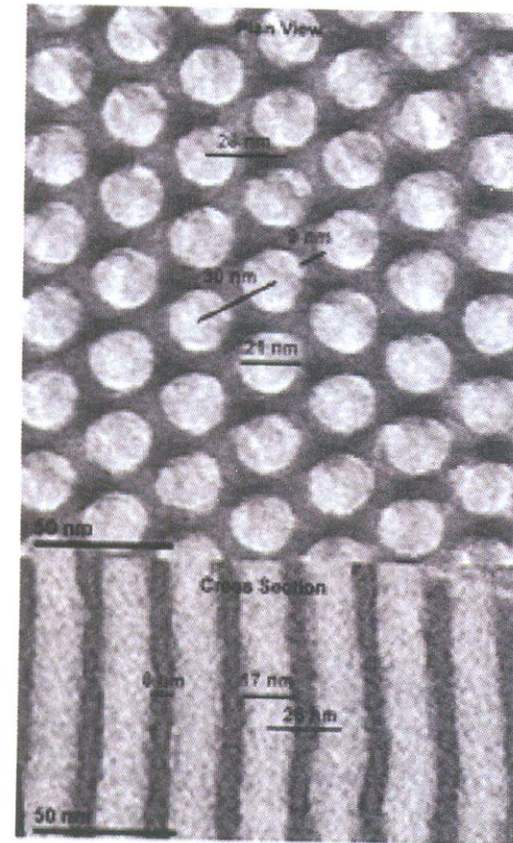
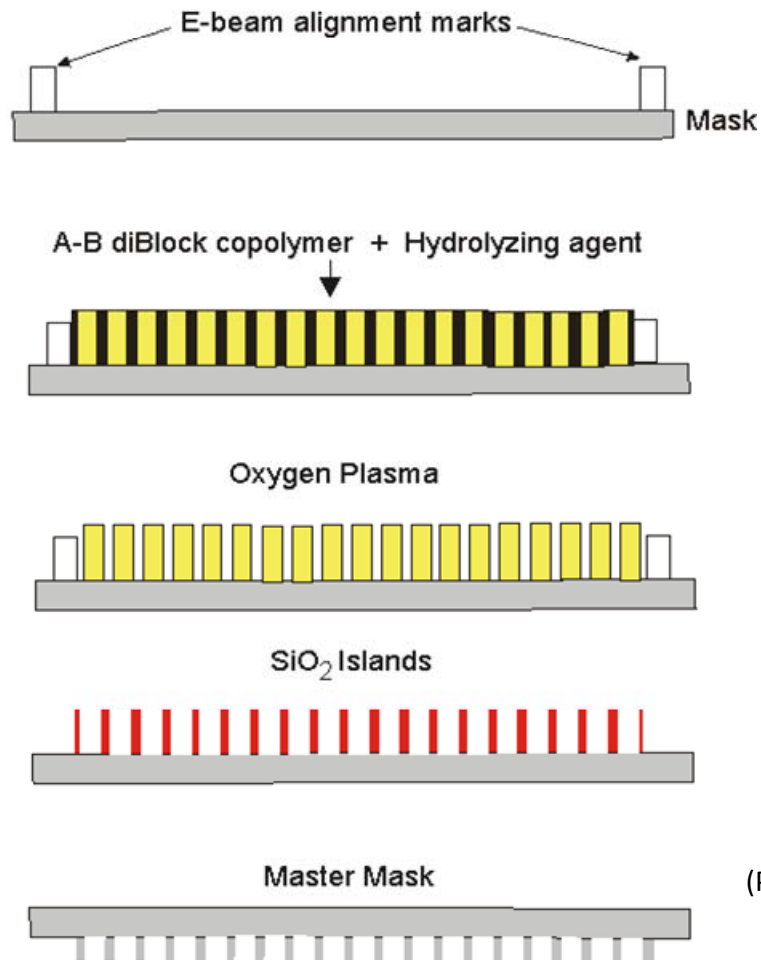


Three Spin Model

Based on Bertero. WD

ECC Advanced.odr

BLOCK COPOLYMER SELF ASSEMBLY.

