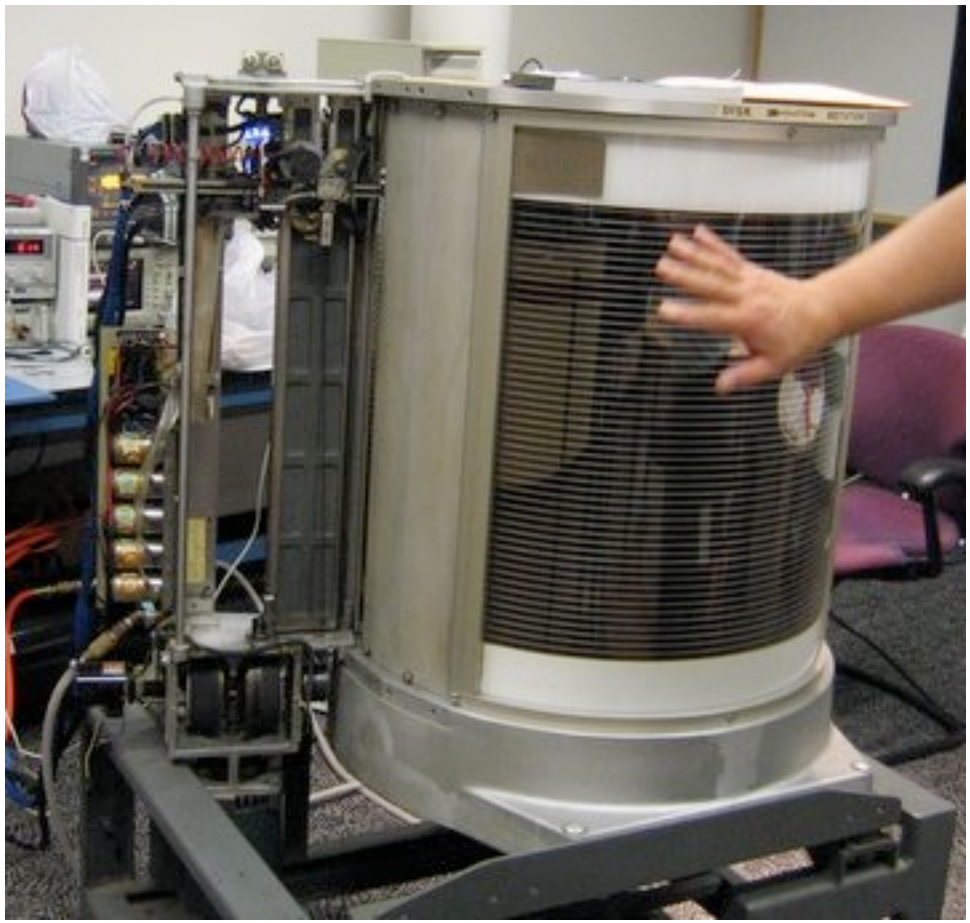
magnetic information storage



IBM 350 RAMAC, the first hard disk

it stored about 4.4Mb

wikipedia.org - "RAMAC"

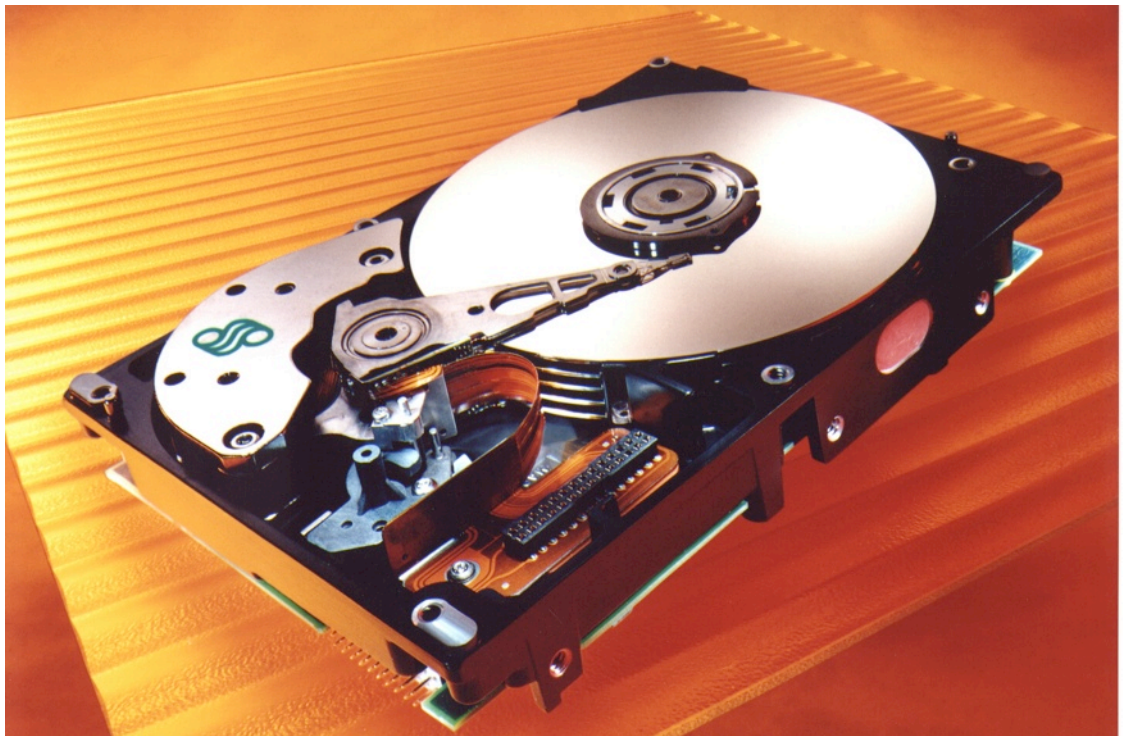
what do I mean by magnetic recording?

what do I mean by magnetic recording?

what do I mean by magnetic recording?

hard disks.

mostly hard disks.



why do we use hard disks?

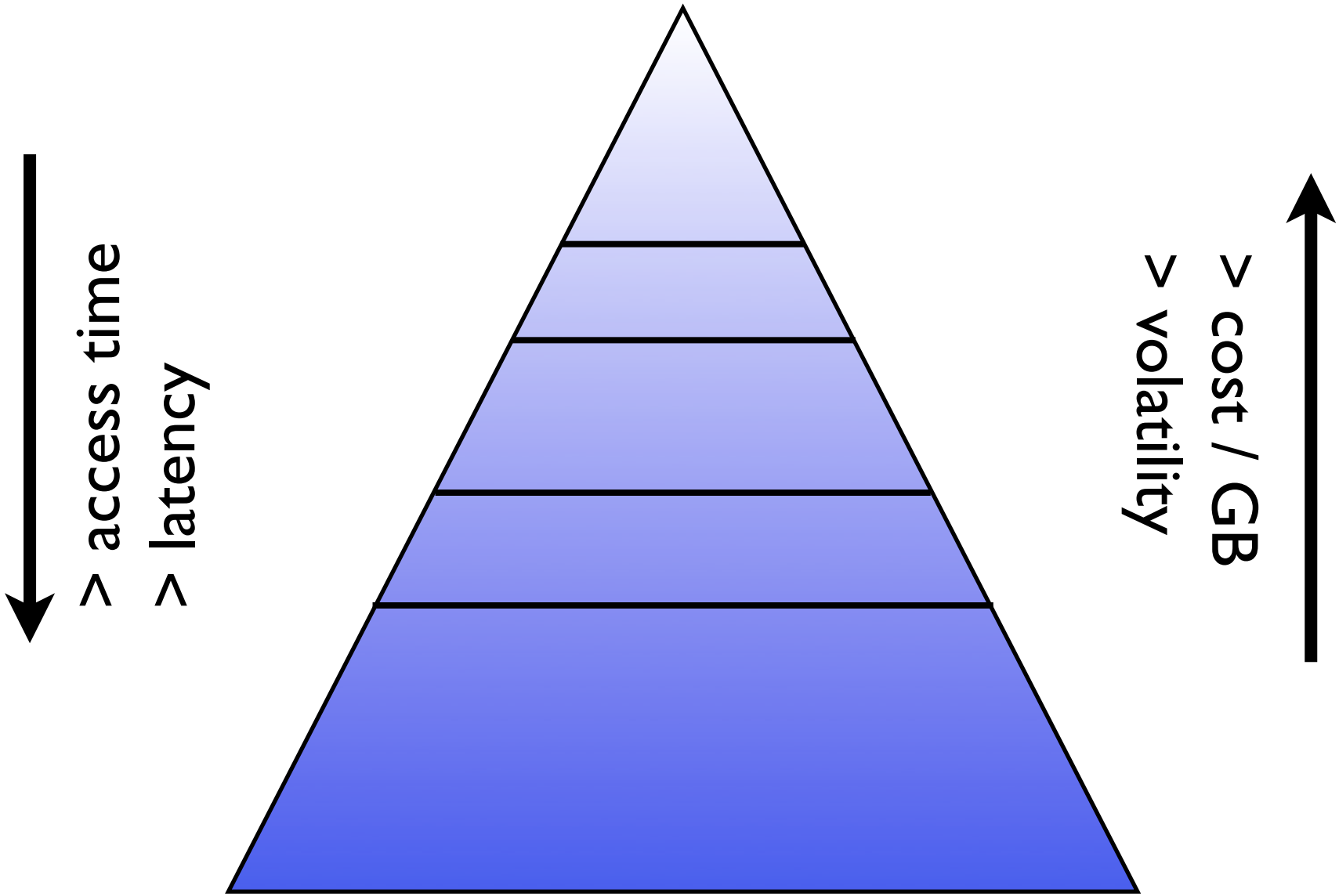
what is their role in a computer?

benefits?

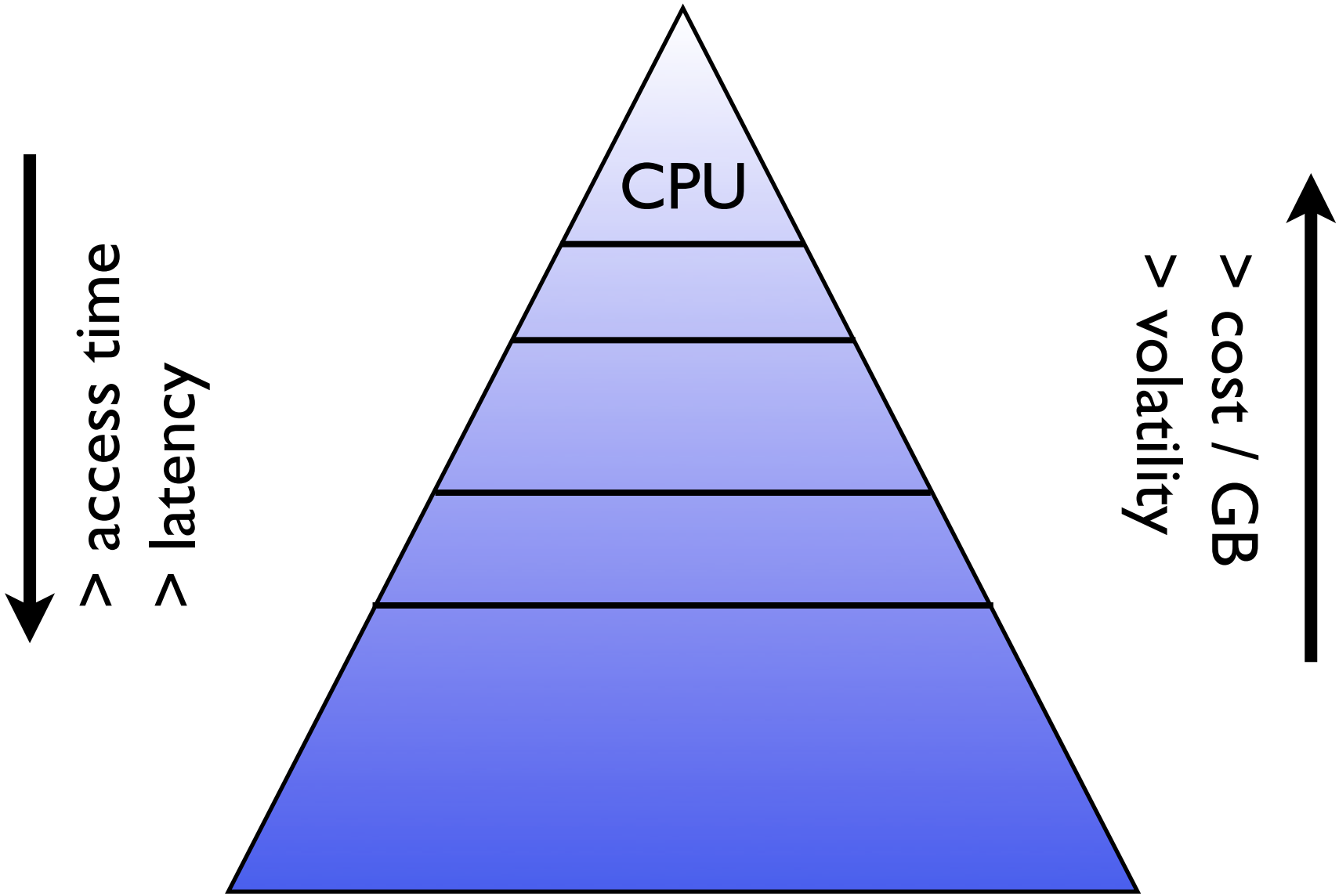
disadvantages?

and the real reason .. $$$

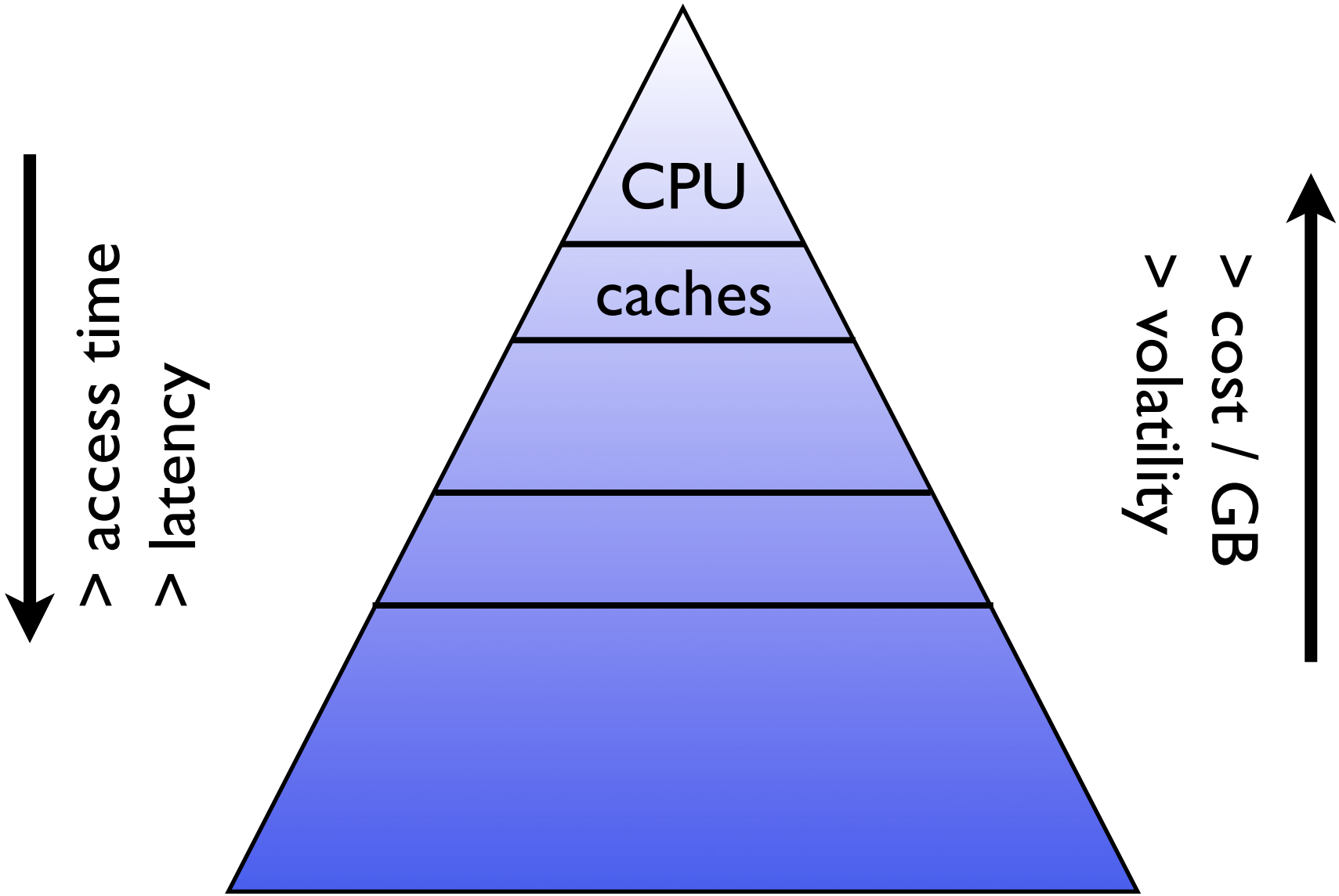
basic PC architecture



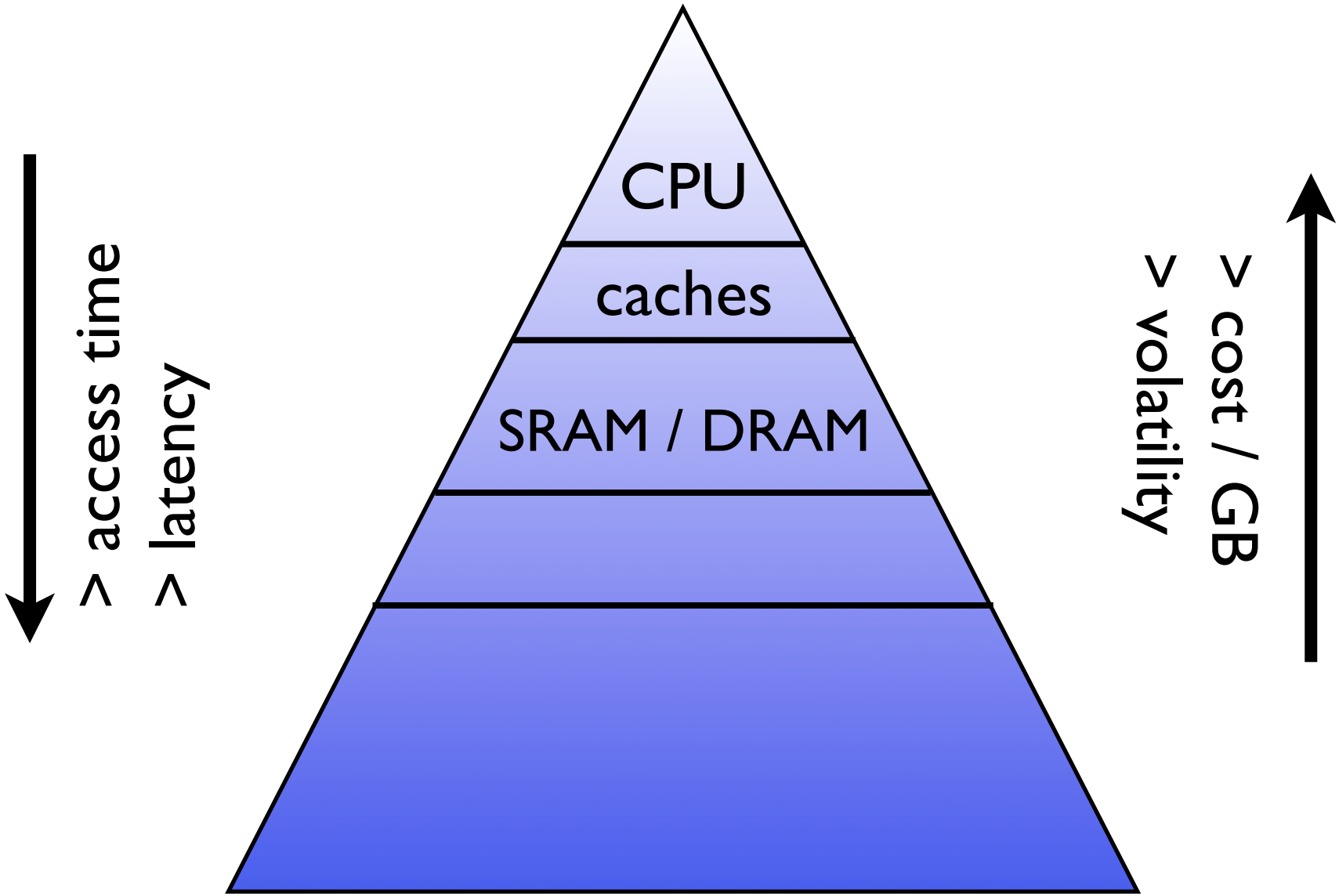
basic PC architecture



basic PC architecture



basic PC architecture



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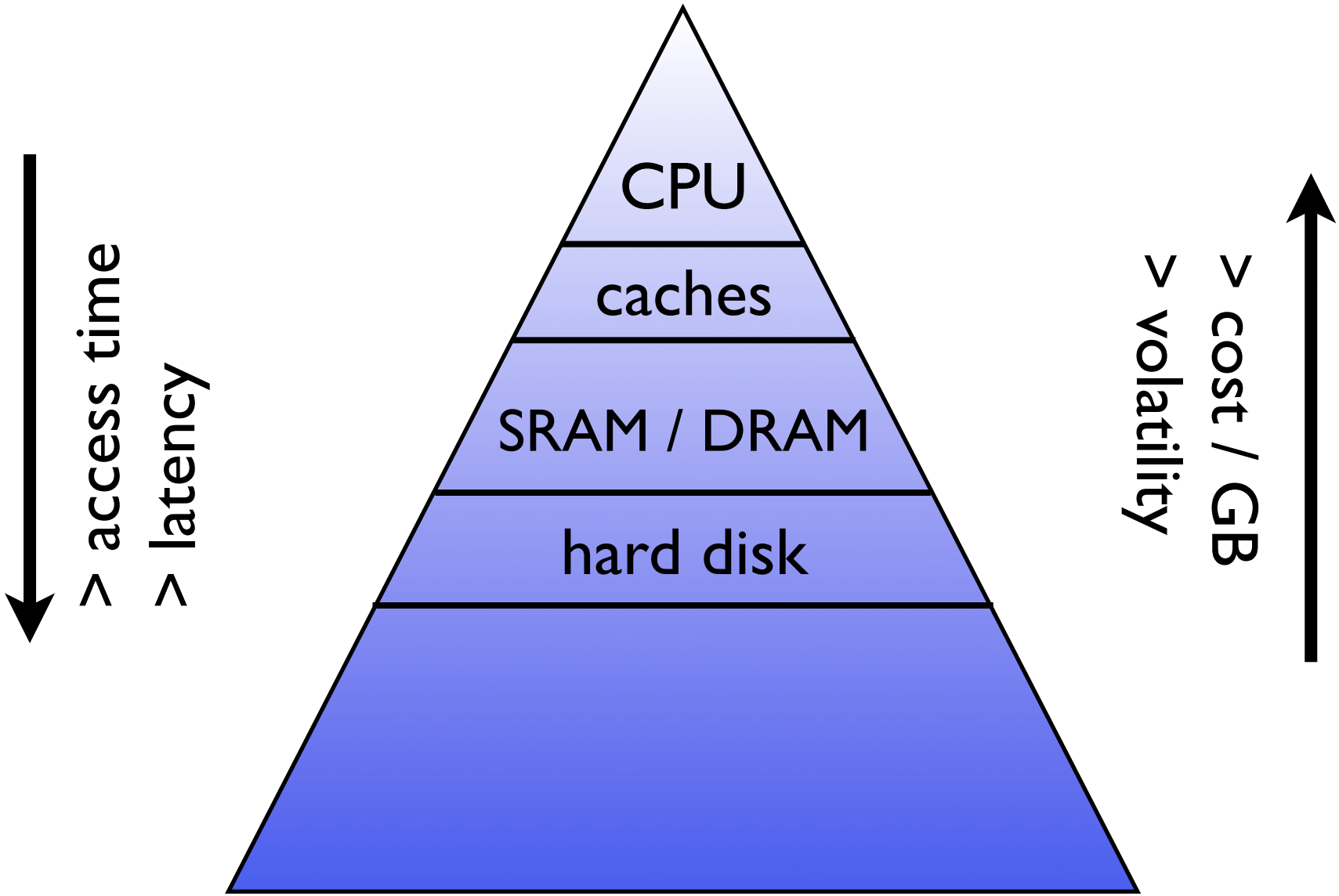
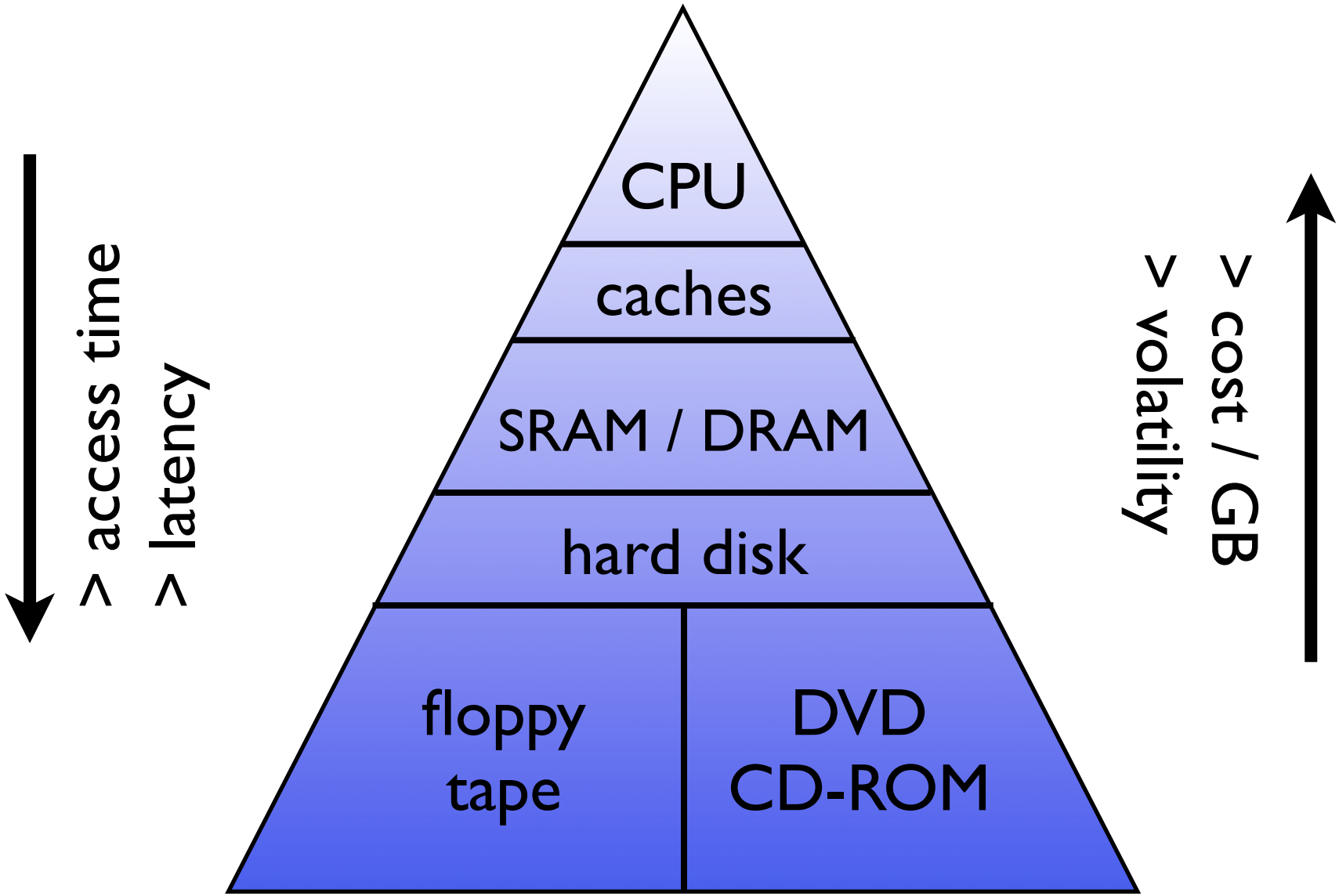