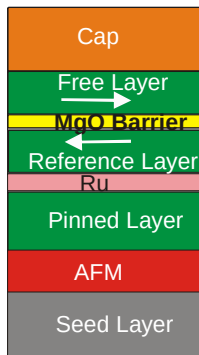


(Photo Courtesy IBM Almaden Research Center)

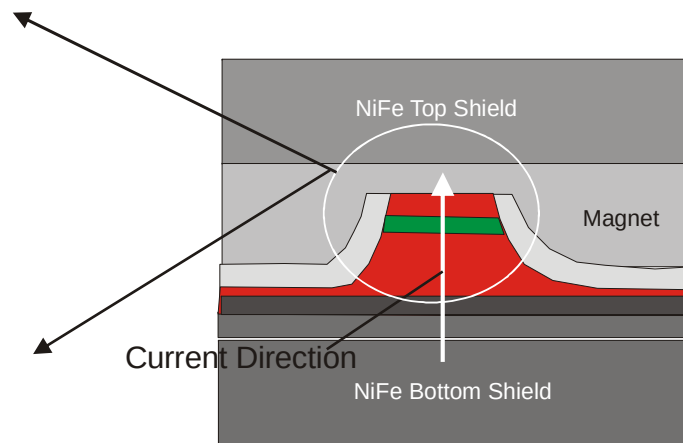
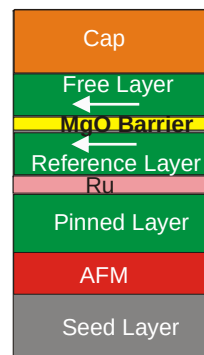
STRUCTURE OF TMR AND GMR CPP SENSORS.

CPP TMR

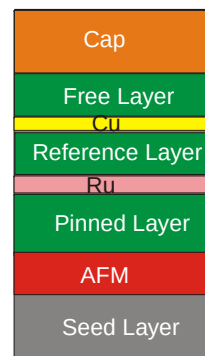
Non-Conducting



Conducting



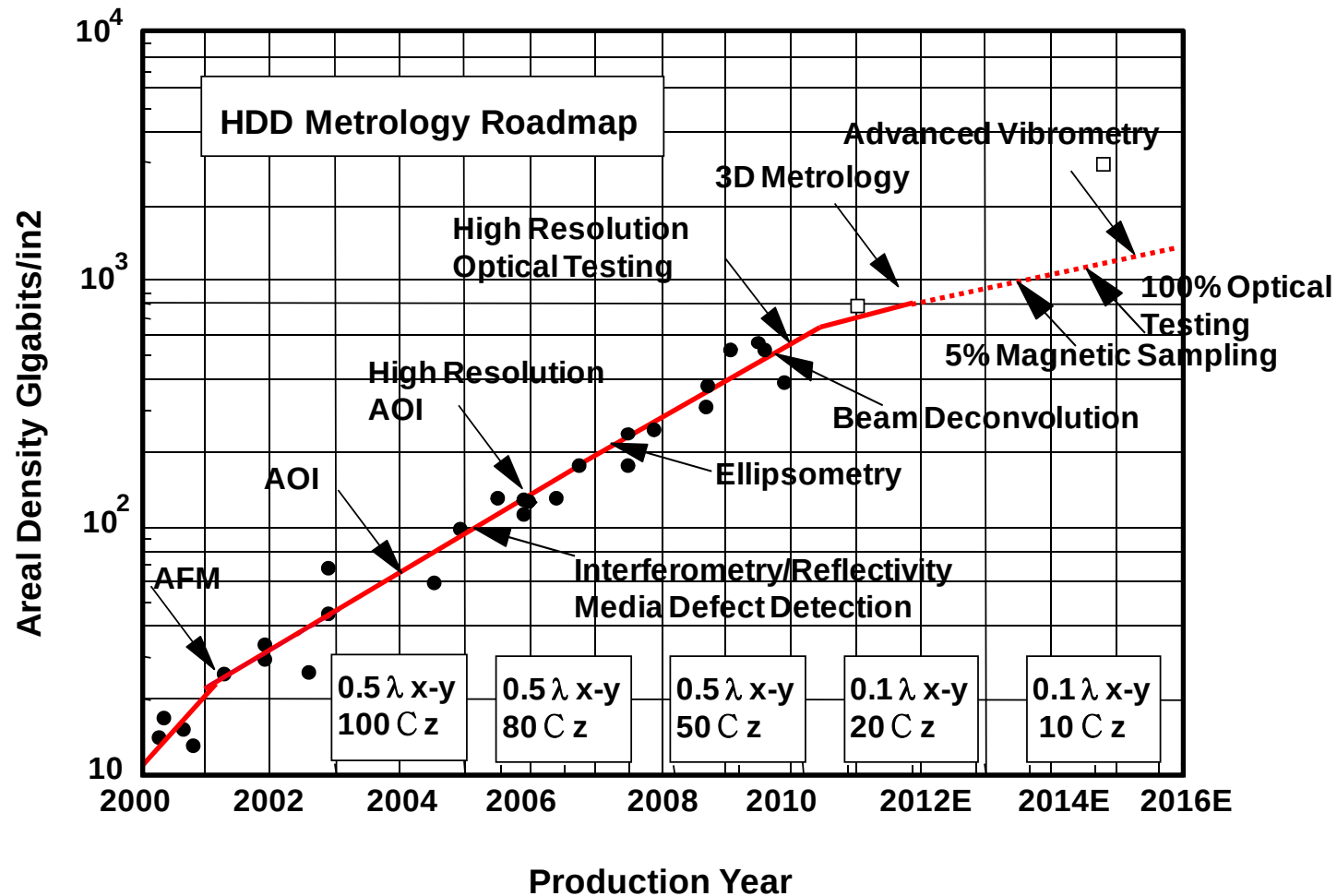
CPP GMR



CPP GMR TMR2011

CPP TMR Read Head Technology

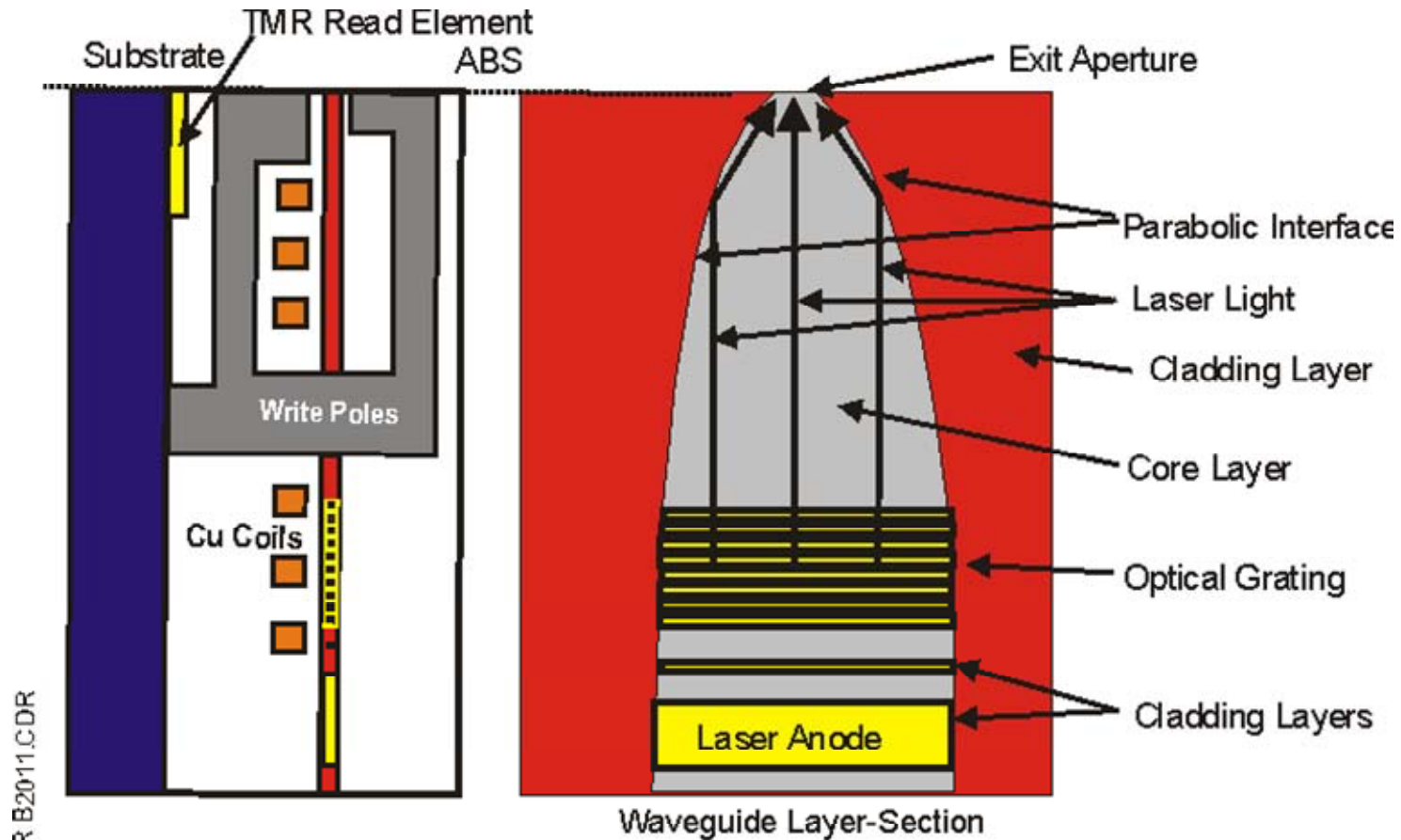
HDD COMPONENT TESTING/METROLOGY ROADMAP VS. AREAL DENSITY.