basic PC architecture



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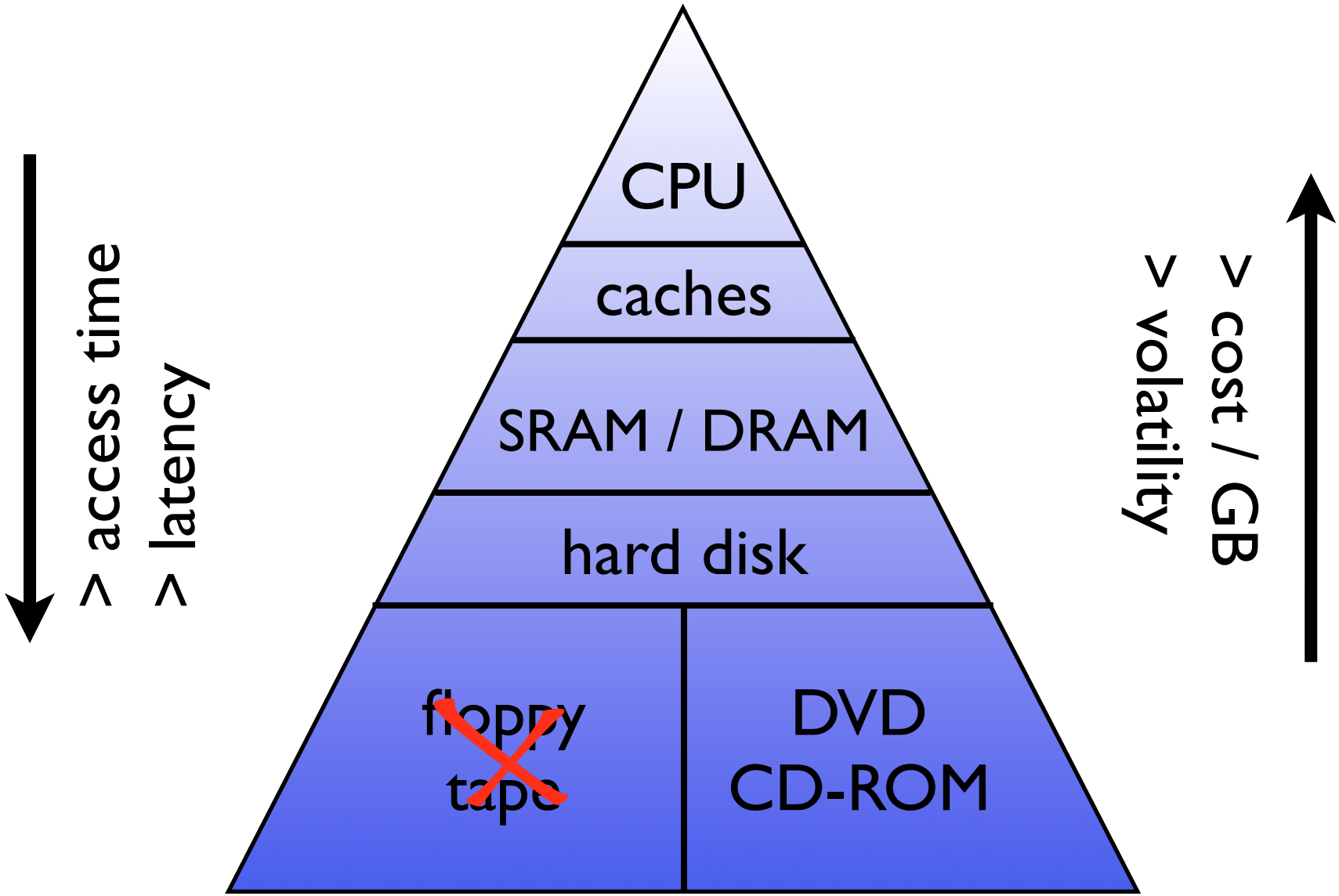
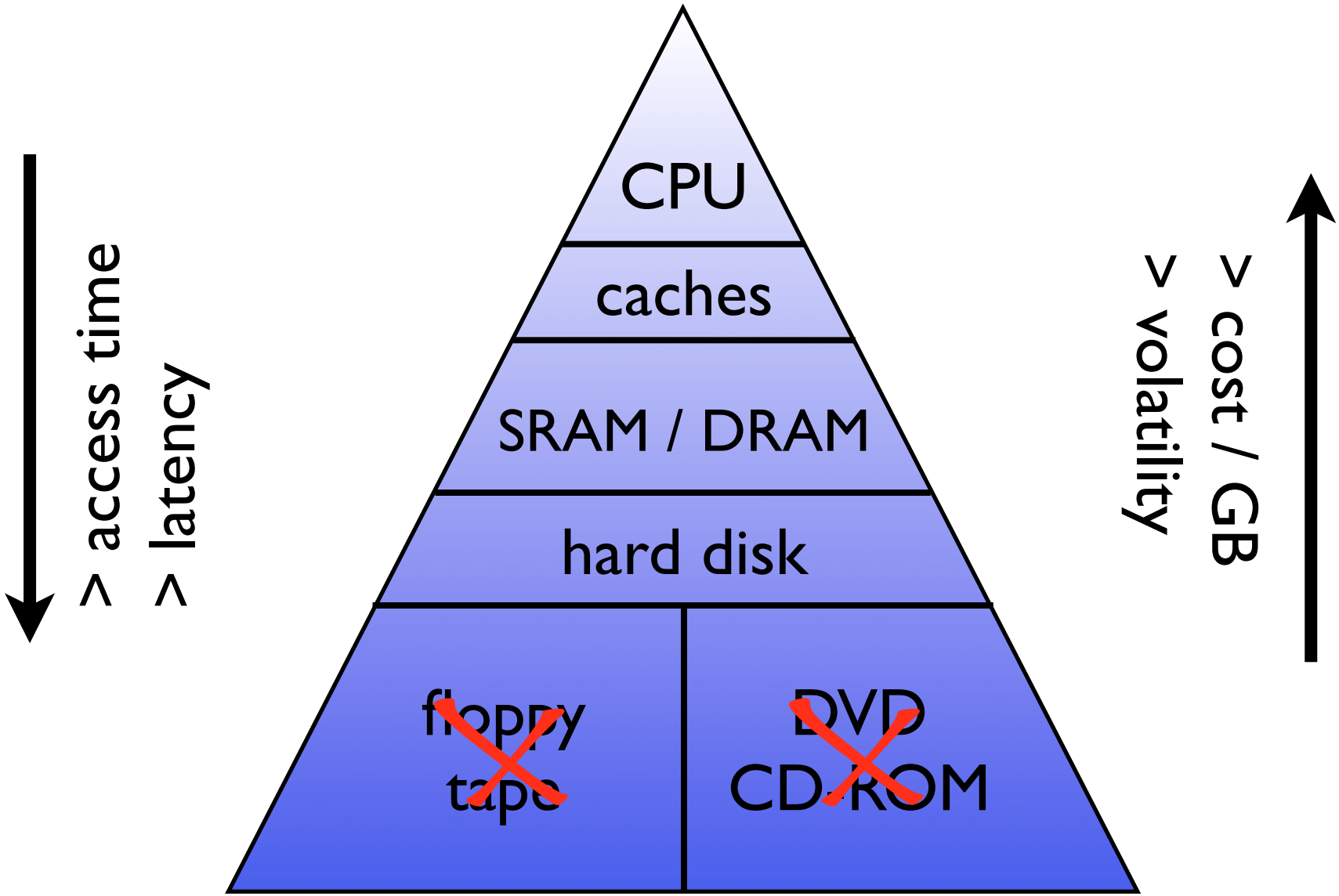


basic PC architecture



terminology

RAM

random access memory

ROM

read-only memory

access time & latency?

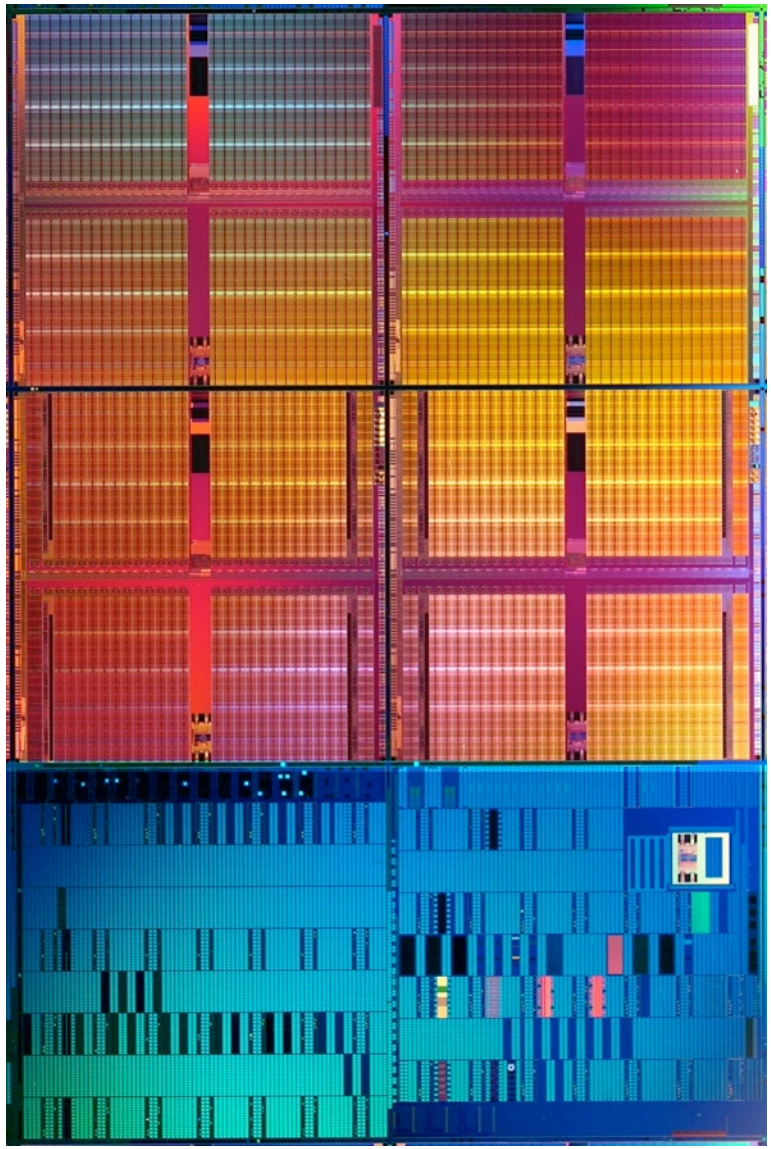
time between request for info & info returned

$ / GB

primary figure of merit.
most other things can be worked around

nonvolatility?

retains data without power



45nm SRAM die intel.com

every bit has a role

cache - *reduce latency to main memory*

- *small* memories close to CPU
- even faster than main memory
- temp storage of frequently accessed items

SRAM / DRAM - *main memory*

- blazingly fast
- relatively large
- voltaile!!

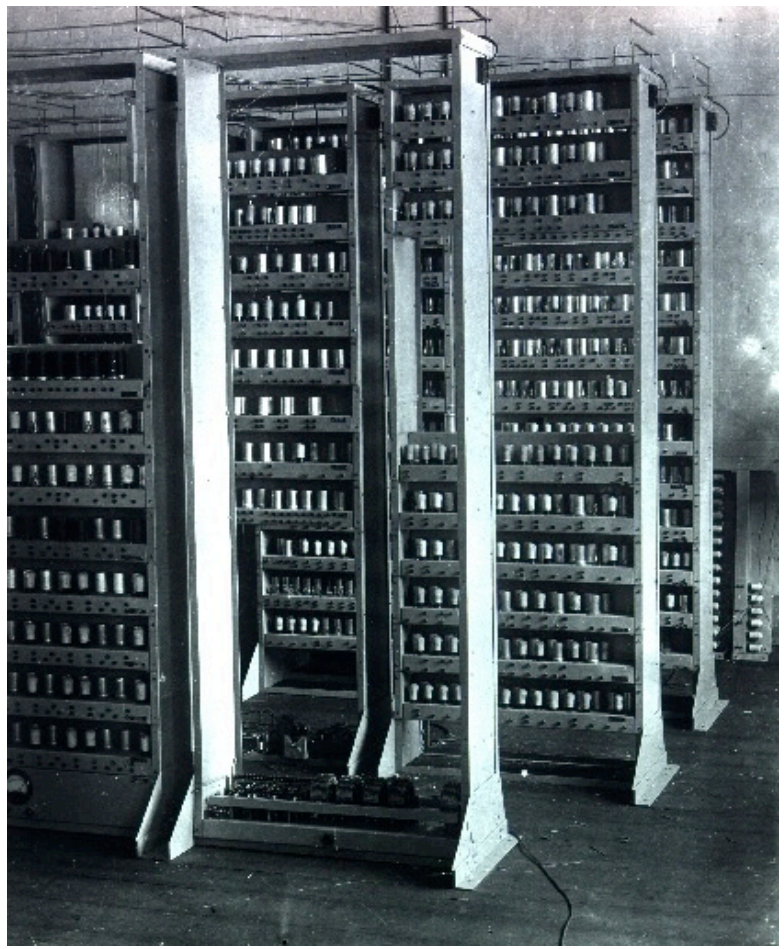
HDD - *mass storage*

- higher latency
- enormous capacity
- nonvolatile

removable

- portability
- backup
- large ROM

EDSAC / wikipedia.org



future paradigm shifts? distributed net storage?

the need for hard disks (tech)

volatility of semiconductor memories!

- *some* sort of nonvolatile storage necessary
- why not just battery backup of SRAM?

cost per GB

- SRAM/DRAM are too expensive
- Flash is too expensive
- cache RAM is more expensive

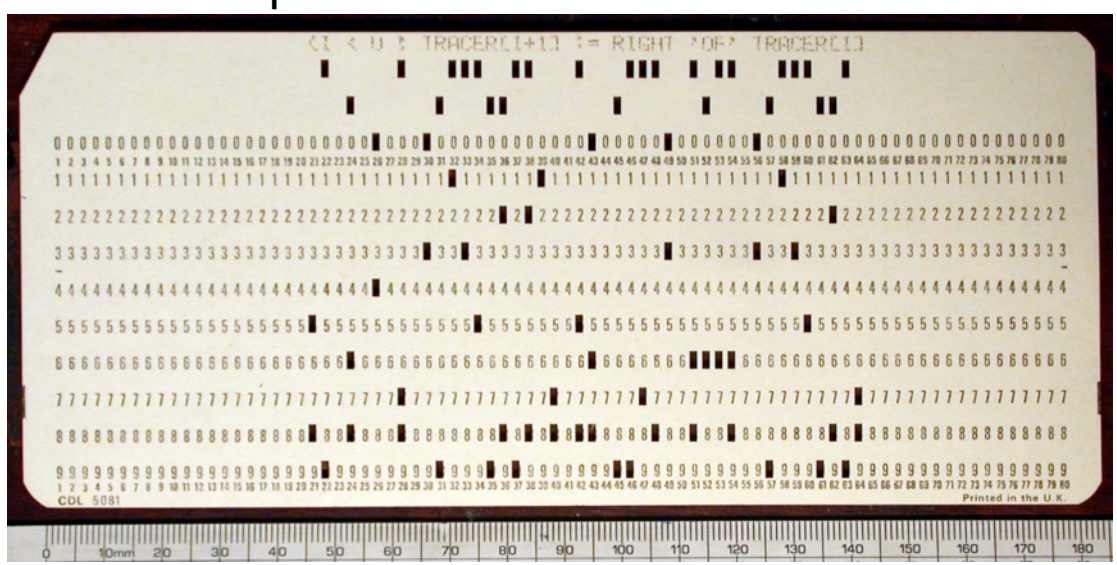
size & throughput

- higher latency, but bandwidth is huge
- enormous sizes

endurance

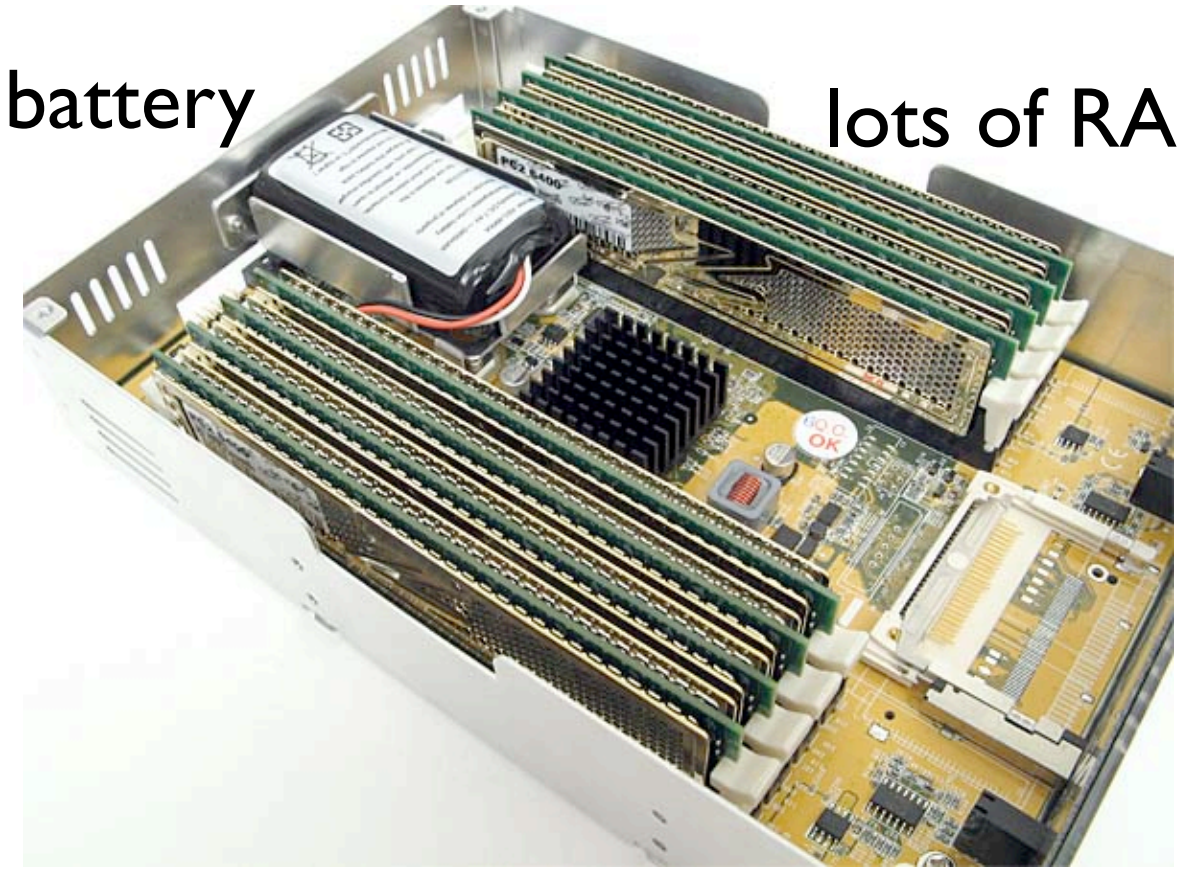
- essentially unlimited cycling
- radiation hard

punched cards are nonvolatile



Back in the day, disks were expensive.

Sometimes, we would trick the system into using RAM as a disk to avoid swapping floppies.



now RAM disks make a comeback ...

the need for mass storage (human)

sound

several MB per minute / lossy
tens of MB per minute / "lossless"

pictures

several MB per image

video

~ 1 MB per sec
several GB per movie
with lossy compression!

data mining

enormous sizes

apple.com

some physics of information storage ...

how do hard disks work, more or less?

wikipedia.org - "Hard_Disk"

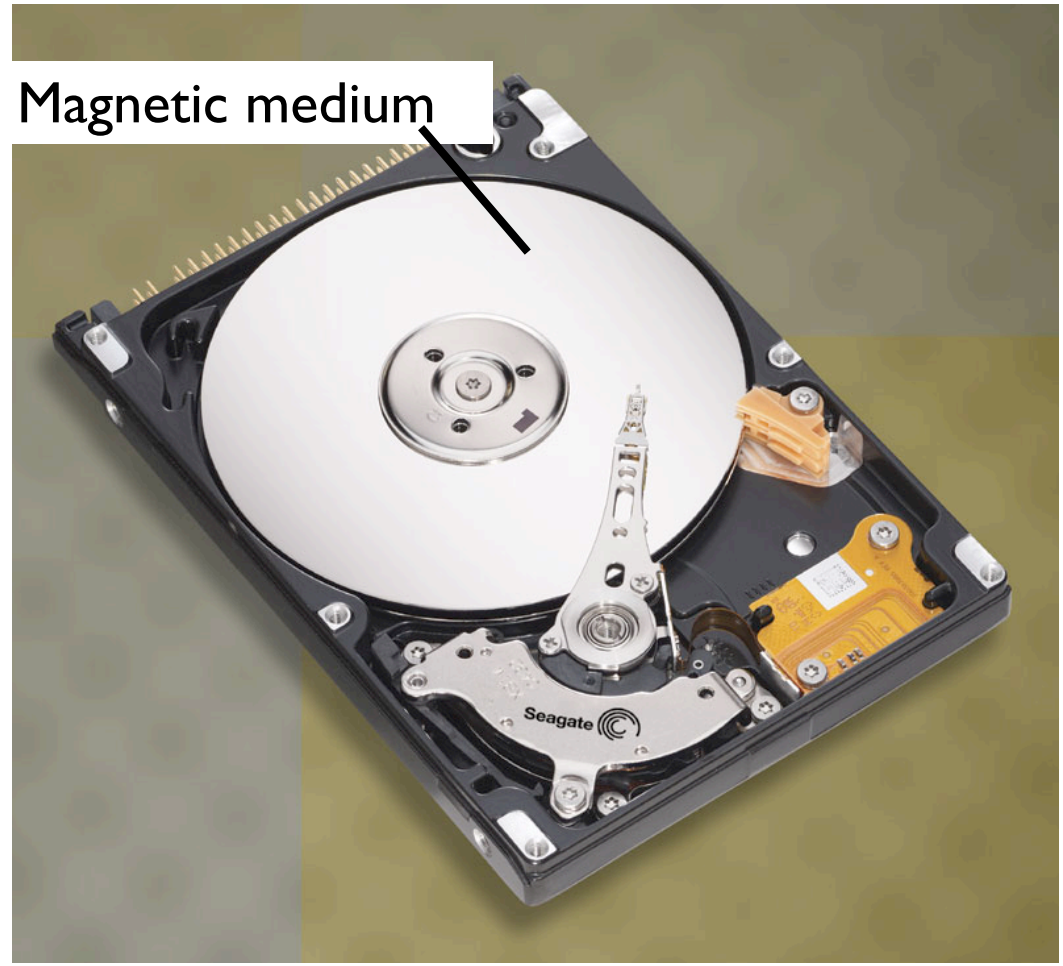
spinning (~10^4 rpm) part holds data.
sliding part reads and writes data.

hard disk drives

160 Gbit 2.5” perpendicular drive for laptops

images from M. Coey

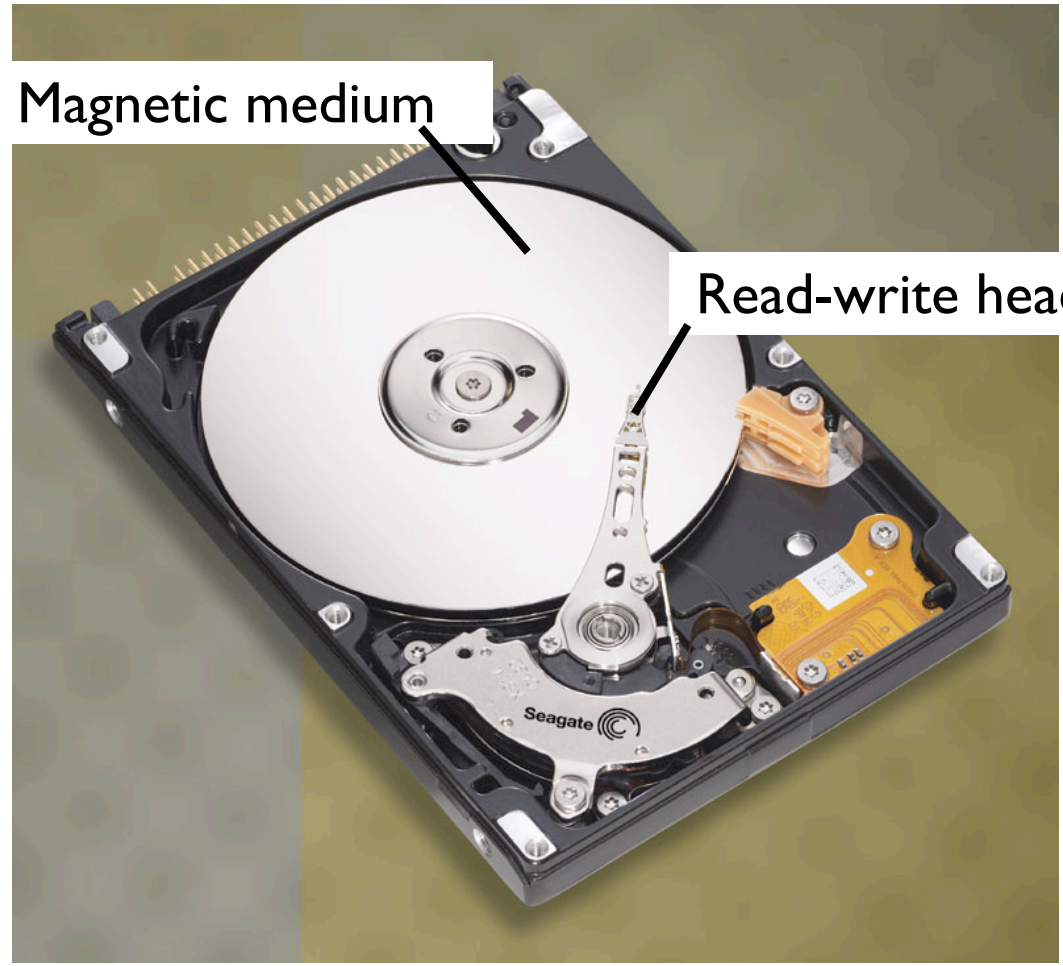
hard disk drives



160 Gbit 2.5” perpendicular drive for laptops

images from M. Coey

hard disk drives



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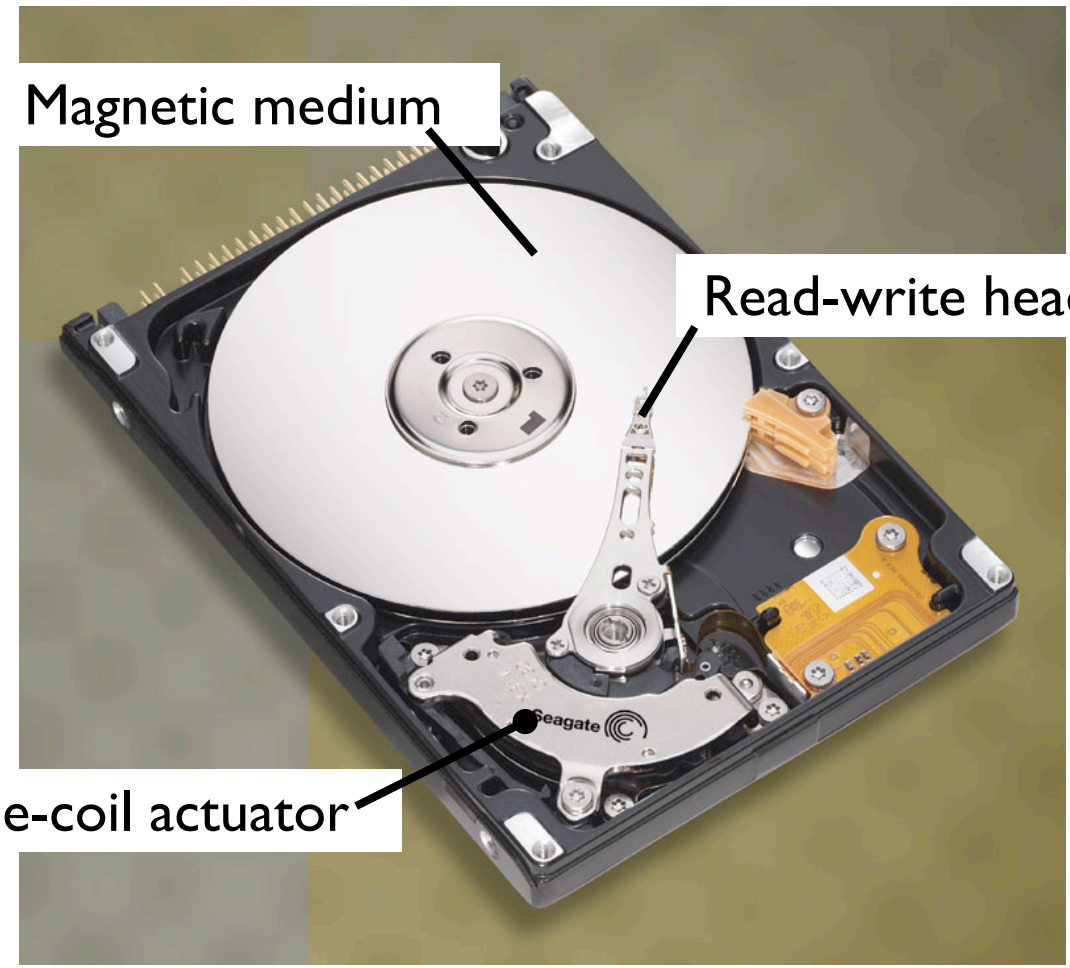
hard disk drives



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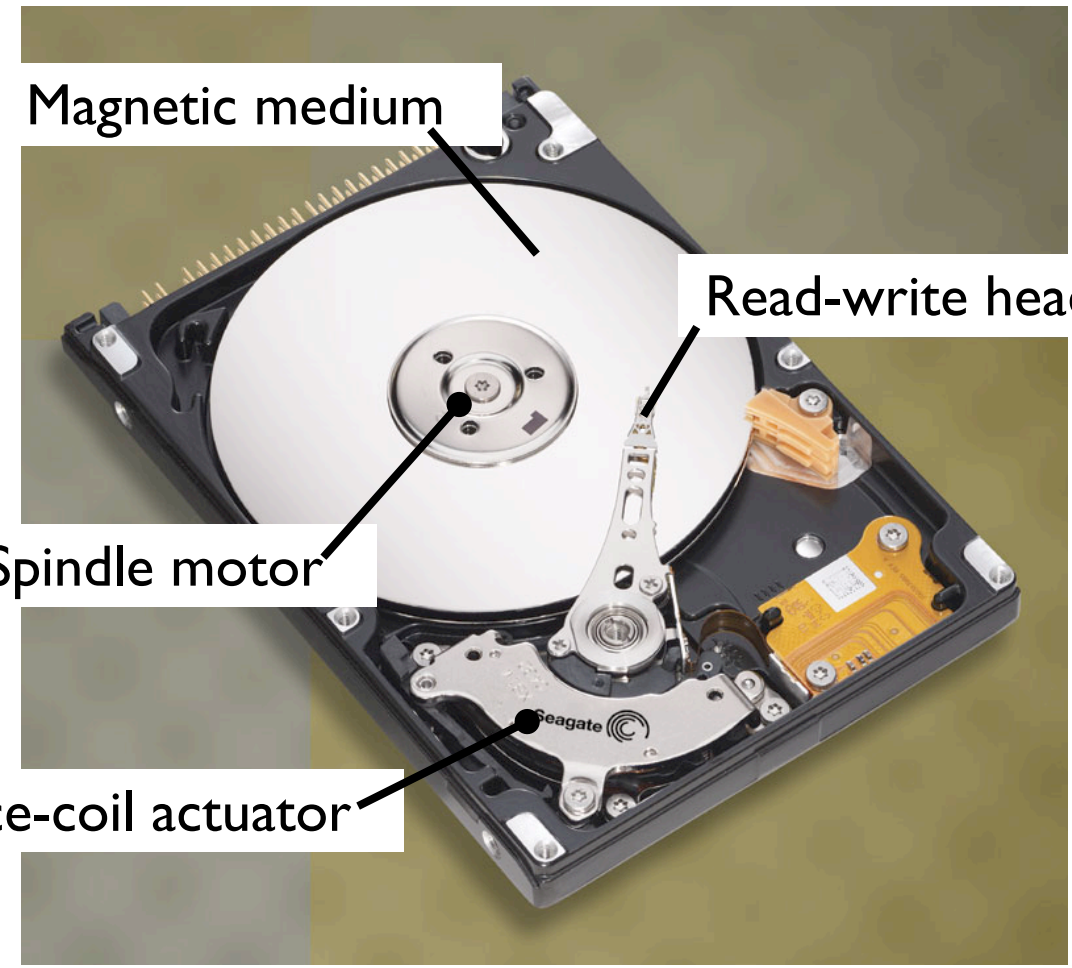
hard disk drives



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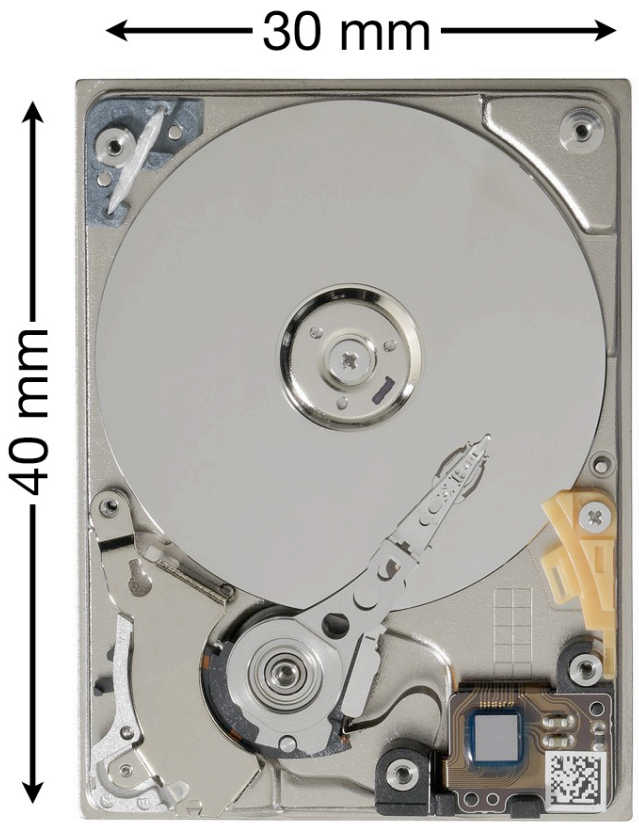
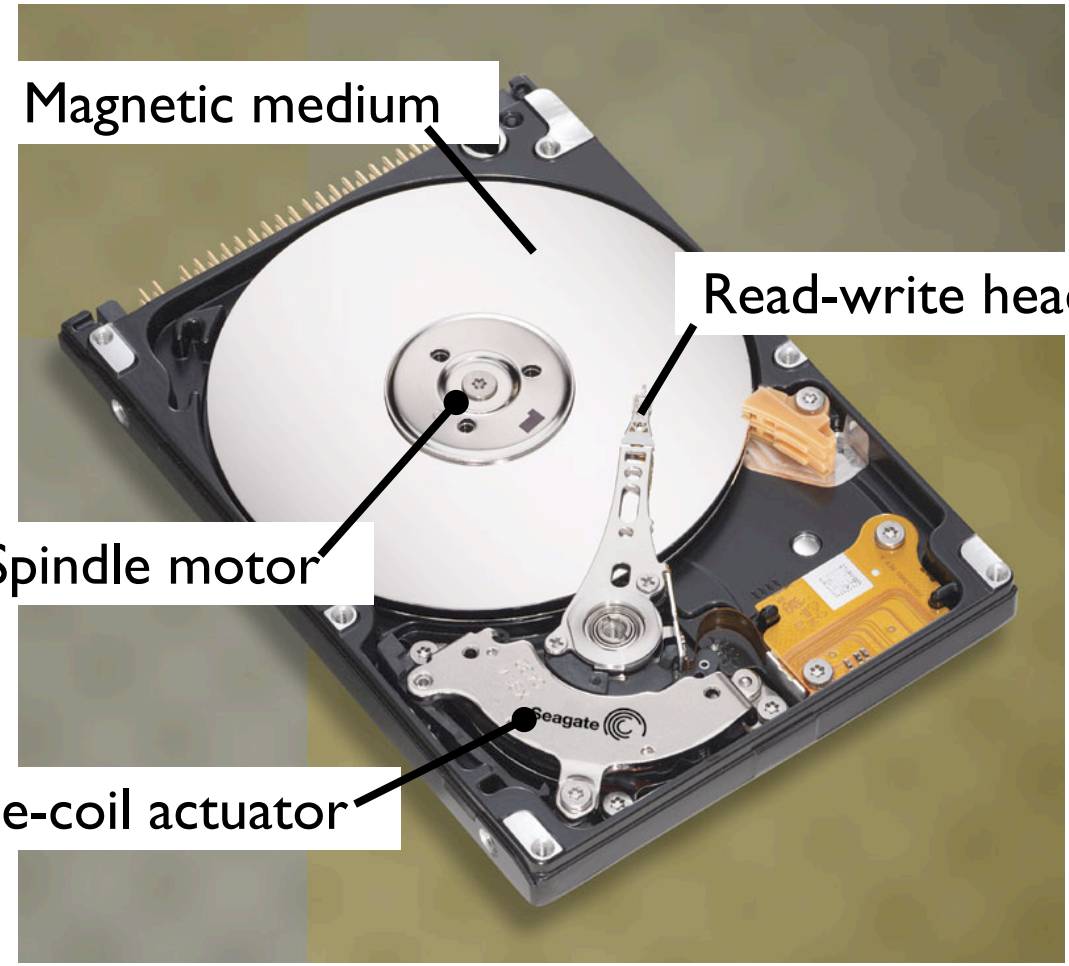


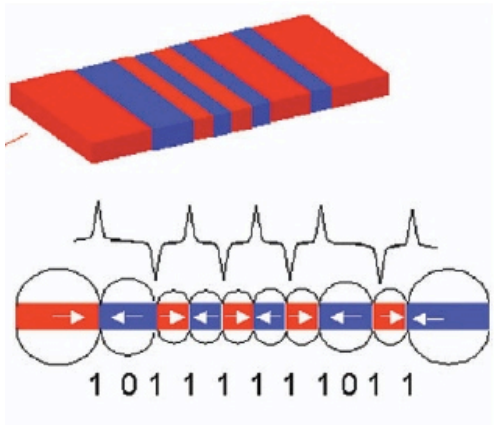
8 Gbit 1” drive for cameras

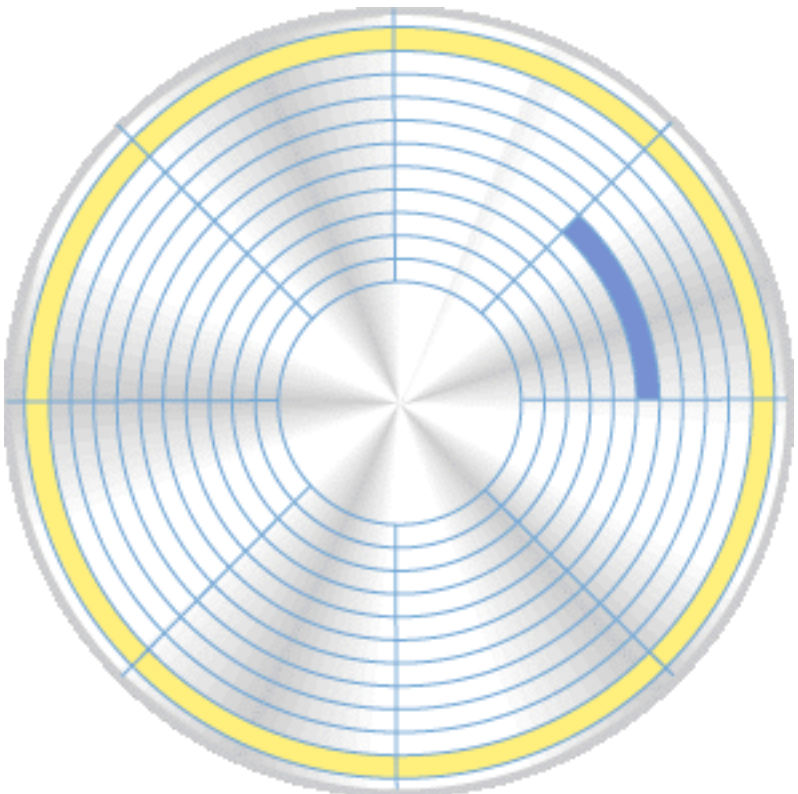


160 Gbit 2.5” perpendicular drive for laptops

images from M. Coey

media basics

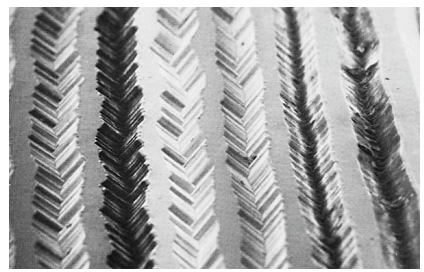




Hard disk
- tiny magnetized regions
- direction (N/S) stores bit
- magnetic sensor reads bits

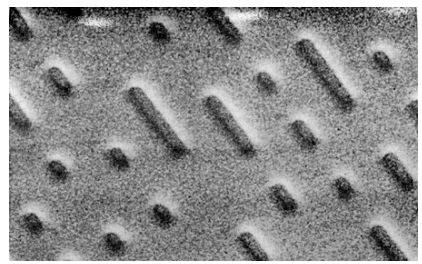
LP records
- tiny bumps
- needle moves

actual record grooves

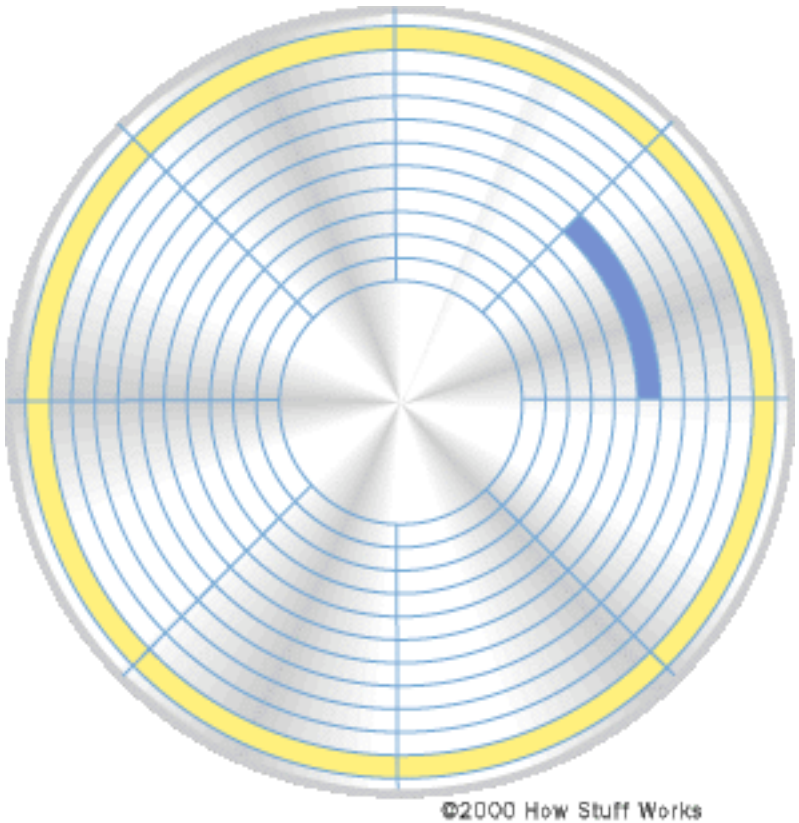


CDs
- pits store bits
- optical reflectivity

actual CD surface



media basics

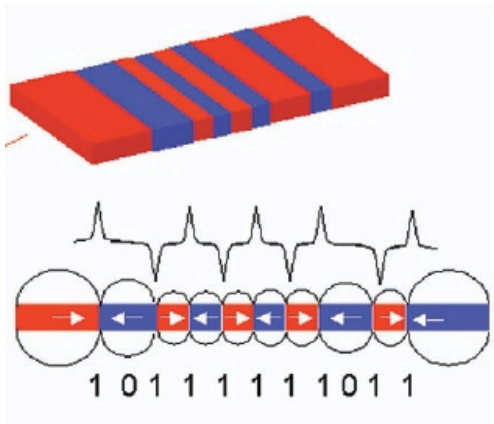


hard disk platters are round.

so how is data arranged?