Edward Grochowski

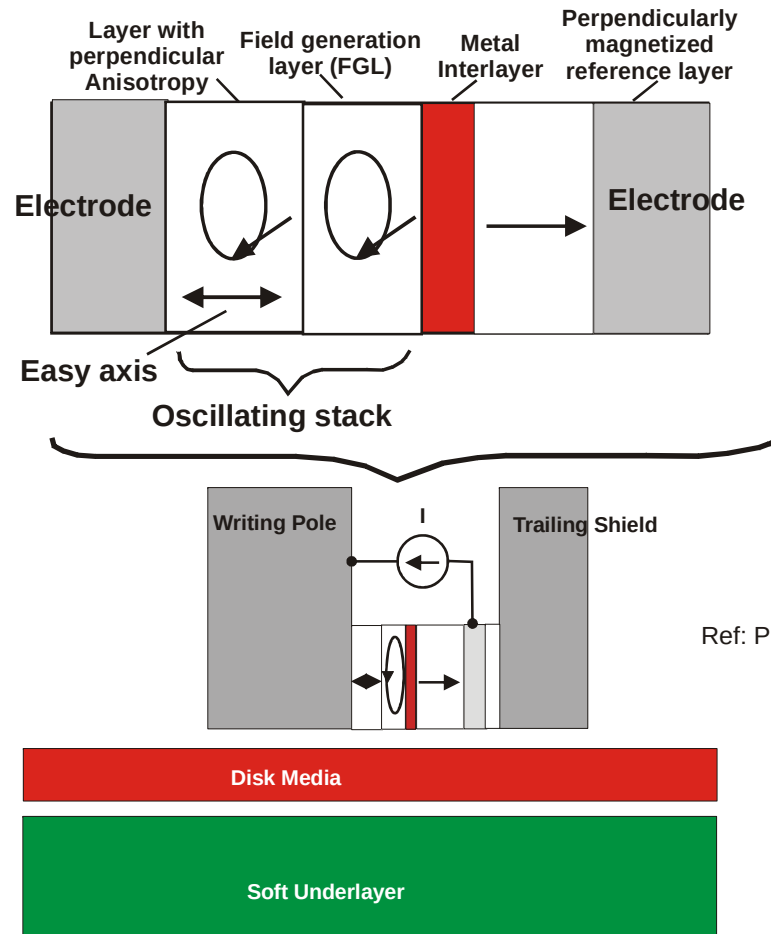
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HEAT ASSISTED MAGNETIC RECORDING WITH LASER SOURCE IN THE HEAD



Source: Seagate Technology Corp.
U.S. Patent 7609480 Shuk et al.