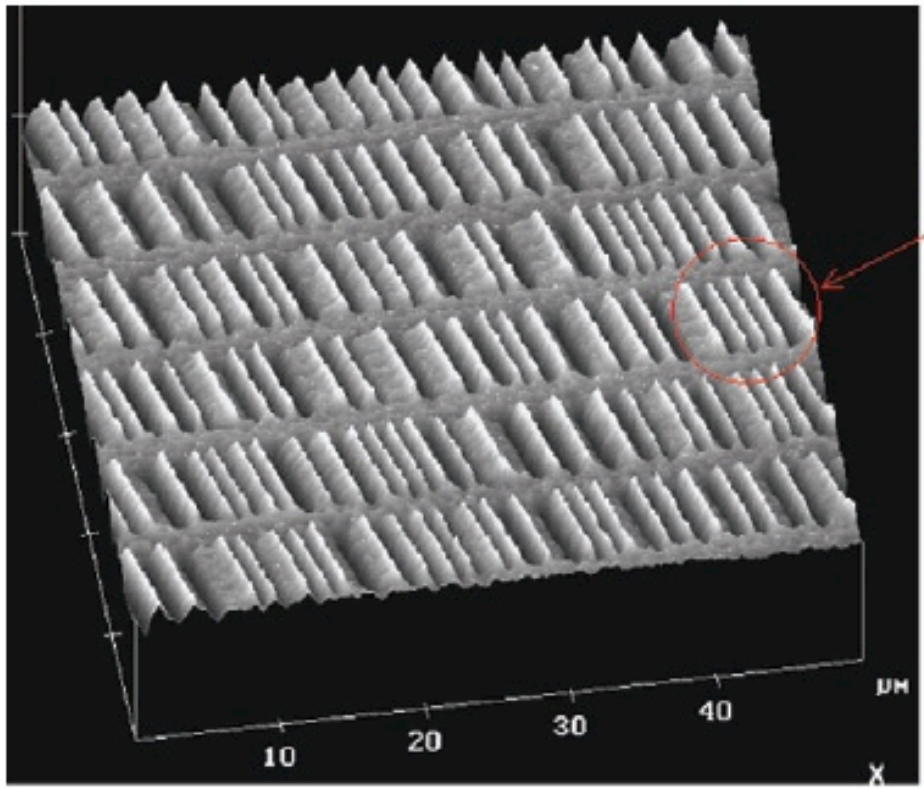
tracks = concentric circles
sectors = wedge of a track

sector has fixed # bytes

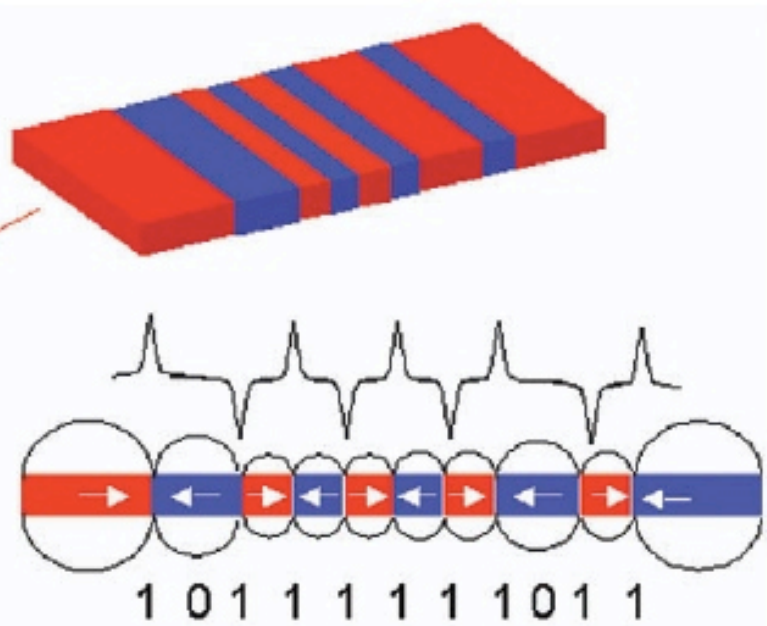


media basics

mfm image



sees transition field



Jimmy Zhu, *Materials Today*, July/Aug 2003

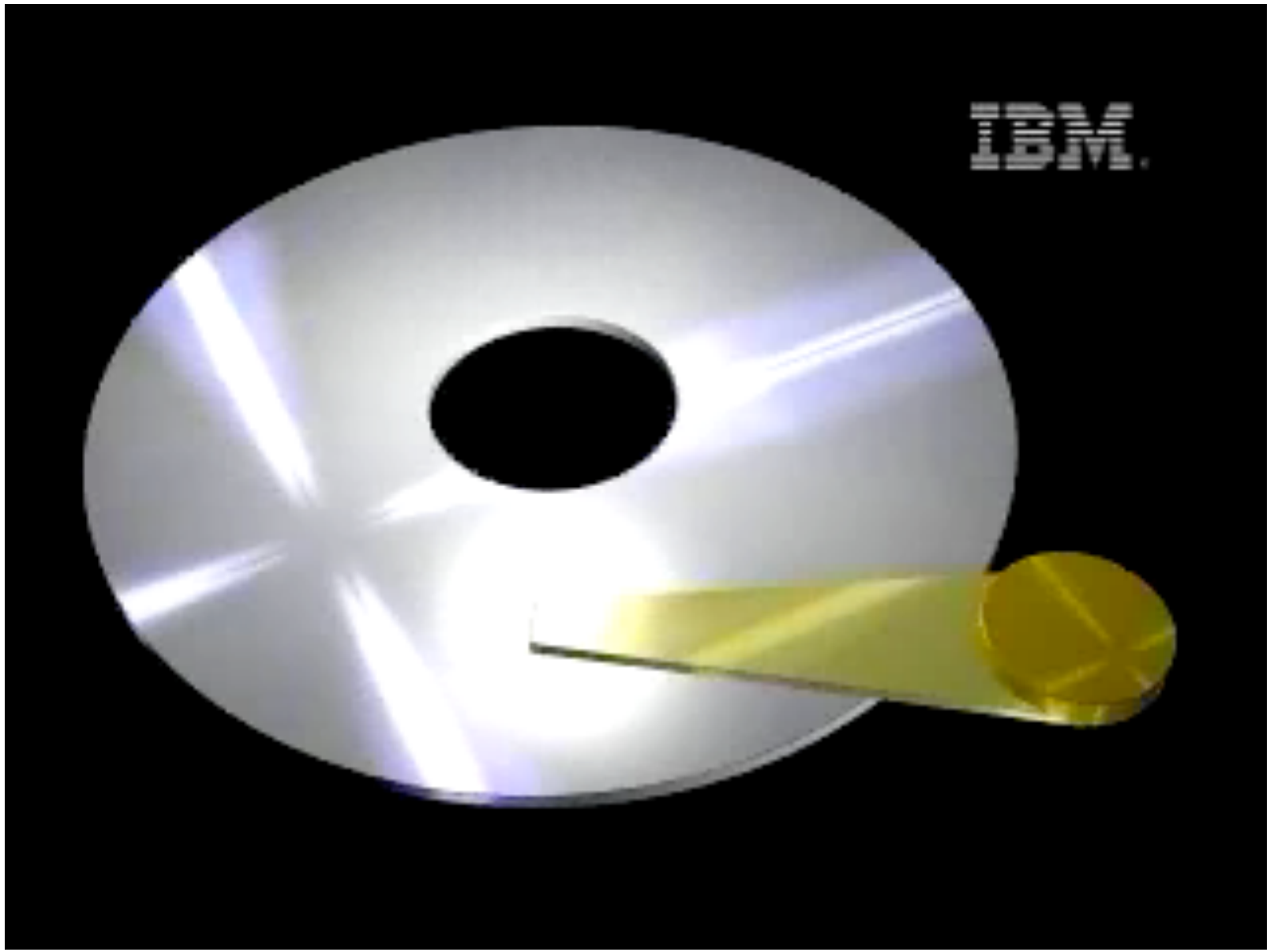
CoCrPt alloy

platters - Al or glass substrate

typical magnetic region

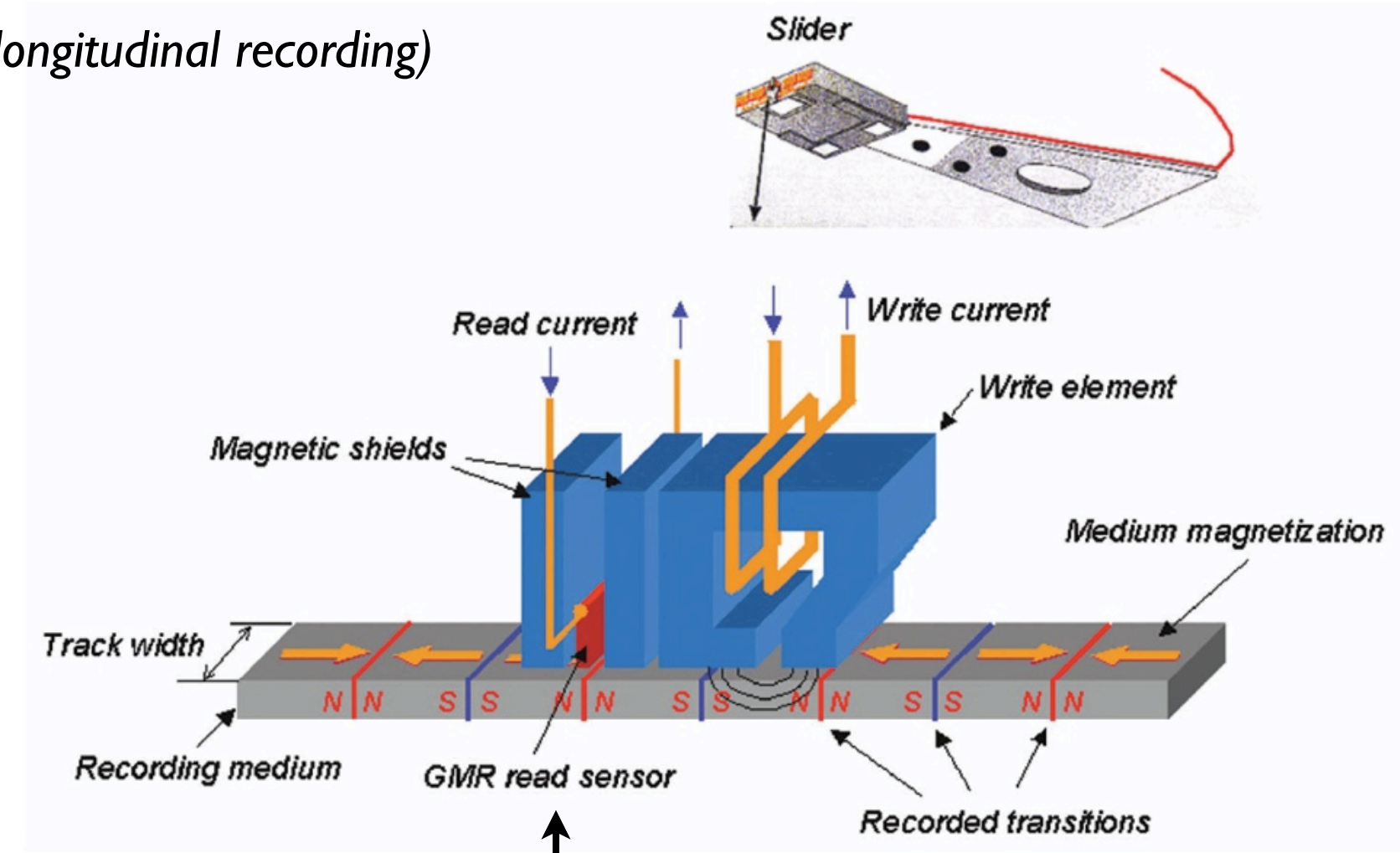
~200-250 nm wide, ~25-30 nm down-track

100 billion bits (Gigabits) per in^2


IBM.

reading and writing basics

(longitudinal recording)



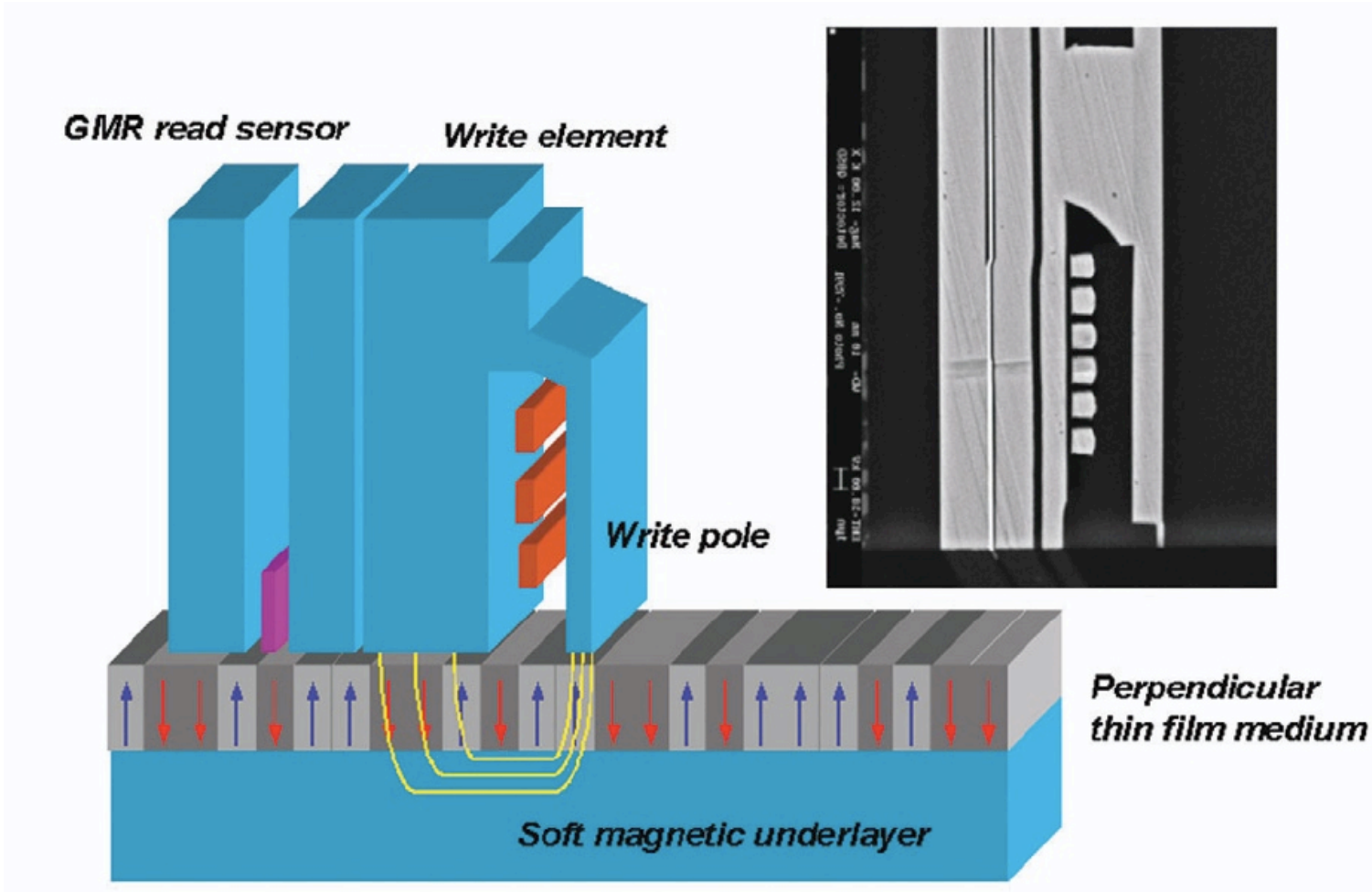
sensor - *magnetoresistive*

Jimmy Zhu, *Materials Today*, July/Aug 2003

reading and writing basics

(perpendicular recording)

Jimmy Zhu, *Materials Today*, July/Aug 2003



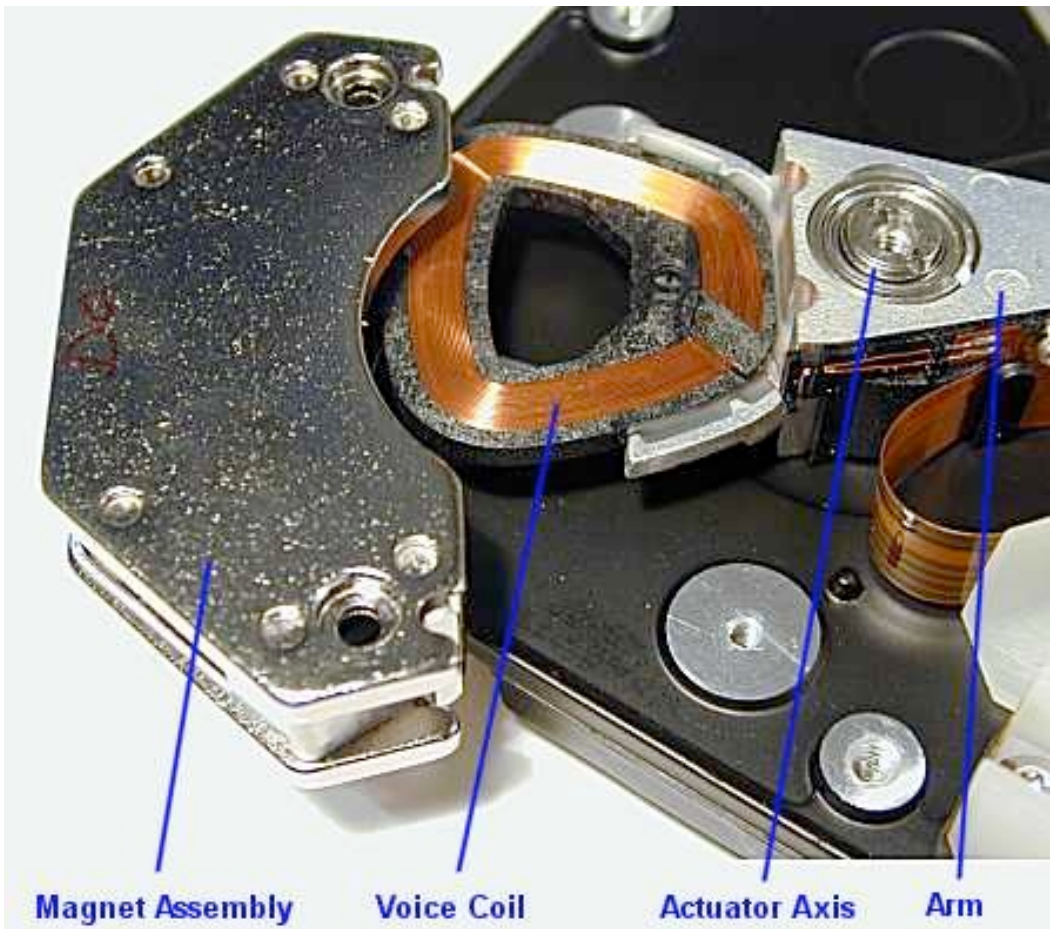
soft underlayer becomes part of the flux guide
... careful concentration of flux ...

read head (and its reflection)

wikipedia.org - "Hard_Disk"

positioning basics

- current powers voice coil†
- field generated moves head L or R
- more precise than stepper motor



www.pcguide.com/ref/hdd/op/actActuator-c.html

† this is the same way a speaker cone moves

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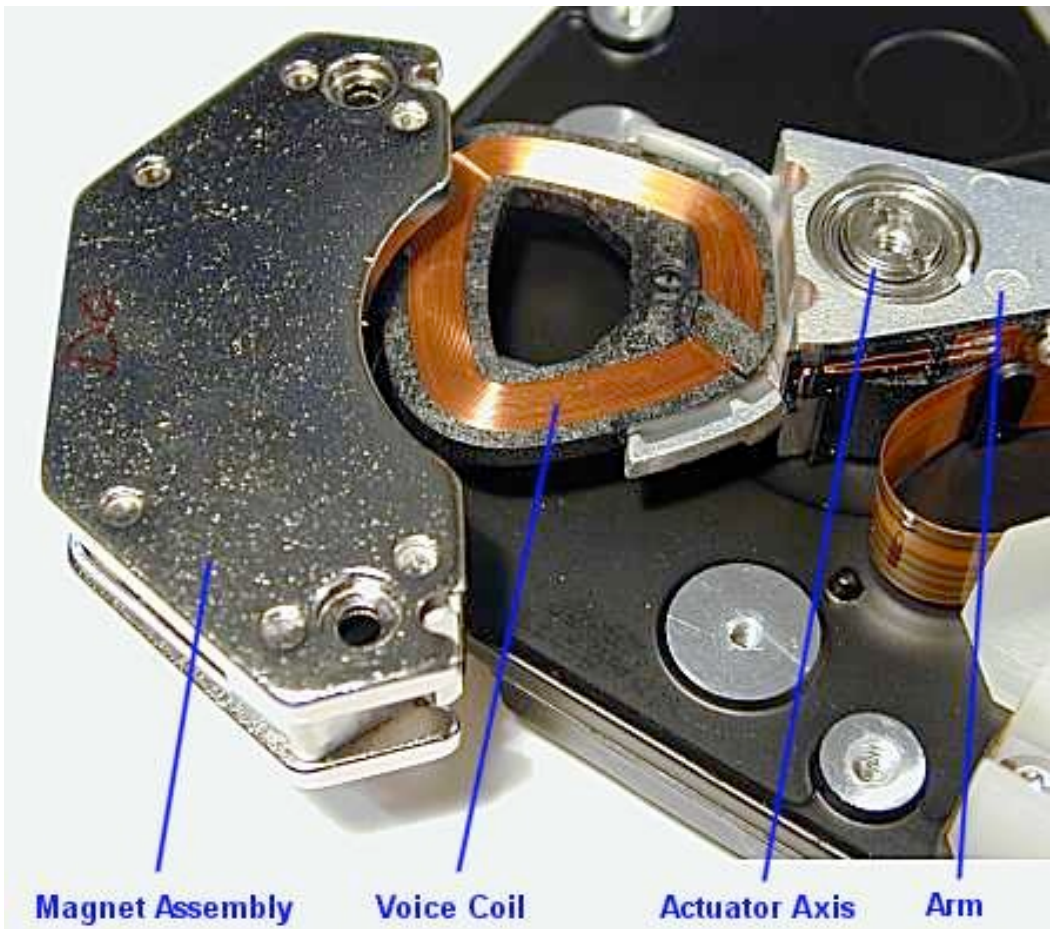


www.pcguide.com/ref/hdd/op/actActuator-c.html

IBM 62PC "Piccolo" HDD, ~1979 - an early 8" disk

wikipedia.org - "Hard_Disk"

† this is the same way a speaker cone moves

why magnets?

microscopic view

magnets remember their state

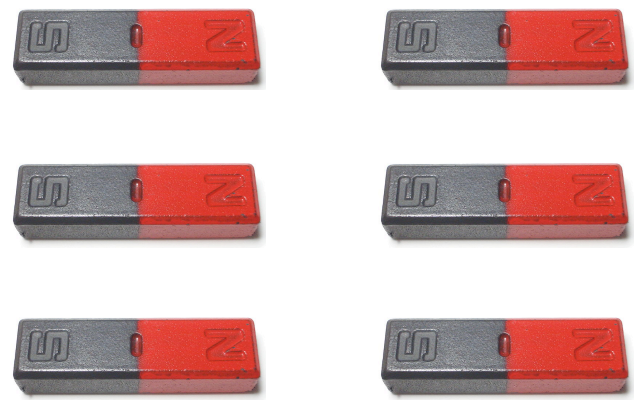
- once magnetized, they stay that way

with a little bit of energy, we can control them

- switch from N to S

why magnets?

microscopic view



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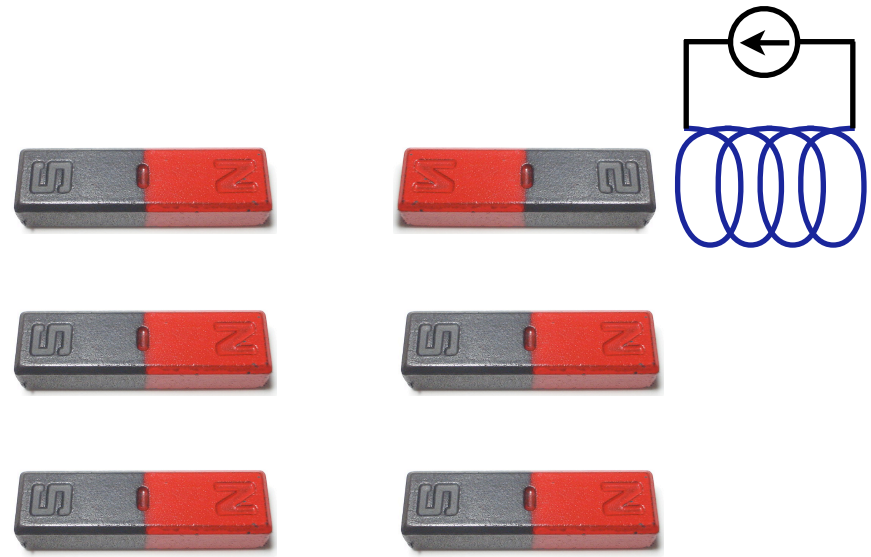
why magnets?

microscopic view

address

local field



magnets remember their state

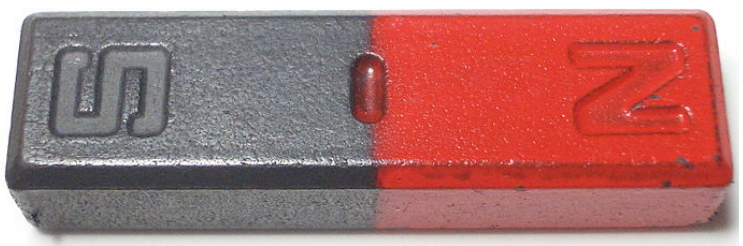
once magnetized, they stay that way

with a little bit of energy, we can control them

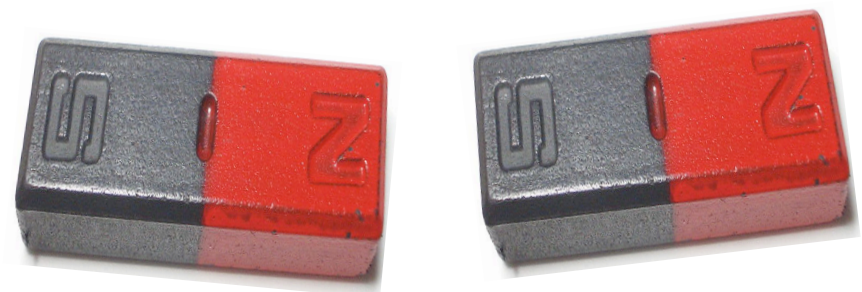
switch from N to S

why magnets?

what happens when
you break a magnet?



you get two magnets



now: do this 25 more times

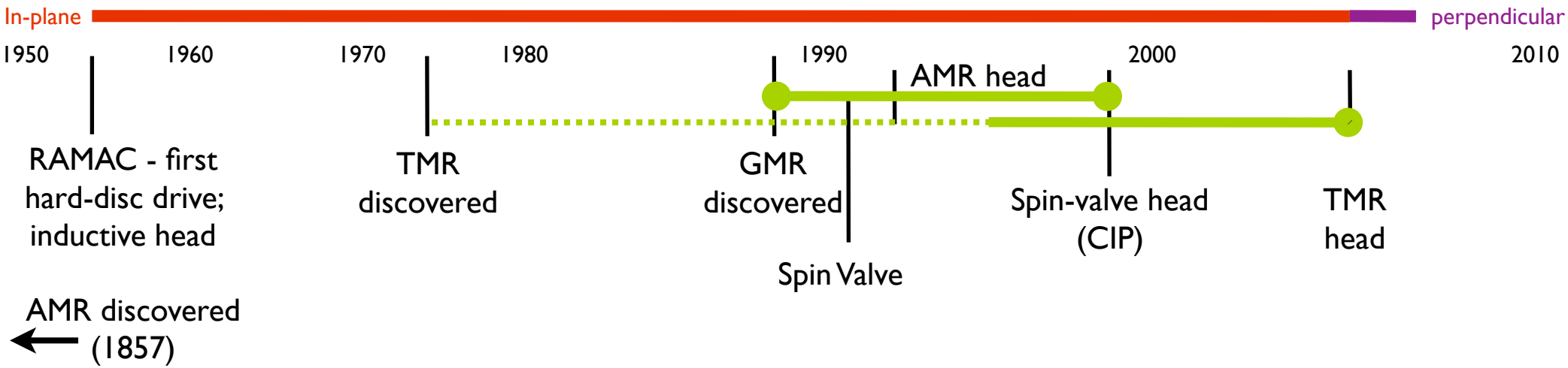
➠ 33 million magnets, all 50nm across

about 1,000 times thinner than a hair

we can make *really tiny* magnets

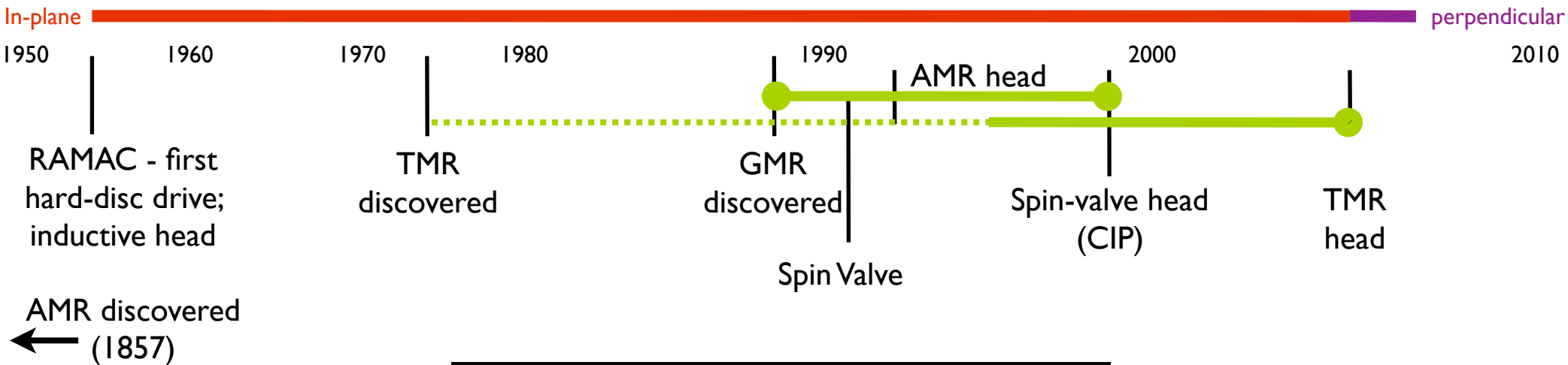
smaller is *better*, to a point

technology timeline



images and text from M. Coey

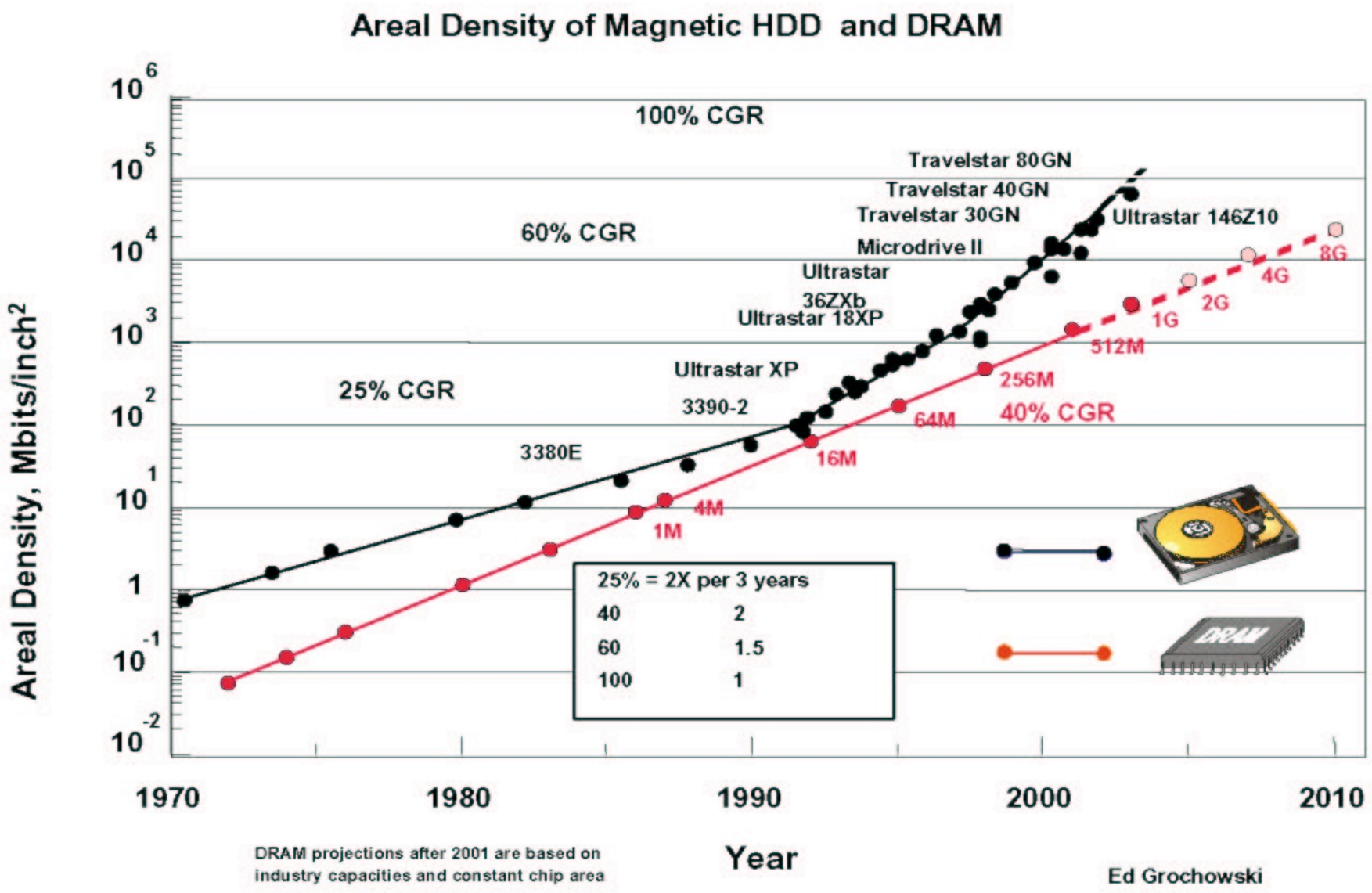
technology timeline



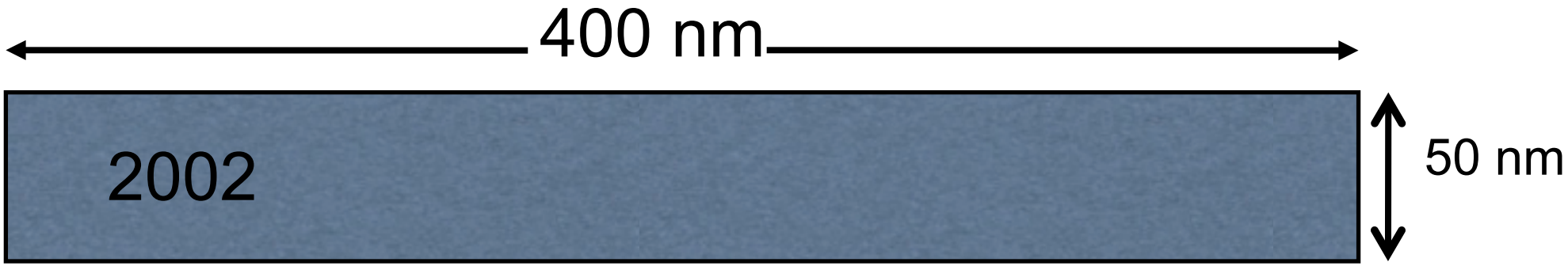
year	capacity	platters	size	rpm
1955	40 Mb	50x2	24”	1200
2005	160 Gb	1	2.5”	18000

images and text from M. Coey

areal density *vs.* DRAM



The incredible shrinking bit!
Predicted relative sizes of HDD storage bits



(assumes areal densities continue to double yearly)

The incredible shrinking bit!
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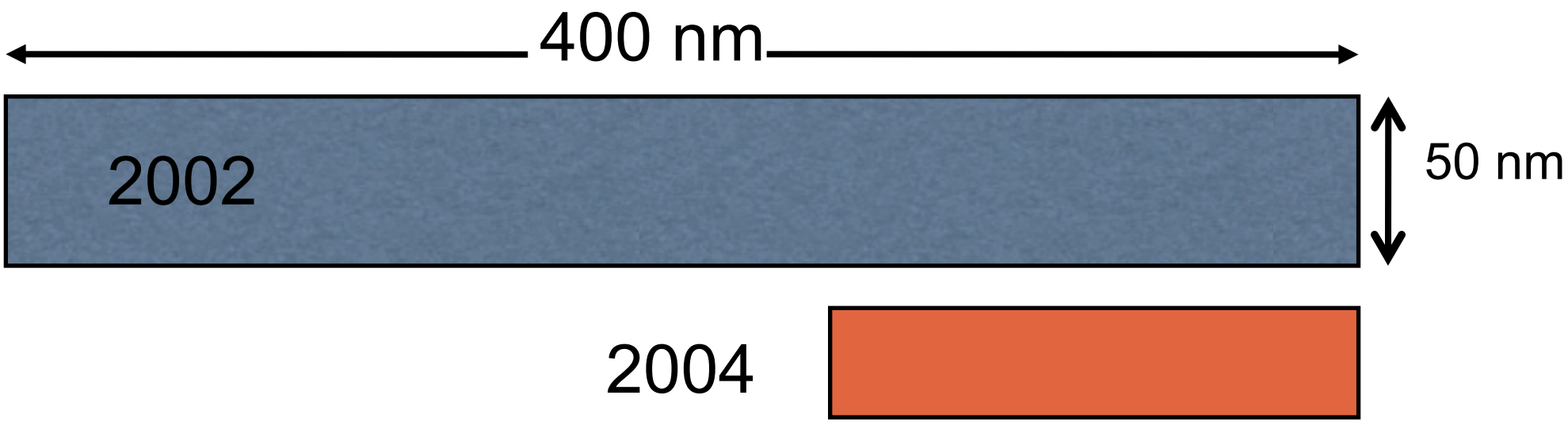

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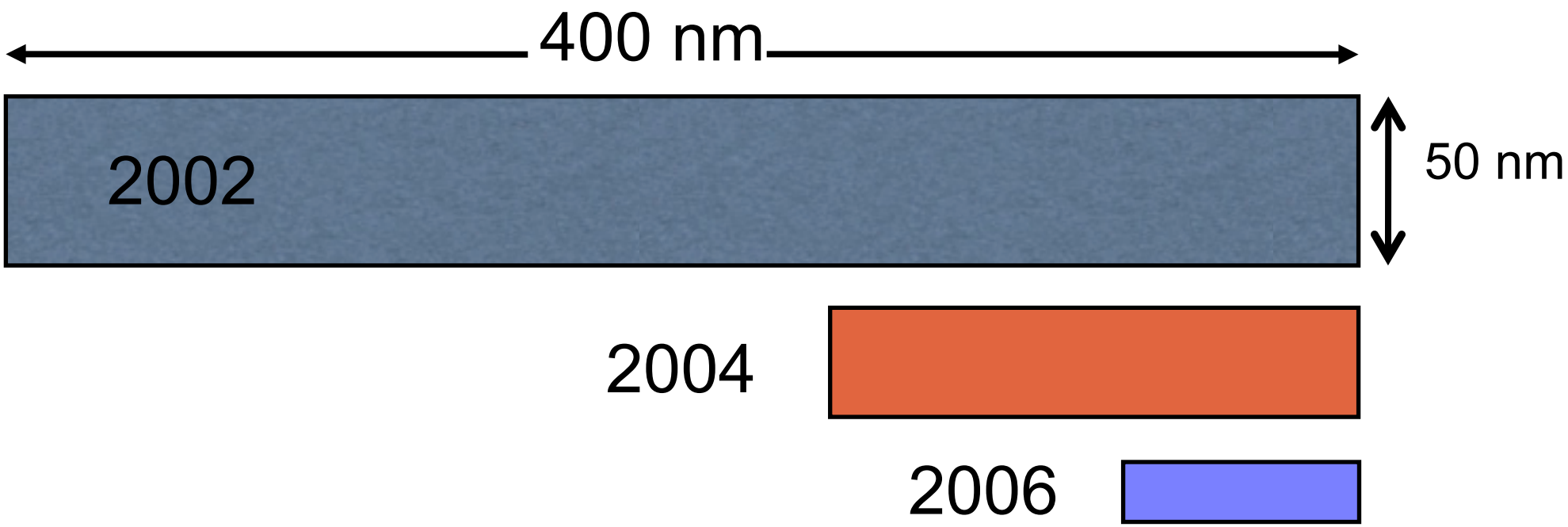

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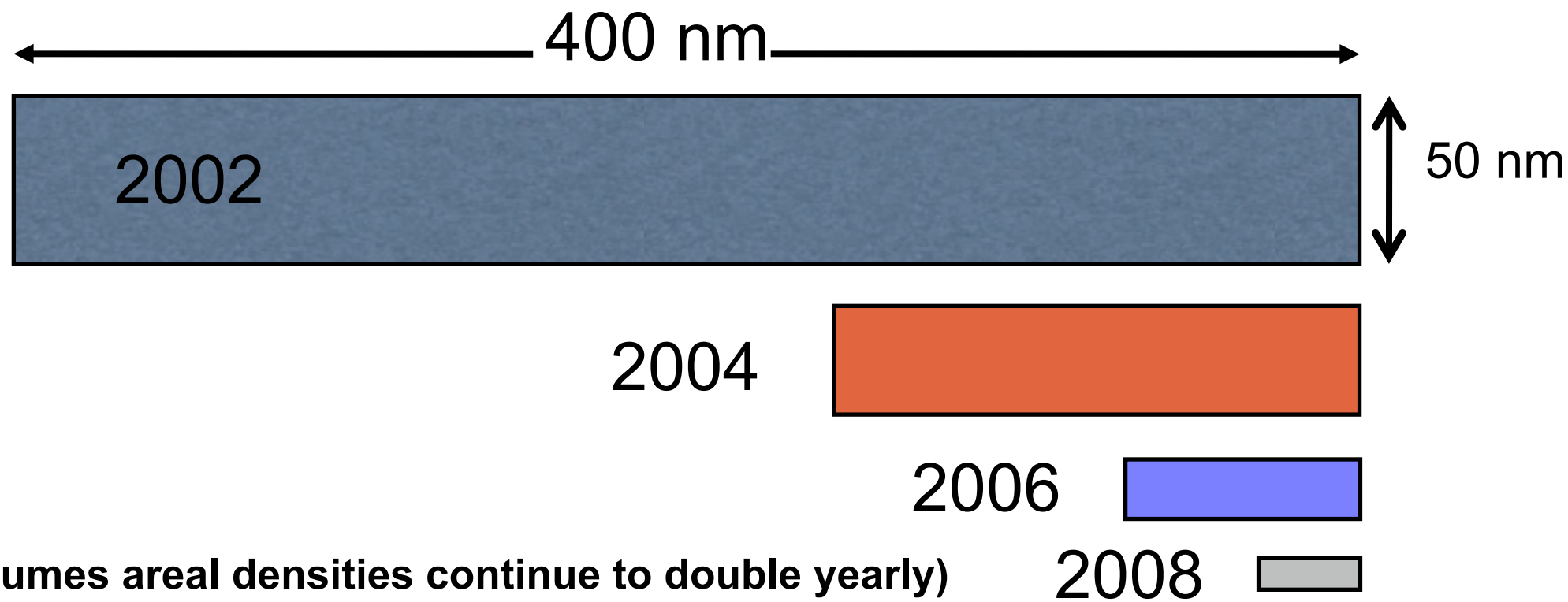

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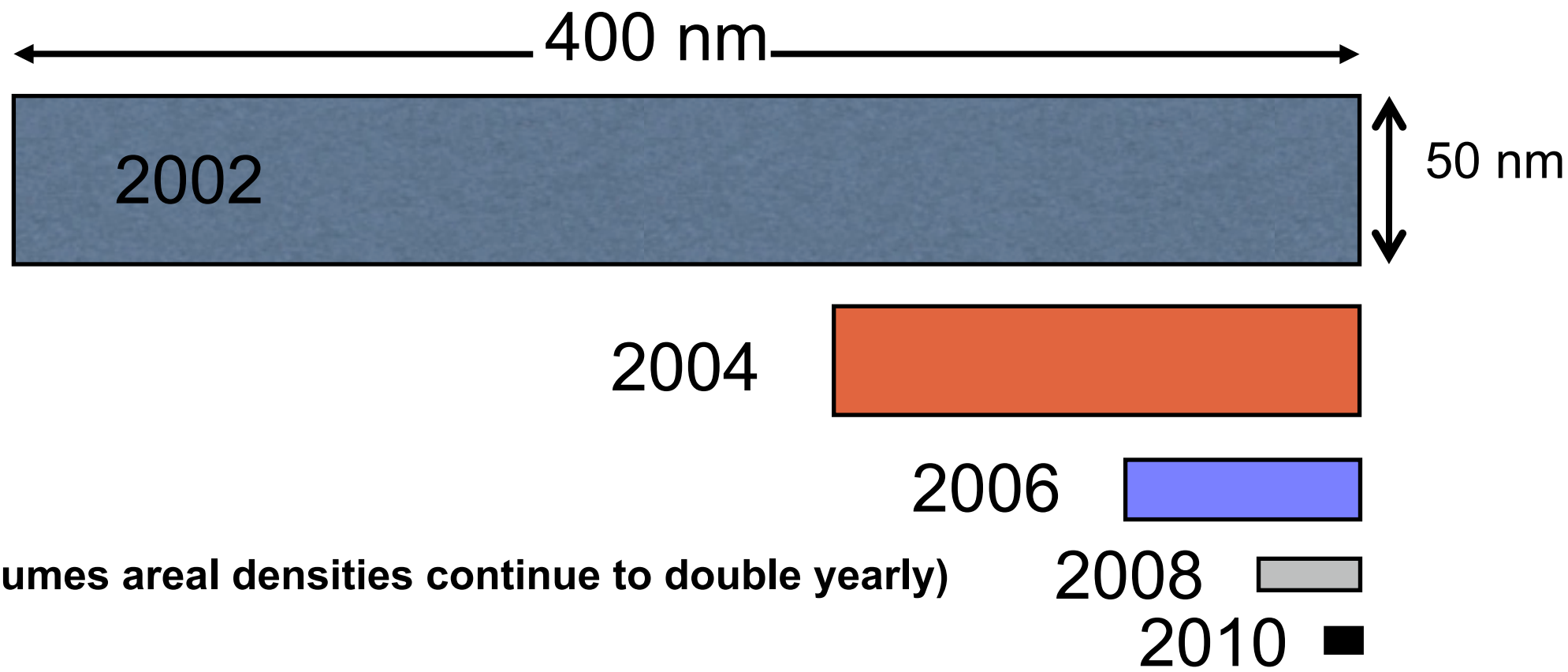

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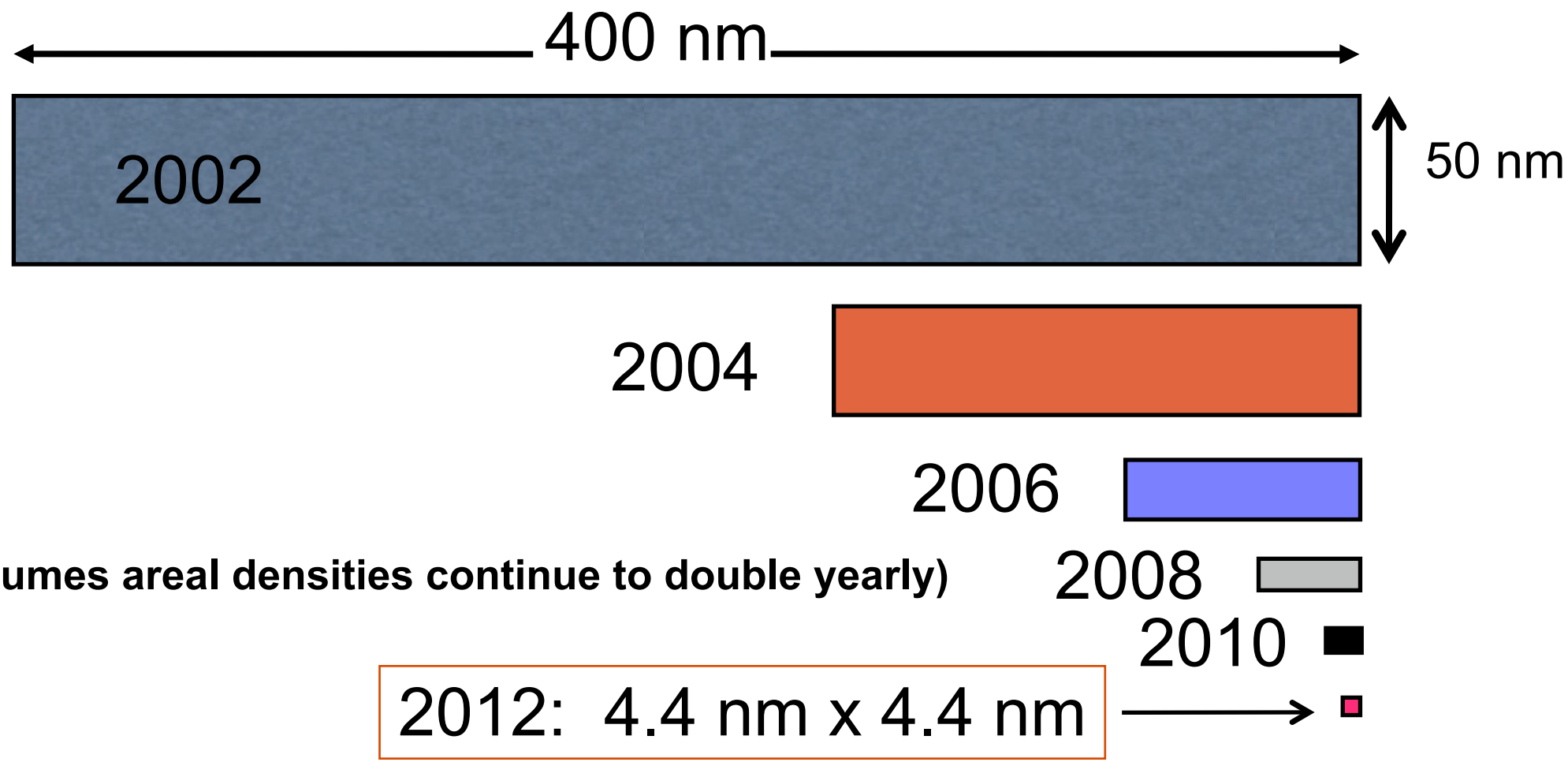

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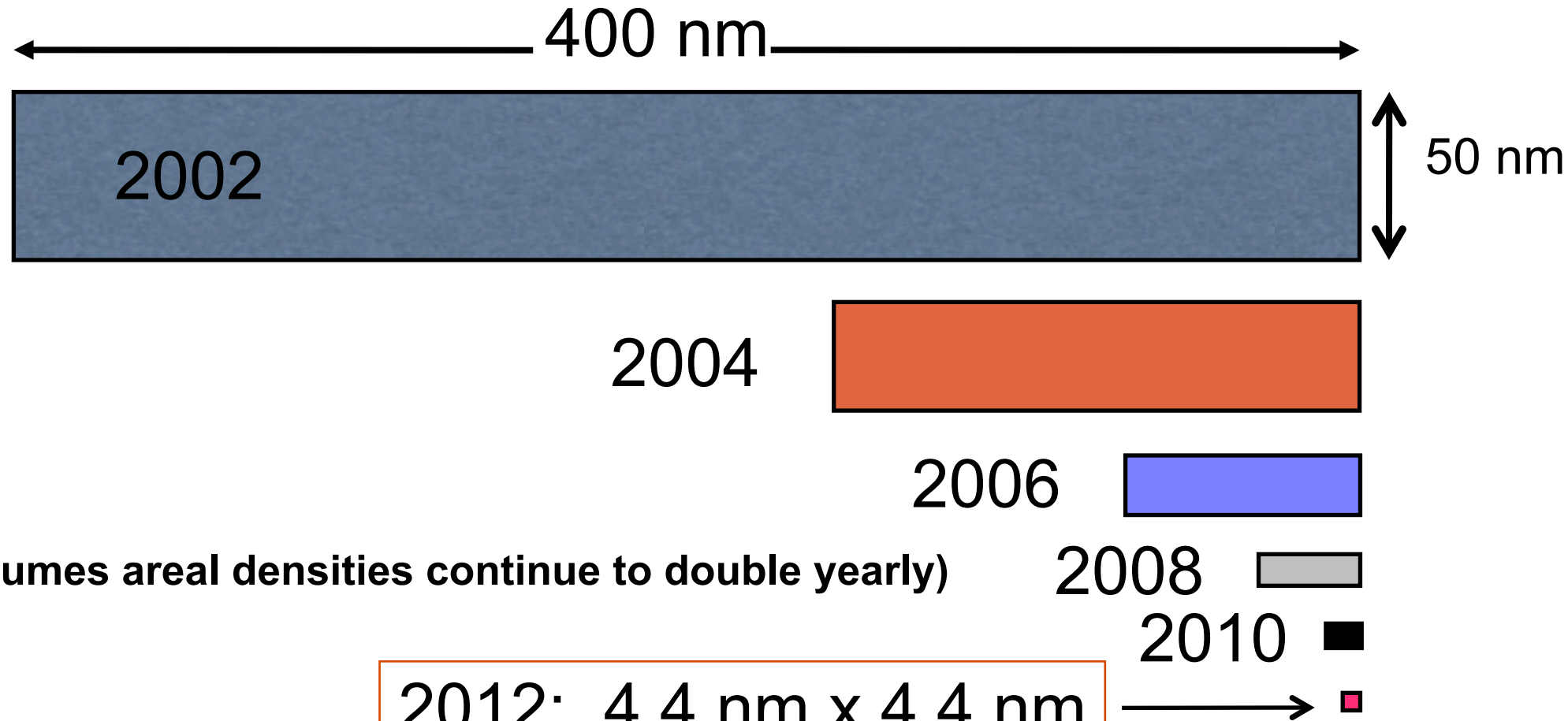


(assumes areal densities continue to double yearly)

this will probably not happen

50 TB per square inch on a quarter ...

- over 3.4 million high-resolution photos, or …
- 2,800 audio CDs, or…
- 1,600 hours of television, or …

50 TB per square inch on a quarter ...

- over 3.4 million high-resolution photos, or …
- 2,800 audio CDs, or…
- 1,600 hours of television, or …

- the entire printed collection of the U.S. Library of Congress

Library of Congress, Jefferson building

so what's the problem?

at some point, they are no longer stable

heat makes them 'wiggle'

like drops of water on a griddle

bits are no longer reliable

so we need stronger magnets ...