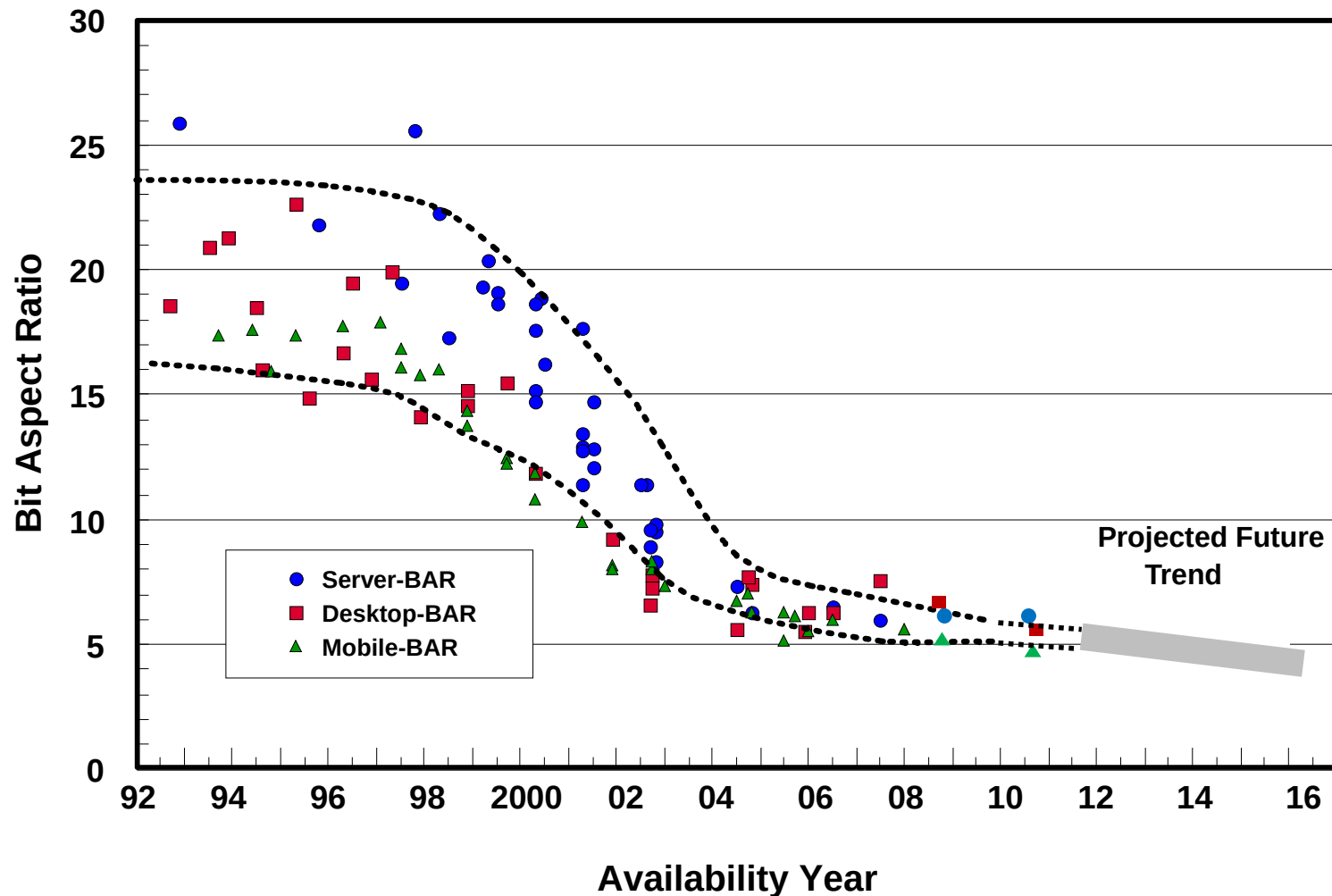
HEAT MICROWAVE ASSISTED MAGNETIC RECORDING (MAMR) PROCESS



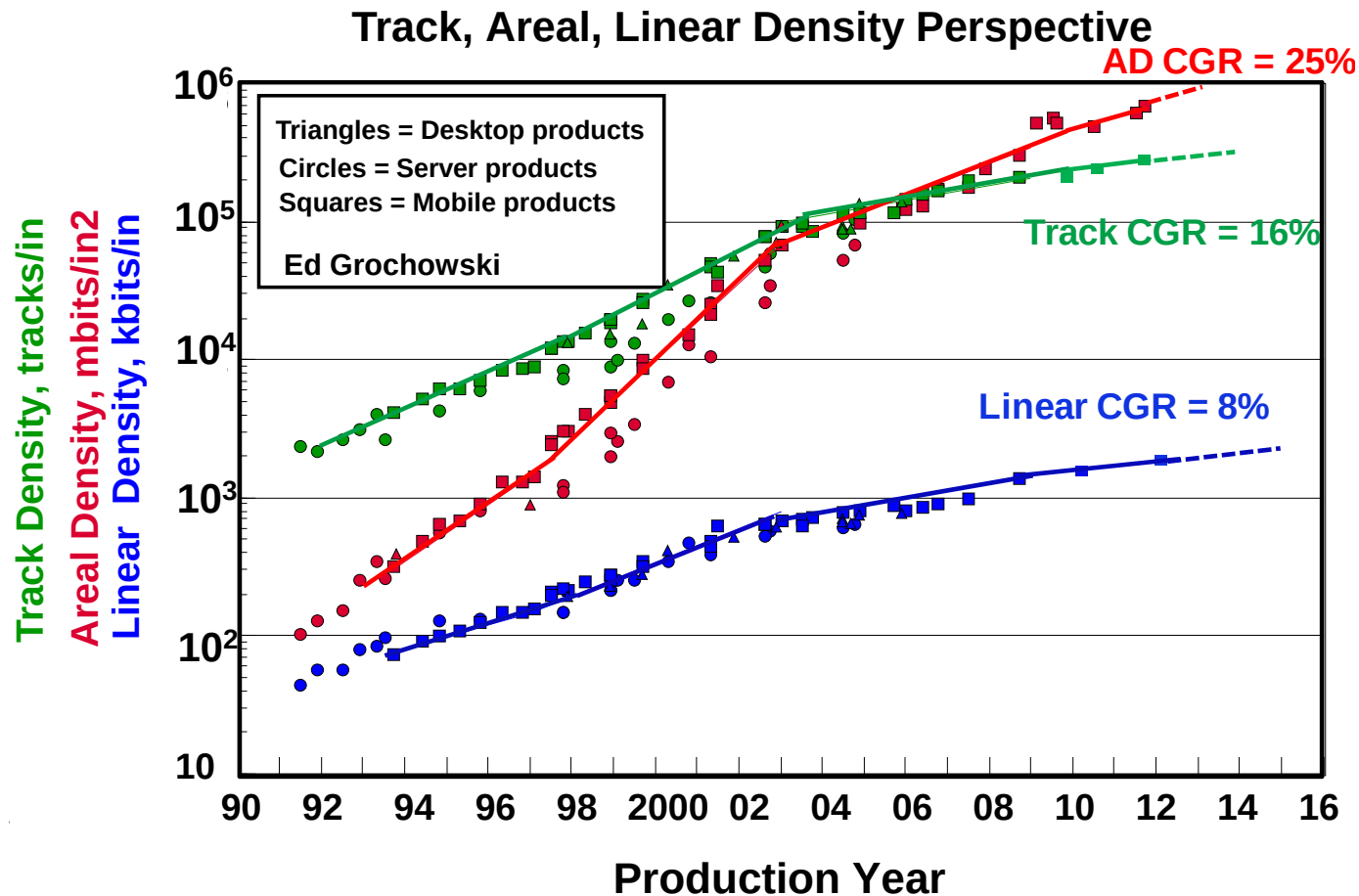
Ref: Prof Jimmy Zhu, CMU

MAMR2011C.cdr

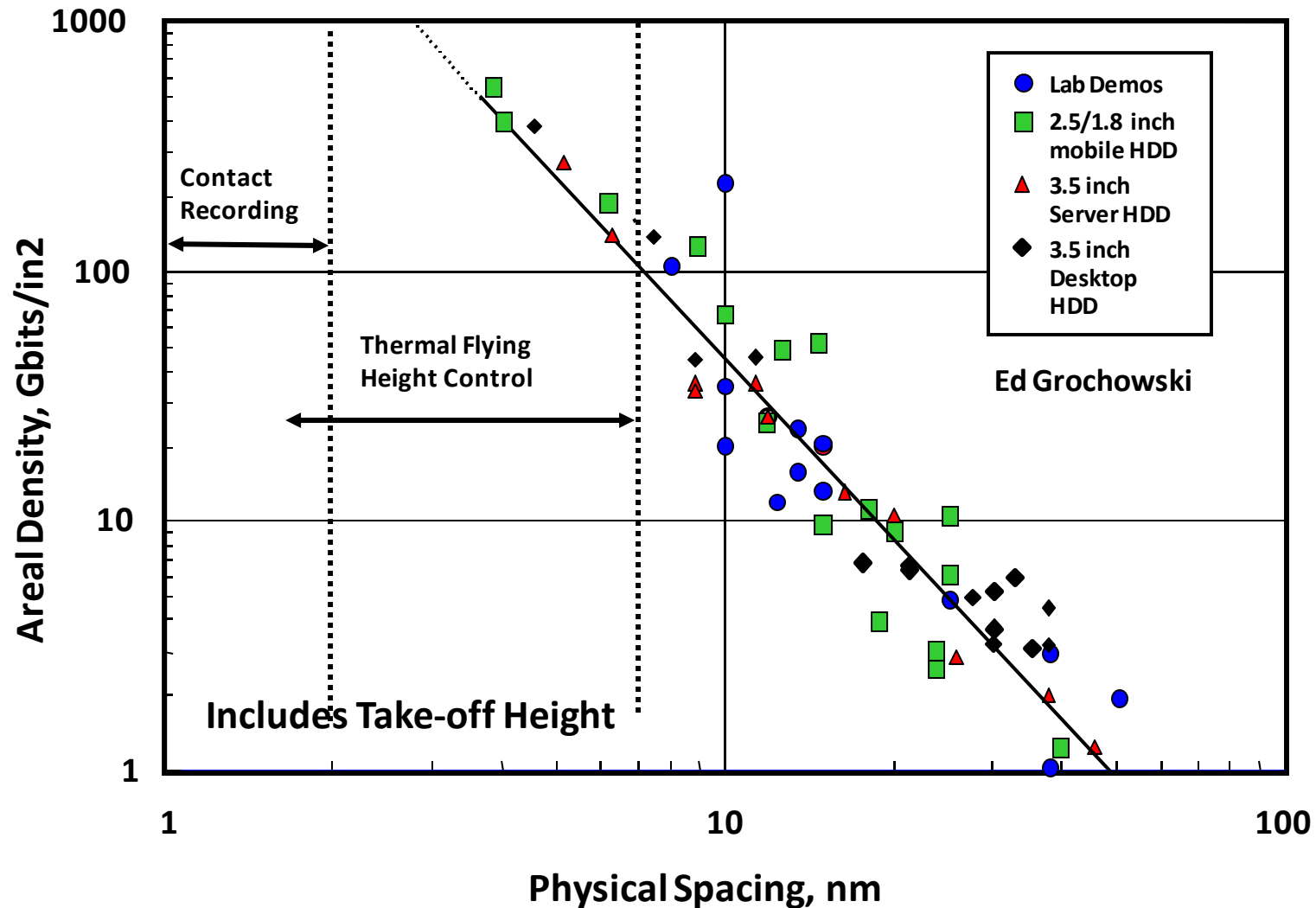
DEVELOPMENT OF BIT ASPECT RATIO WITH TIME.



TRACK DENSITY, LINEAR DENSITY AND AREAL DENSITY TRENDS.



HDD SPACING AND AREAL DENSITY RELATIONSHIP.



HDD COMPANY REVENUE AND INDUSTRY CAPITAL EQUIPMENT SPENDING ESTIMATES (2007 TO 2016).

Year	Total HDD Est. Revenue	Total HDD Industry Capital Est. Equipment Spending	% Capital Equipment Spending/Revenue
2007	\$32.6 B	\$2.28 B	7.0%
2008	\$32.9 B	\$2.37 B	7.2%
2009	\$30.2 B	\$1.35 B	4.5%
2010	\$34.8 B	\$3.01 B	8.6%
2011	\$41.5 B	\$3.64 B	8.8%
2012	\$48.5 B	\$4.23 B	8.7%
2013	\$54.2 B	\$4.83 B	8.9%
2014	\$60.5 B	\$5.66 B	9.4%
2015	\$67.6 B	\$6.77 B	10.0%
Total (2007- 2015)	\$402.7 B	\$34.14 B	8.1% (avg)