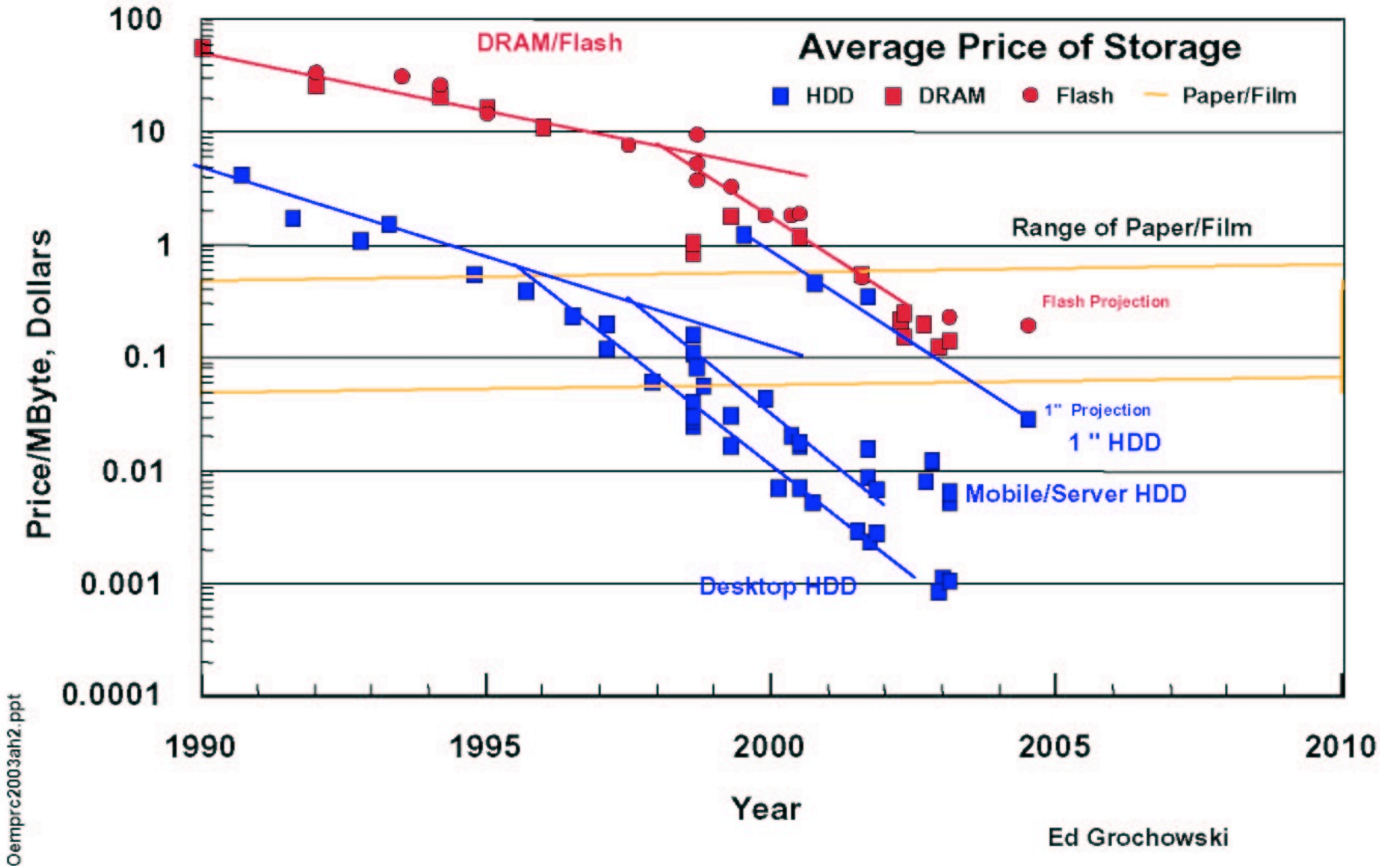
... which need more field to magnetize

... which needs more power

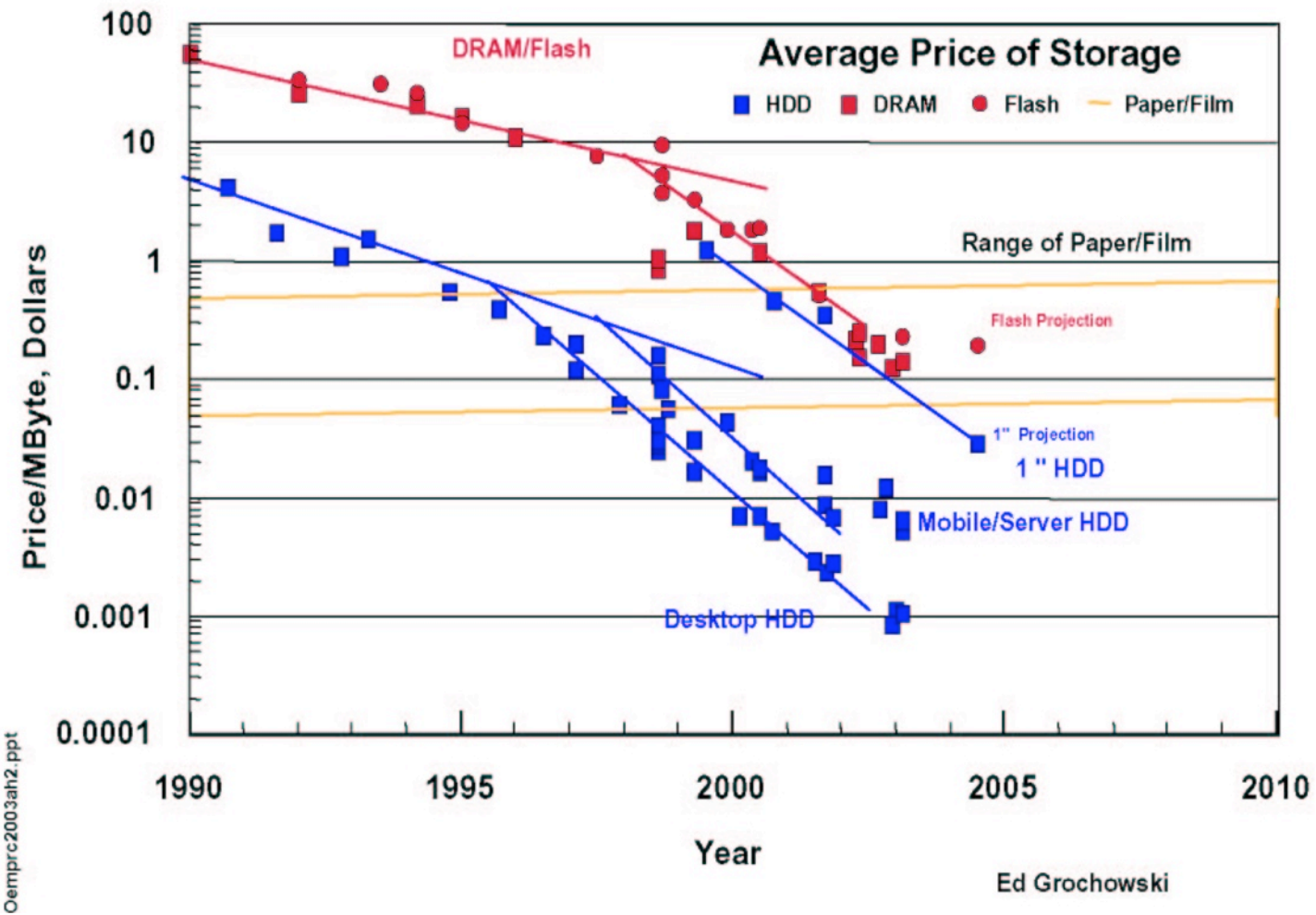
HUGE challenge in nanoscale materials science!

1 bit needs k_BT ...

$$$ *vs* flash and DRAM



price is the real advantage.



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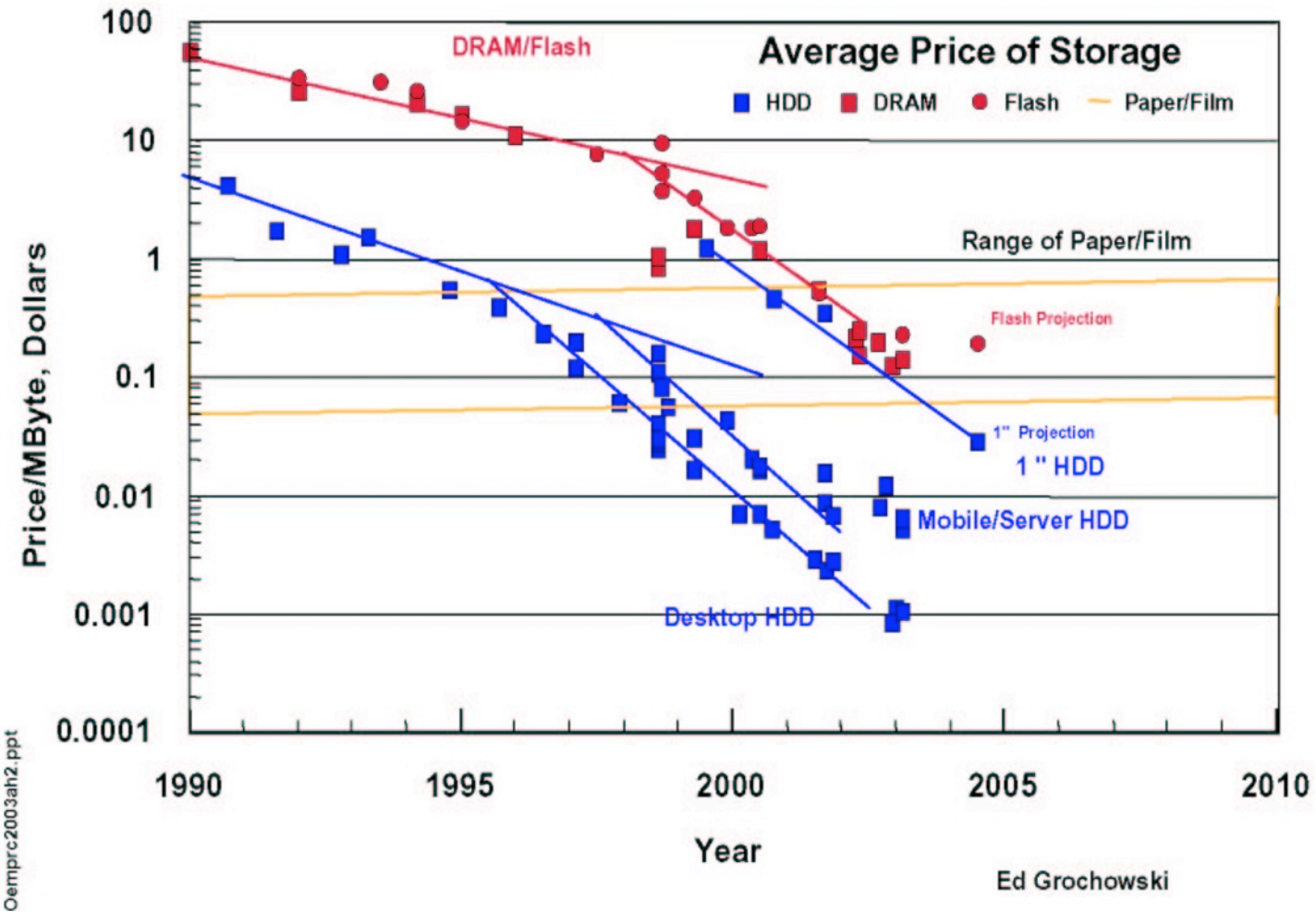

flash is beating the 1" HDD in some apps

e.g., mp3, camera

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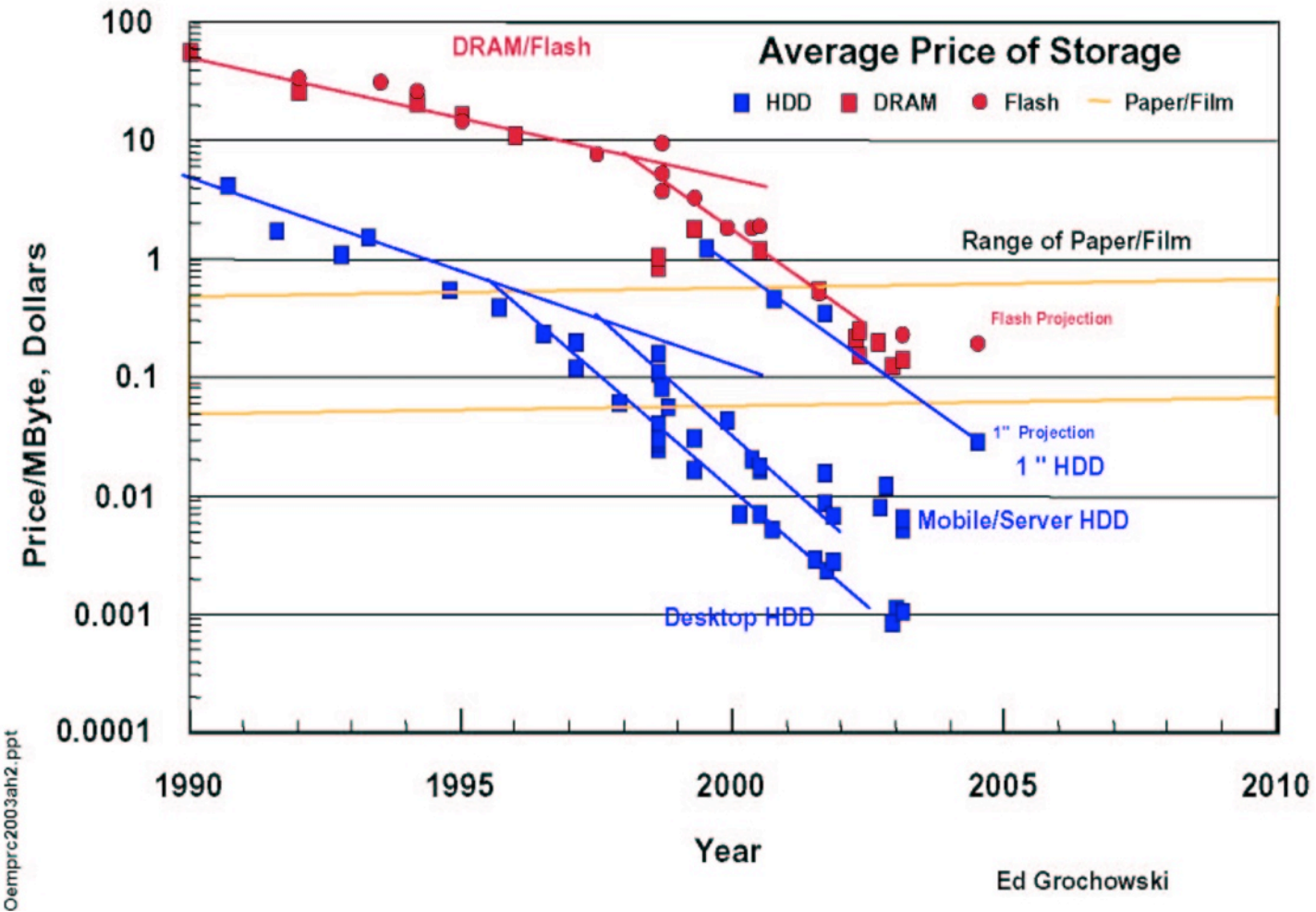


flash is beating the 1" HDD in some apps

e.g., mp3, camera

power consumption may be the larger issue

power consumption is not an advantage

latency ...

fundamental limits of magnetism & thermal stability?

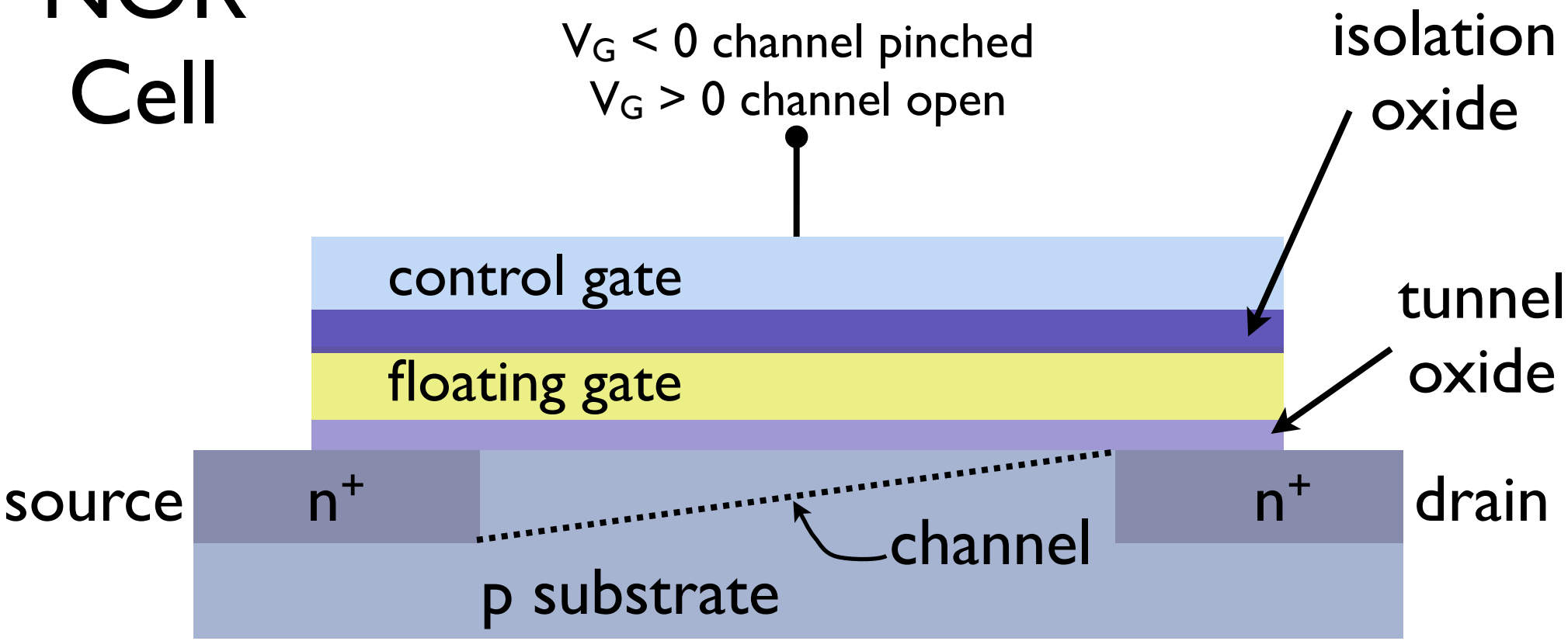
SO!

how does flash work?

how about RAM?

the basics of Flash

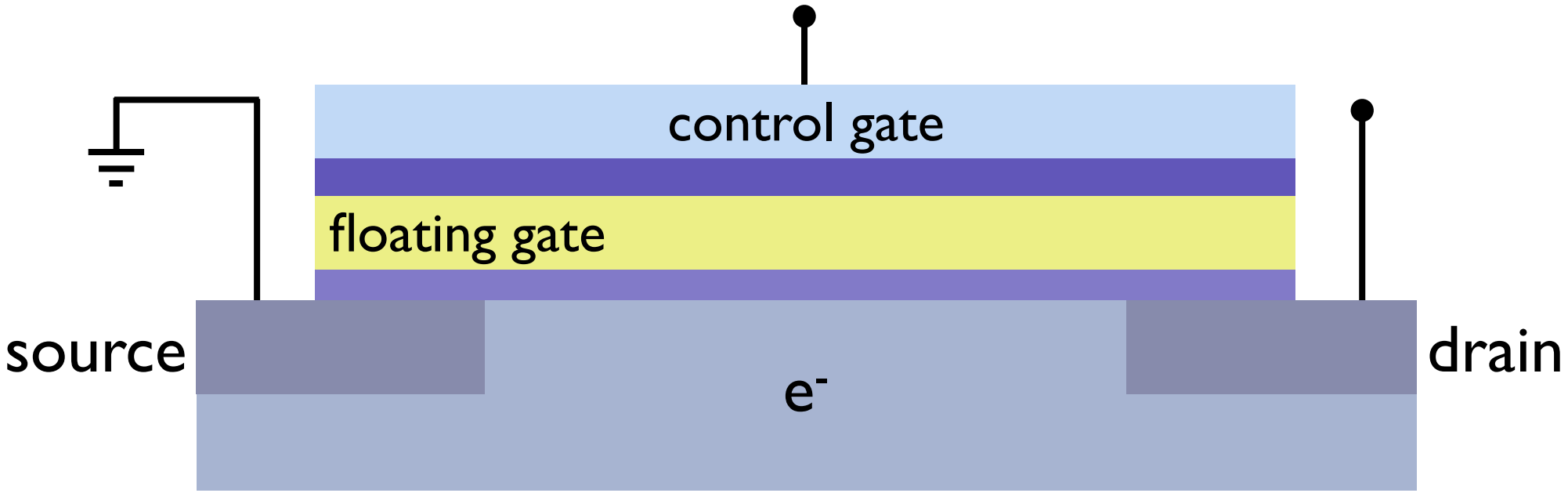
NOR Cell



- like a MOSFET
- uses 2 gates

writing

"hot electron injection"



- ~7V to drain
  pull e^- through channel
- ~12V to control gate / open channel
  injects e^- into floating gate through tunnel oxide
- floating gate now charged

writing

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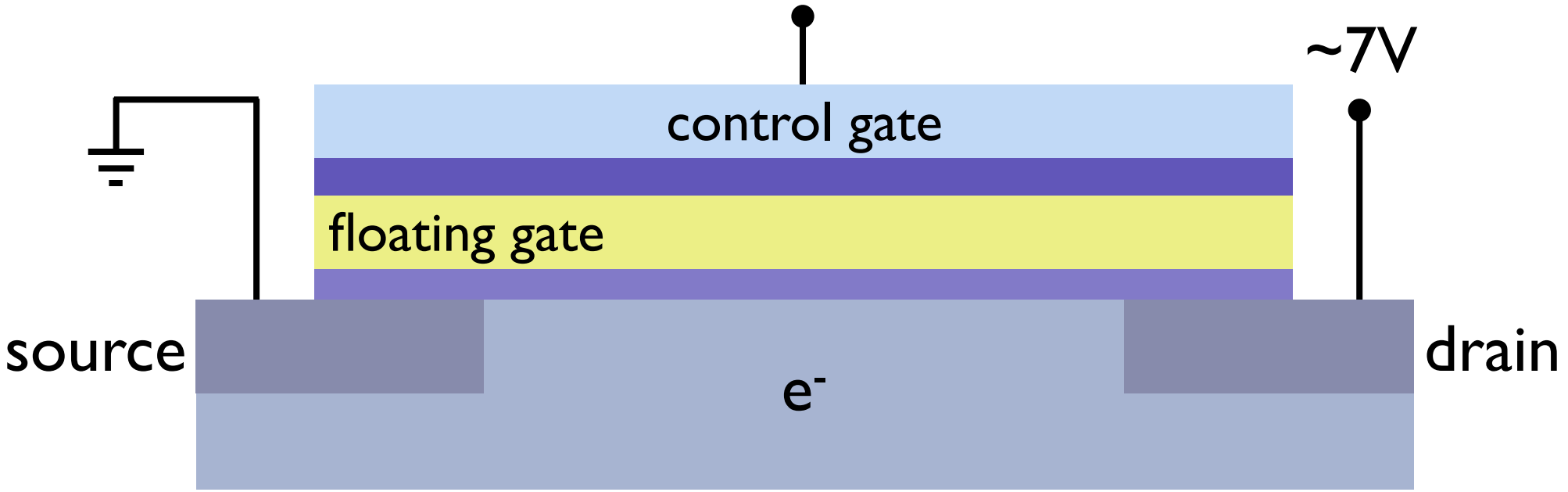

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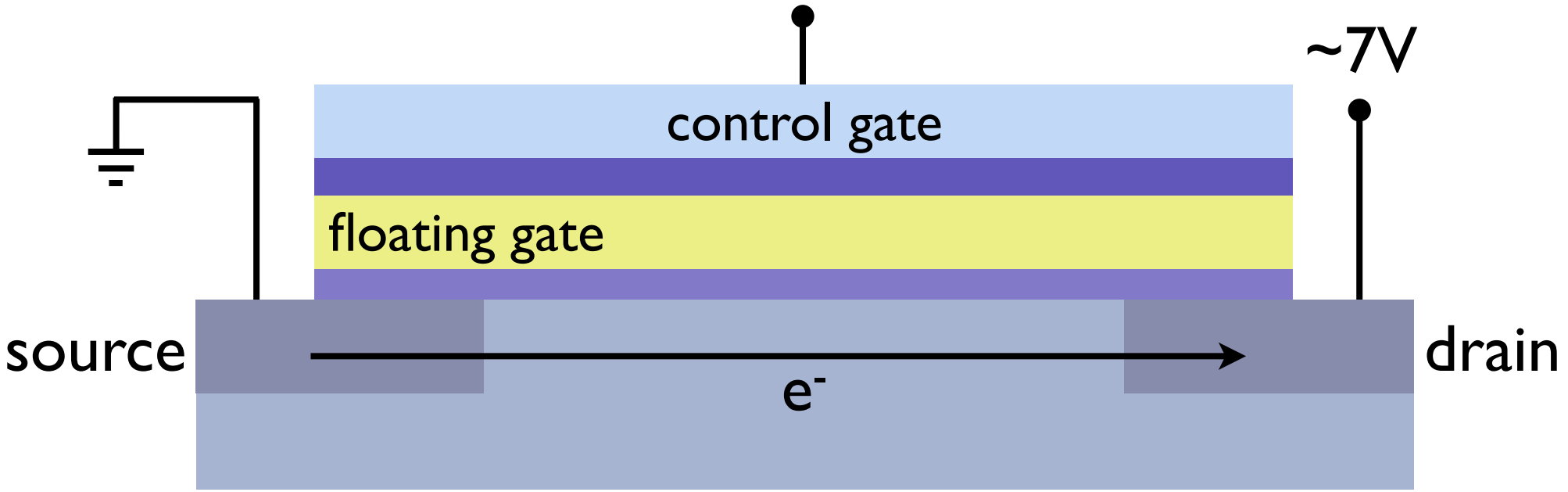

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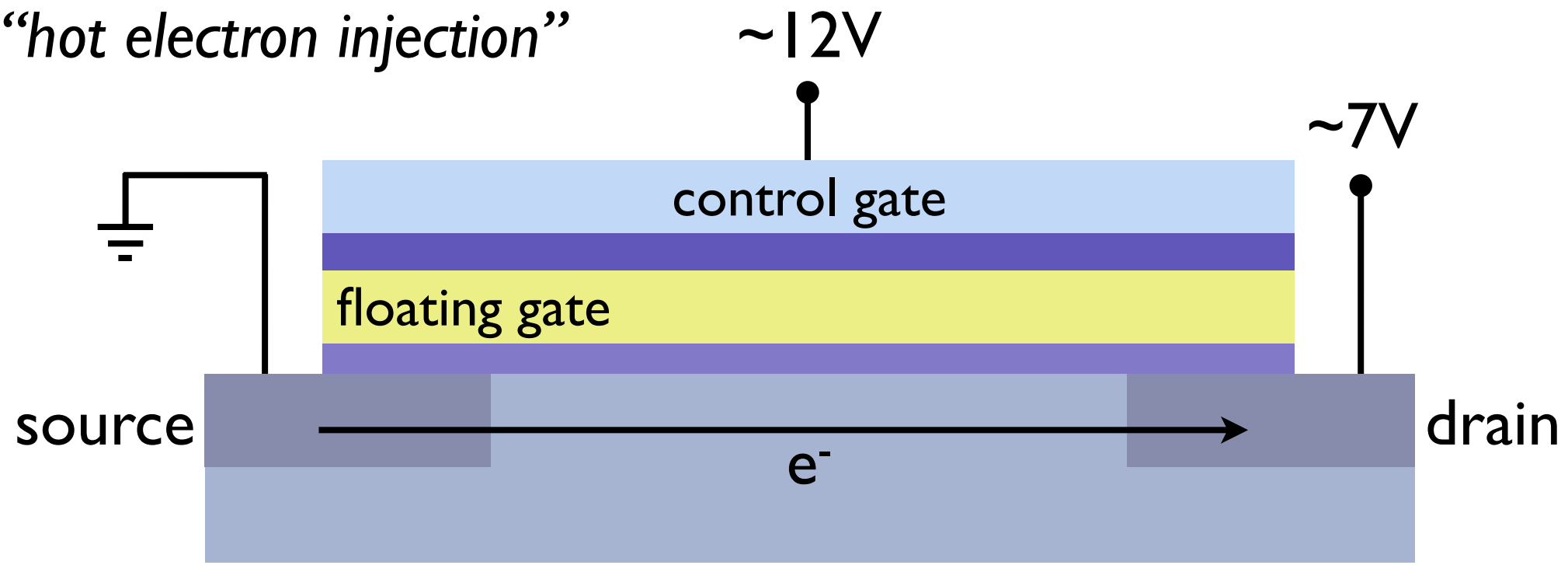

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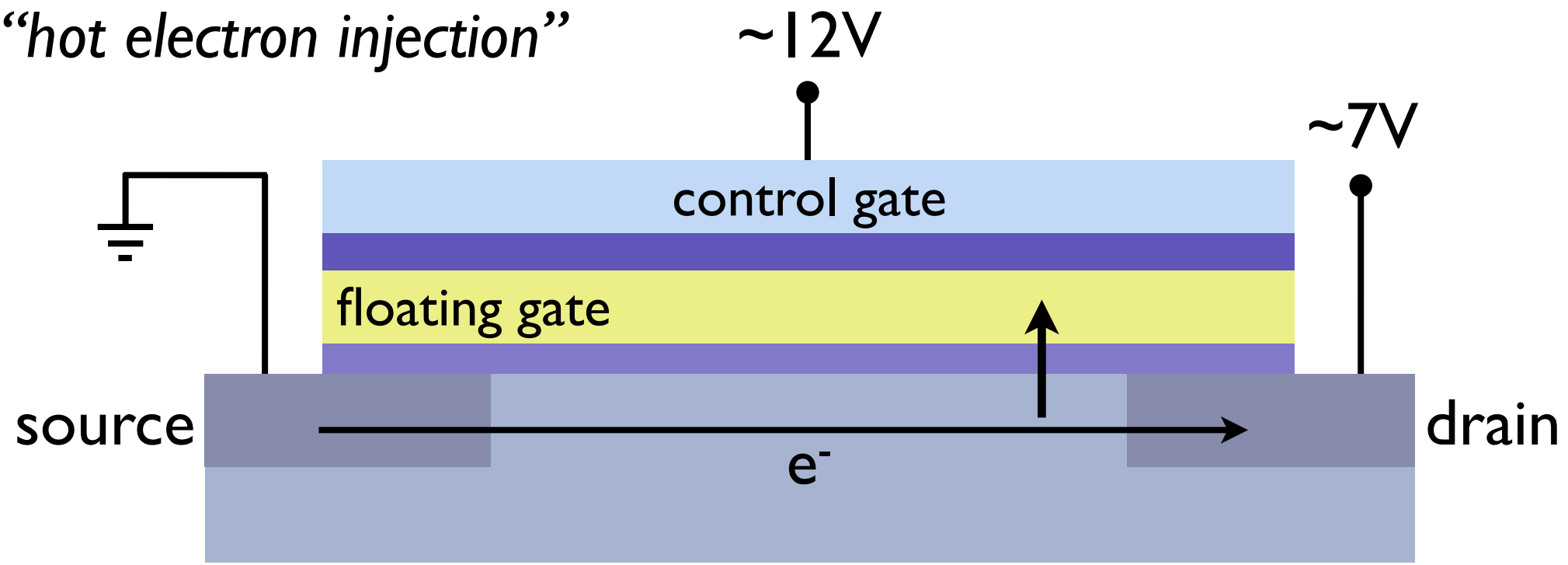

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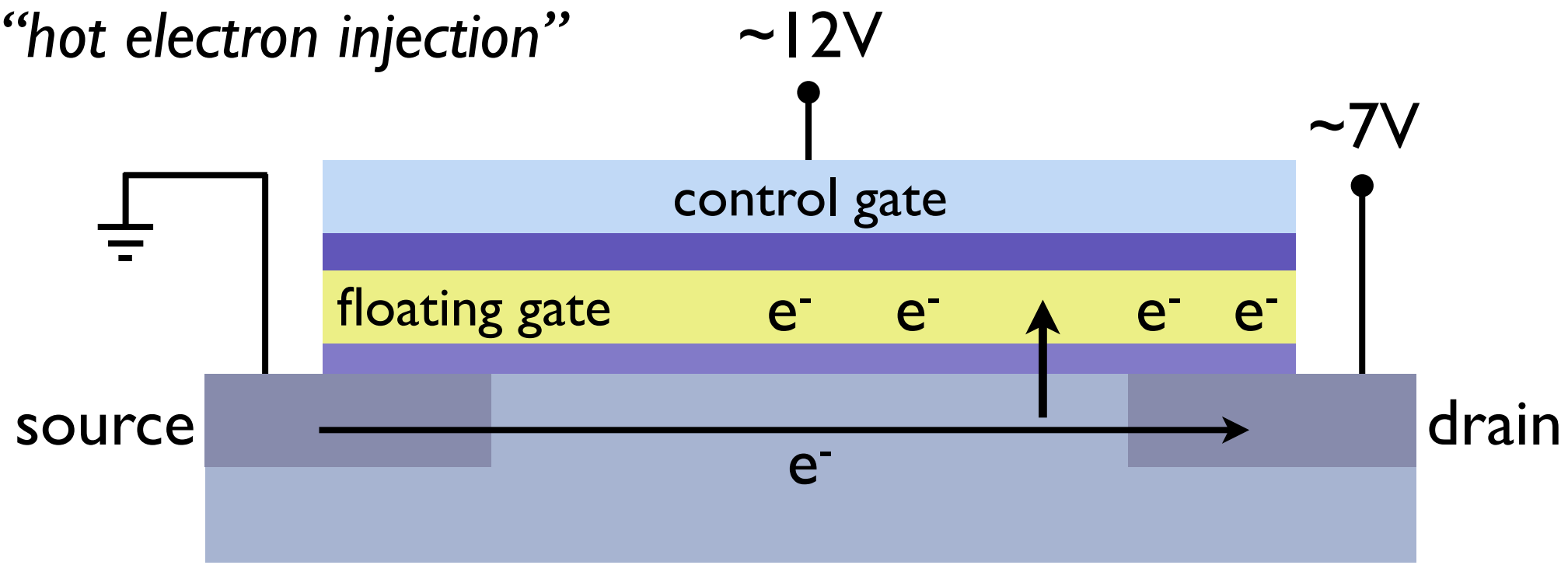

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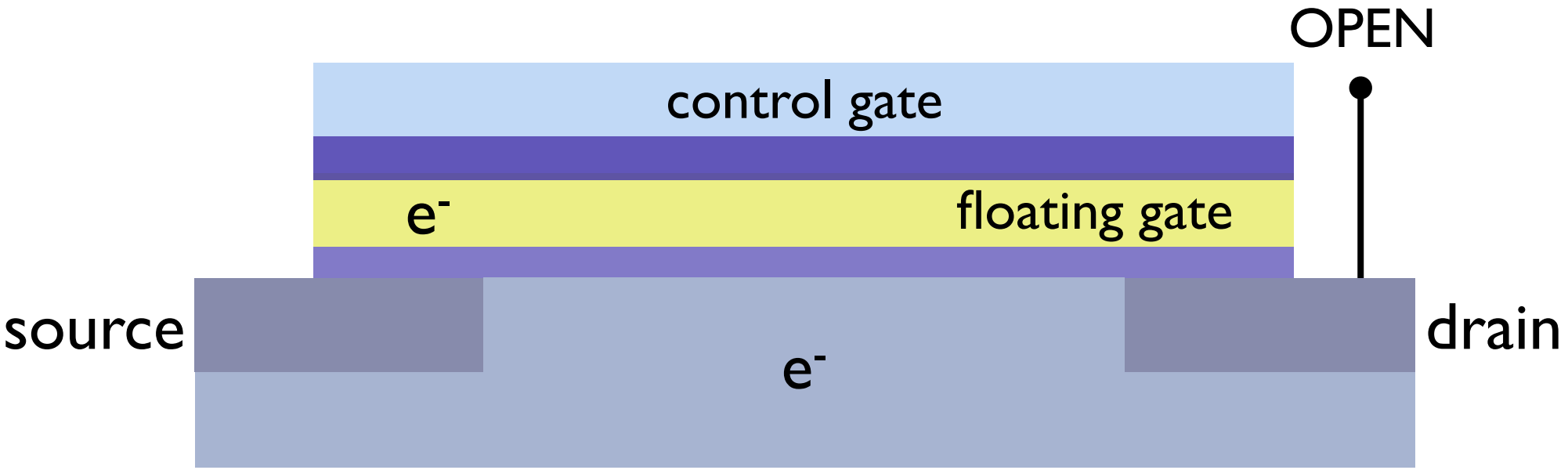
erasing

reset all bits to "1"



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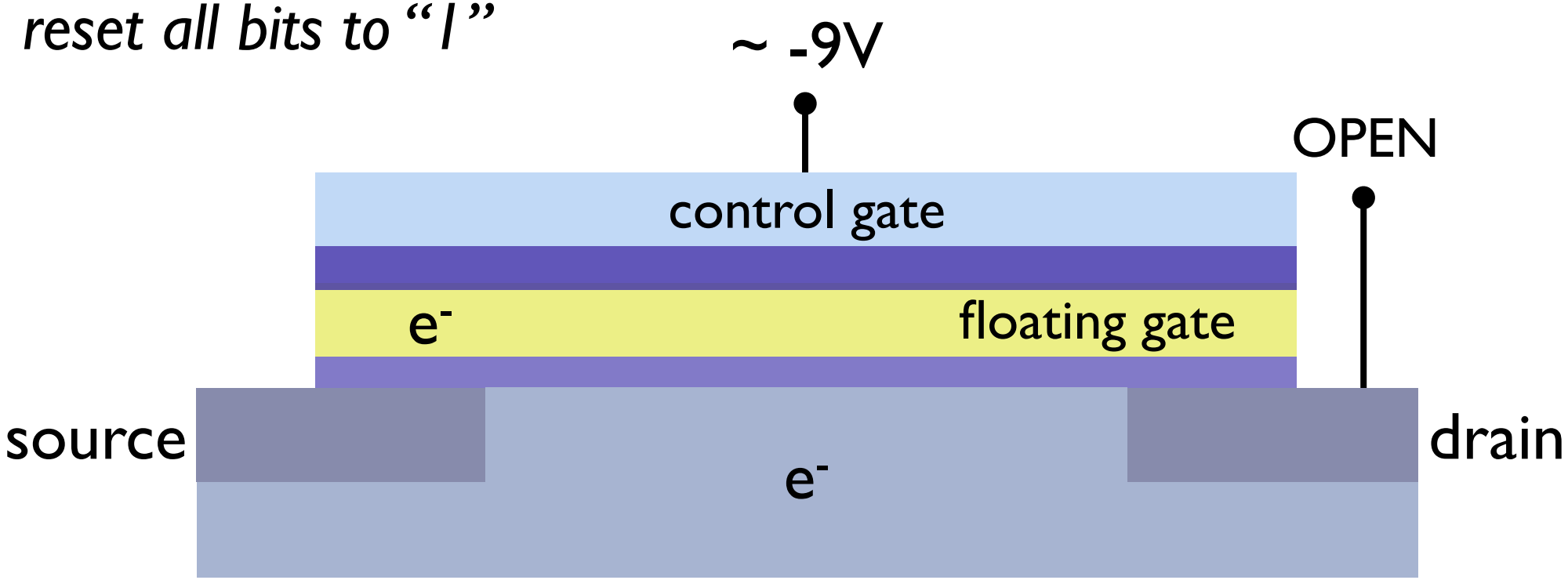

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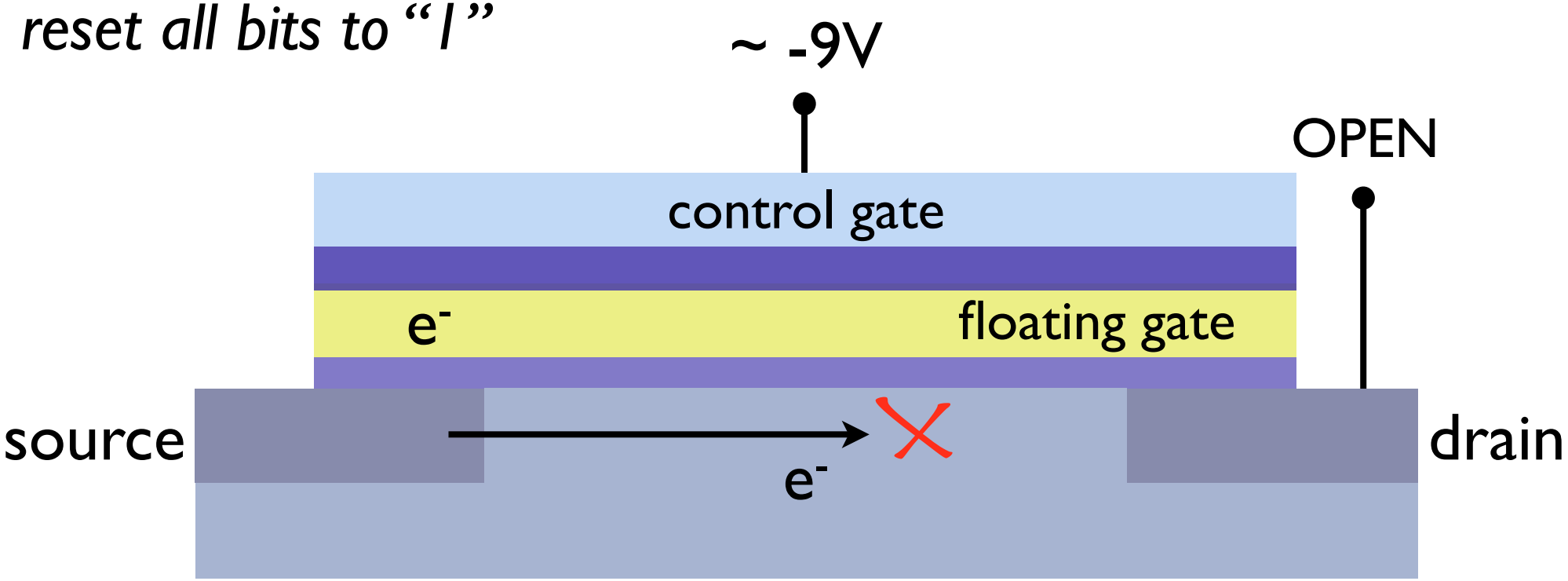

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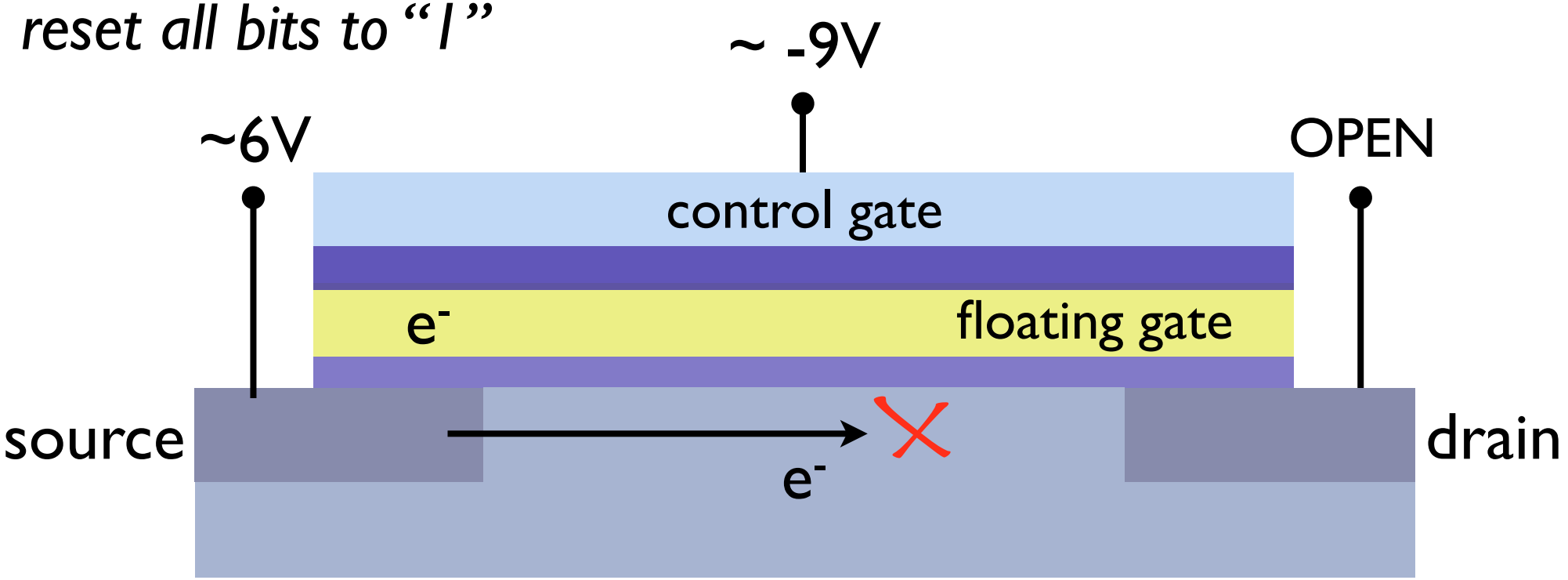

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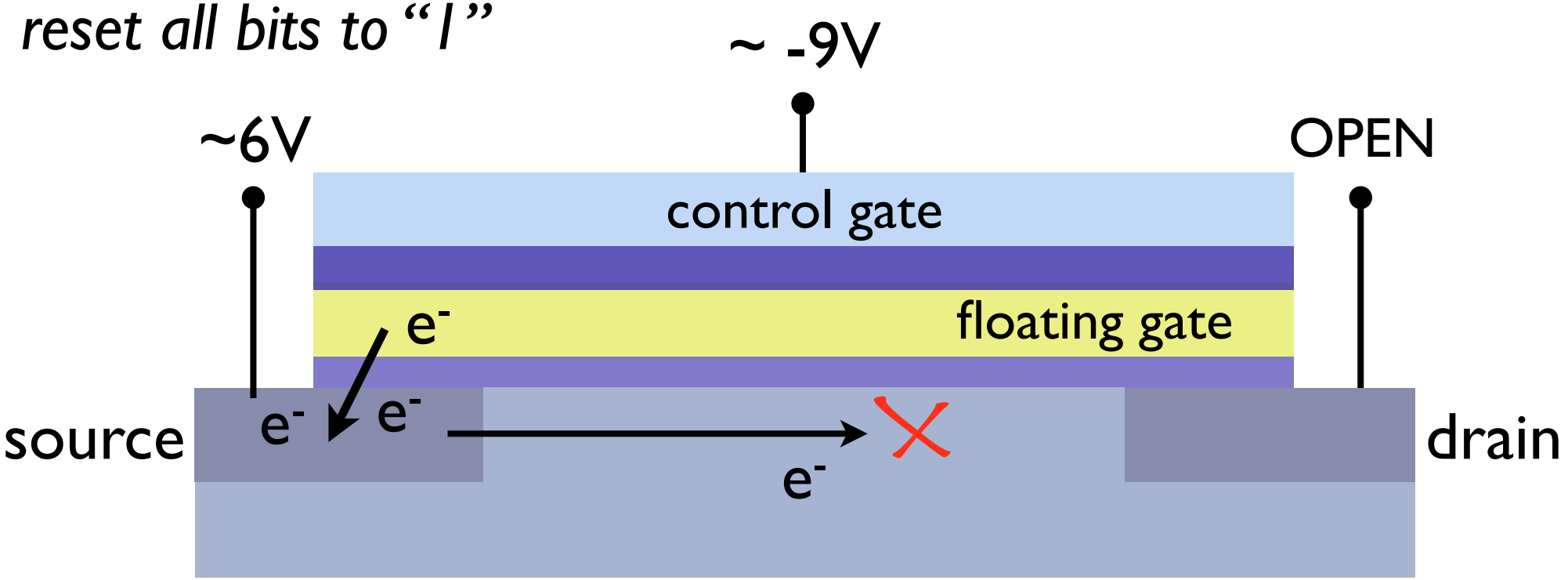

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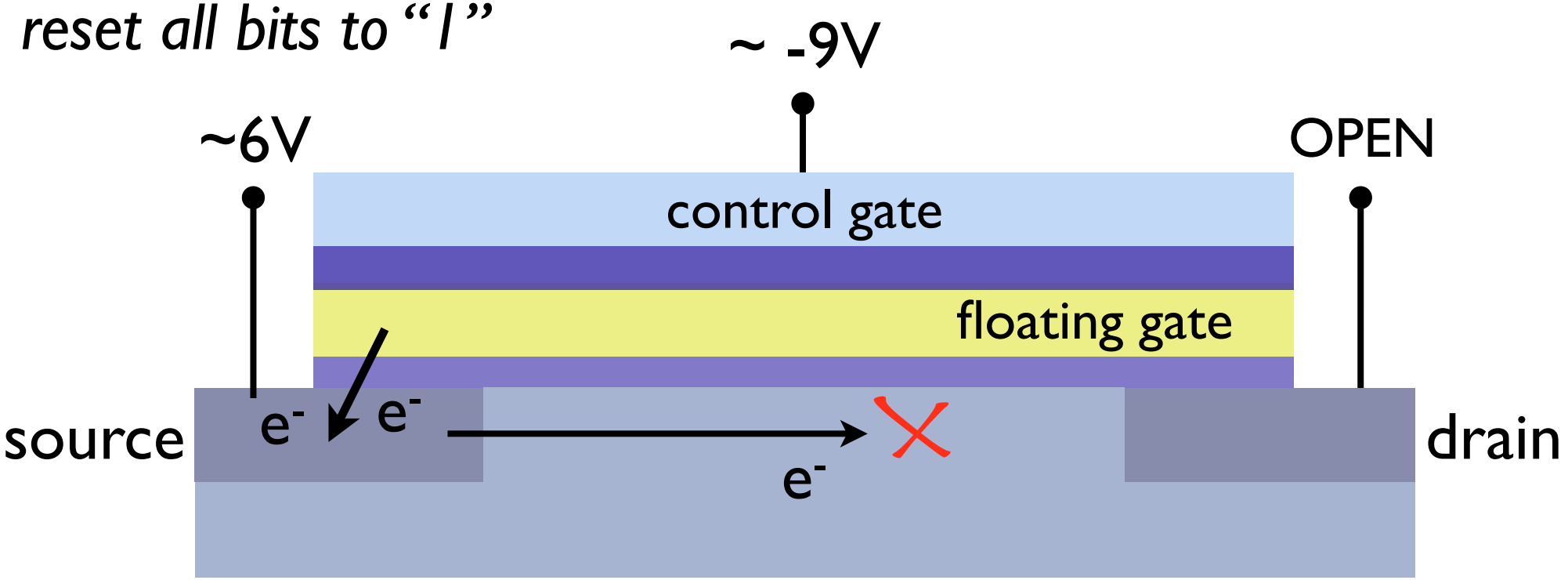

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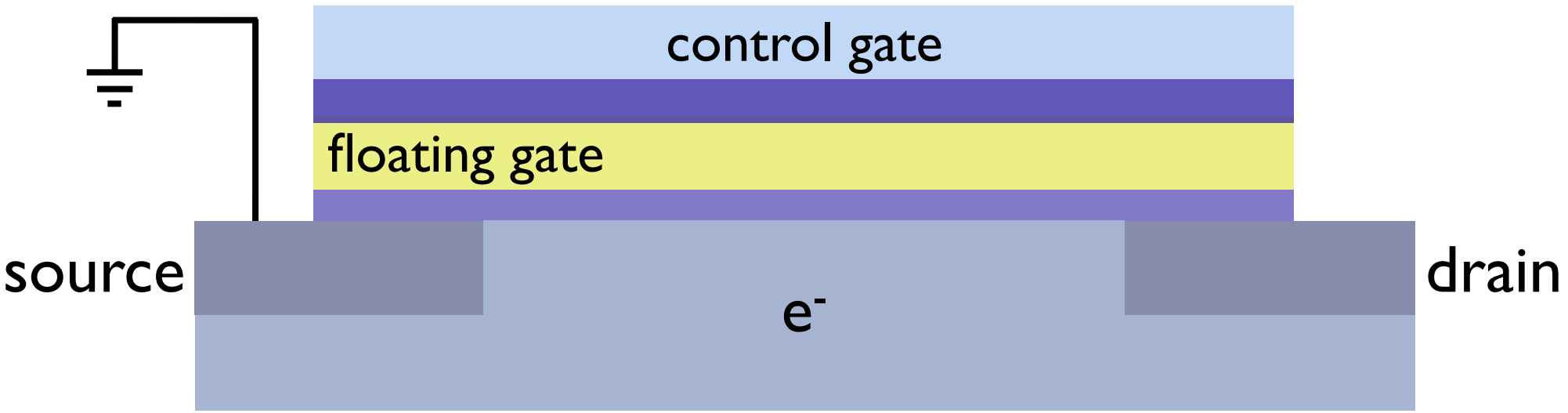

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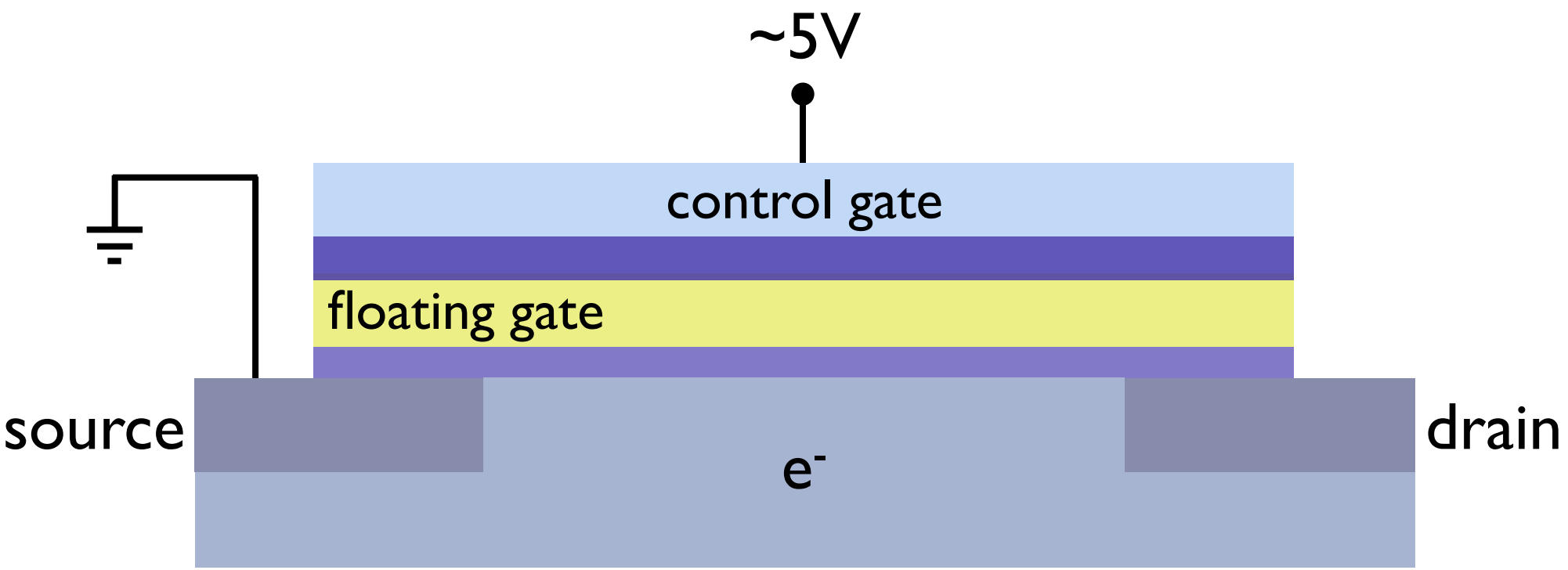
  presence of charge modulates I_{SD} !

reading



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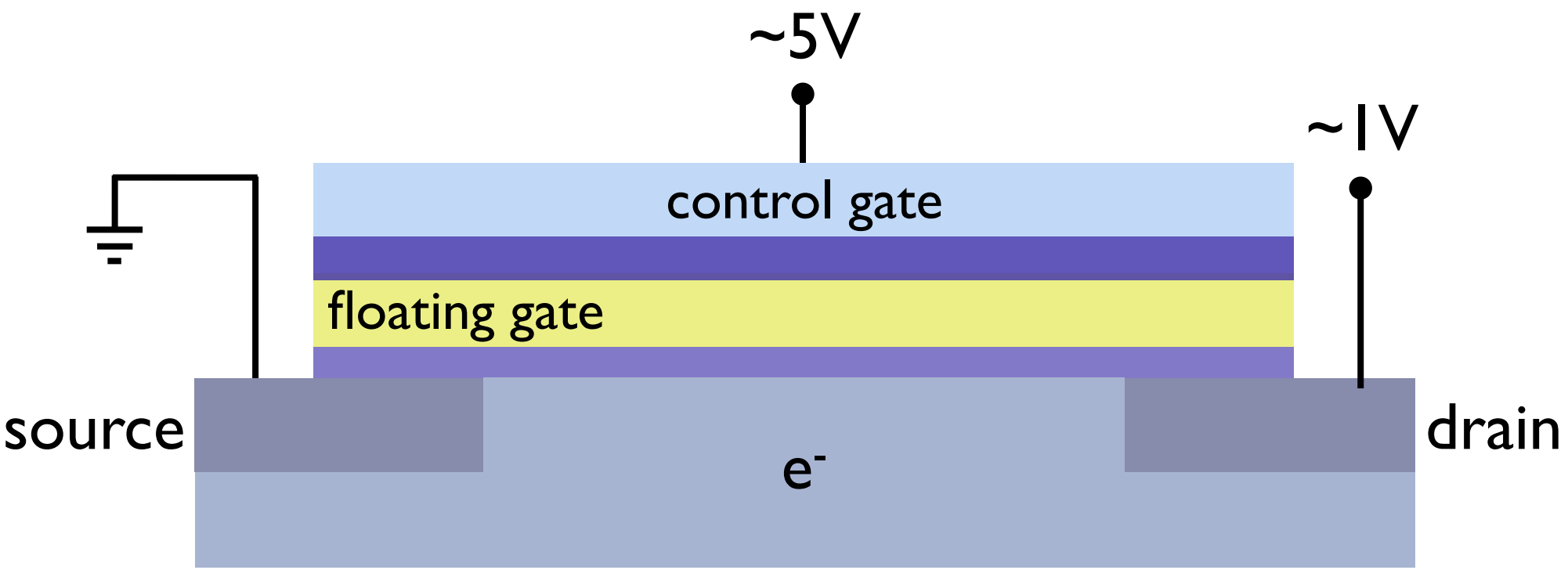

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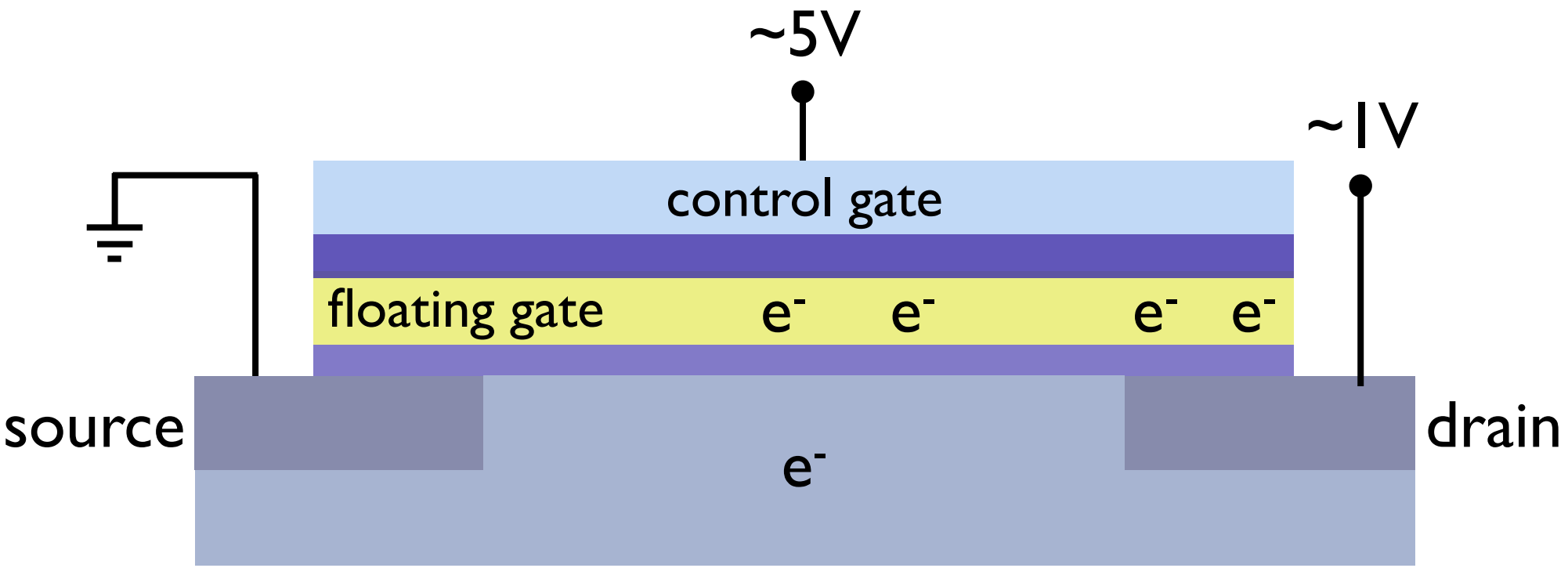

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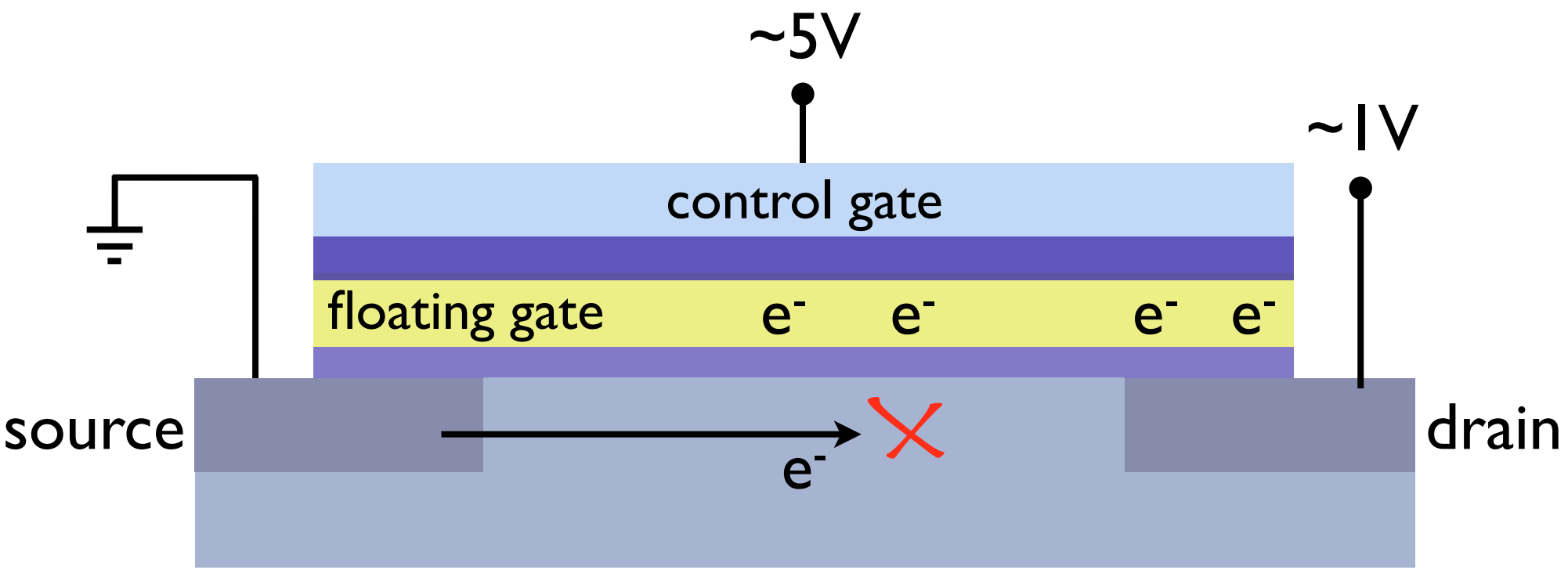

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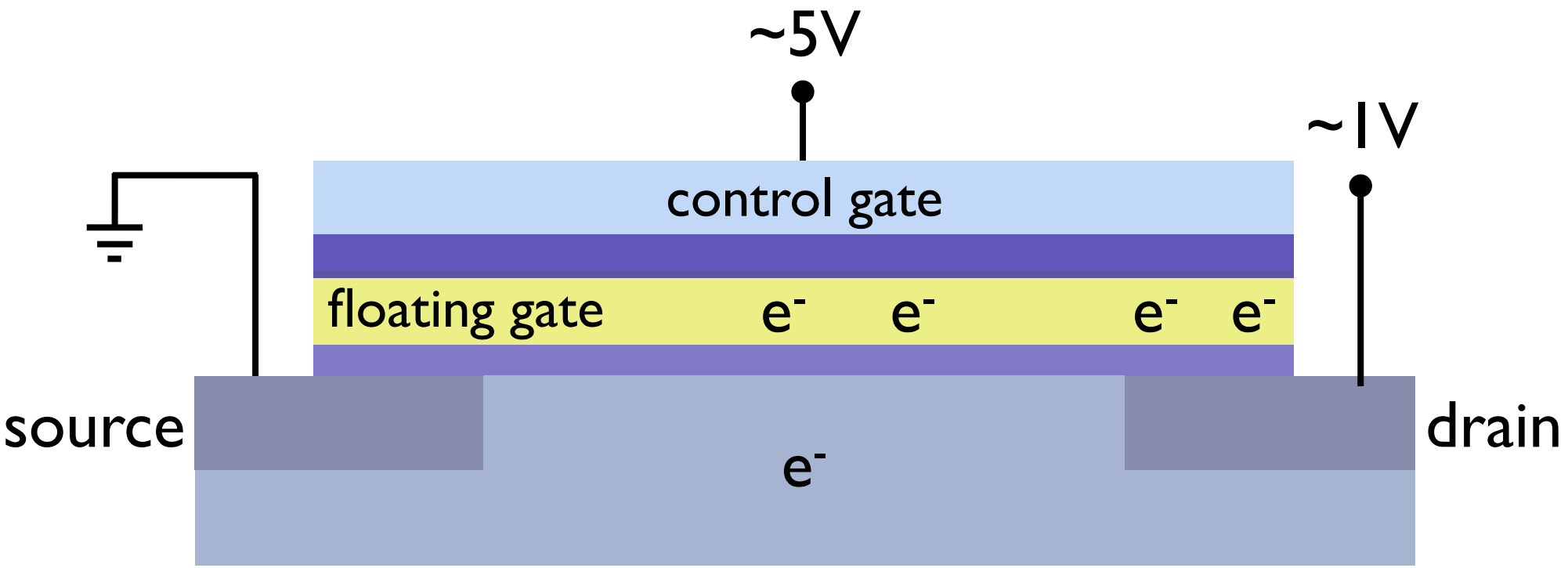

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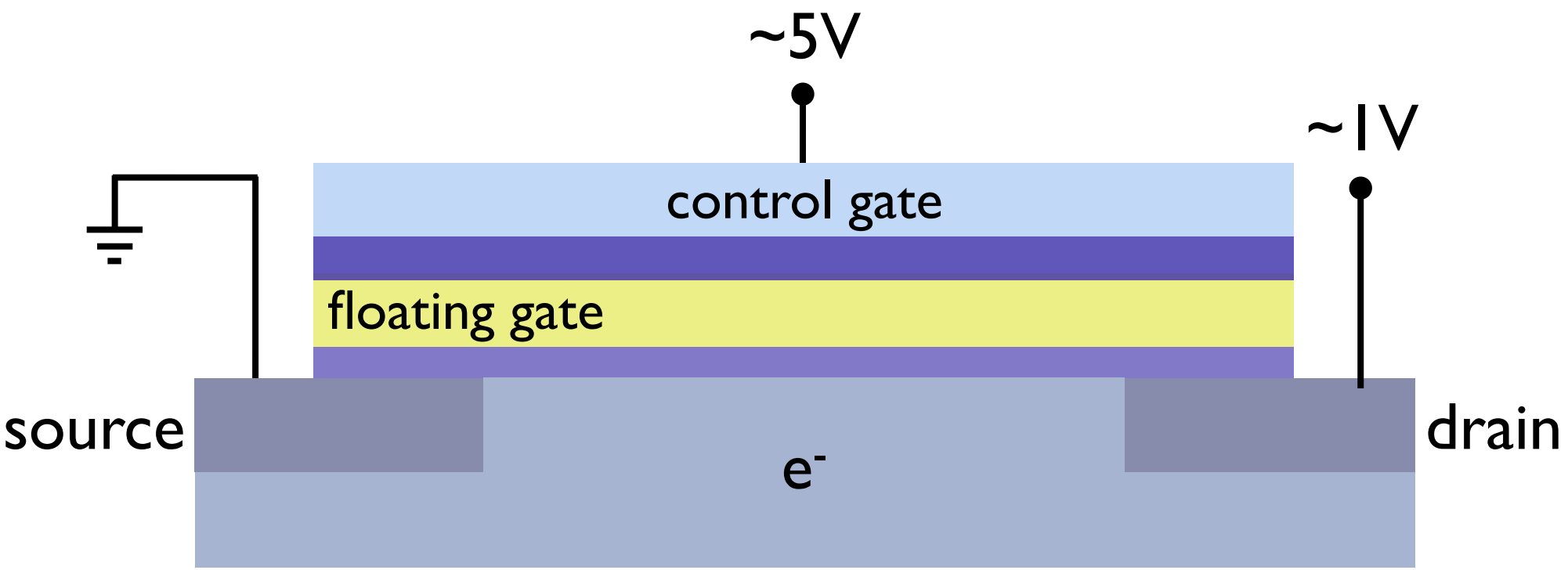

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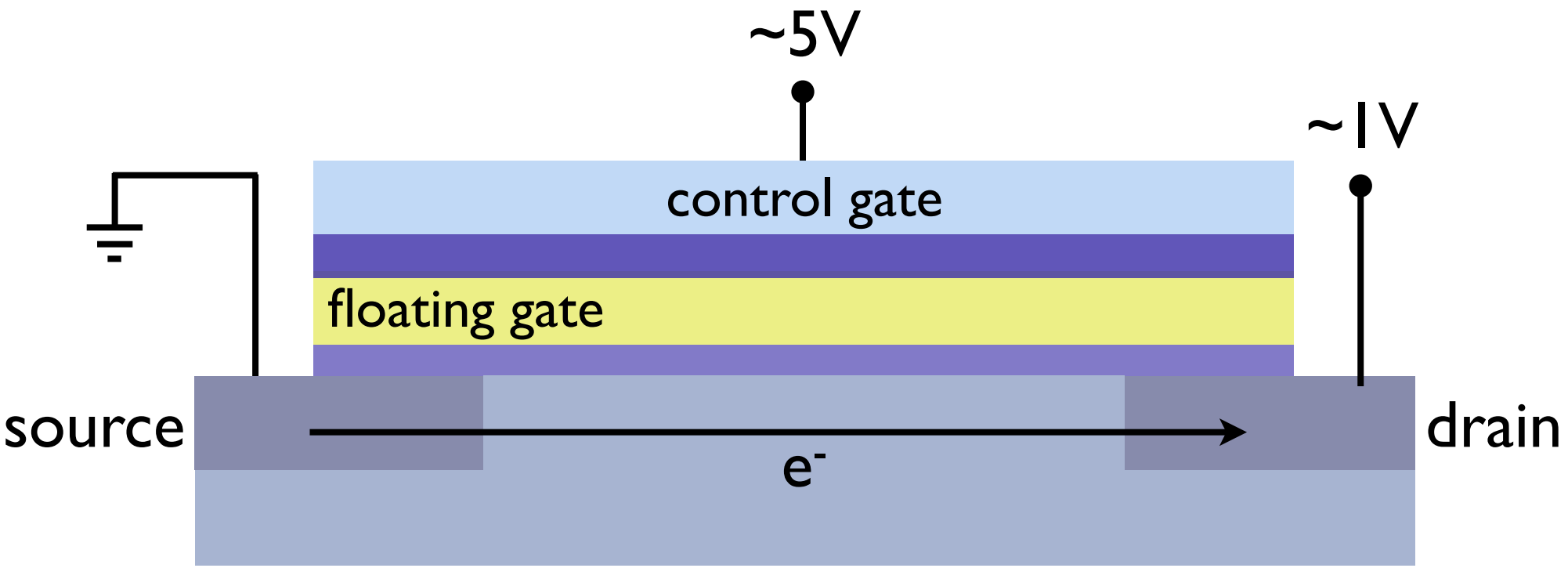

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+ no mechanical limitations

+ lower latency

  = attractive for speed, noise, power consumption, reliability.

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  = attractive for speed, noise, power consumption, reliability.

- cost/GB still significantly higher (but decreasing rapidly!)

- finite number of erase/write (typically 10^6 cycles guaranteed)

  unable to support an OS (swap!)

  warranties on flash-based disks trending ≥ HDD