3D: Beyond Conventional Flash and into the Future

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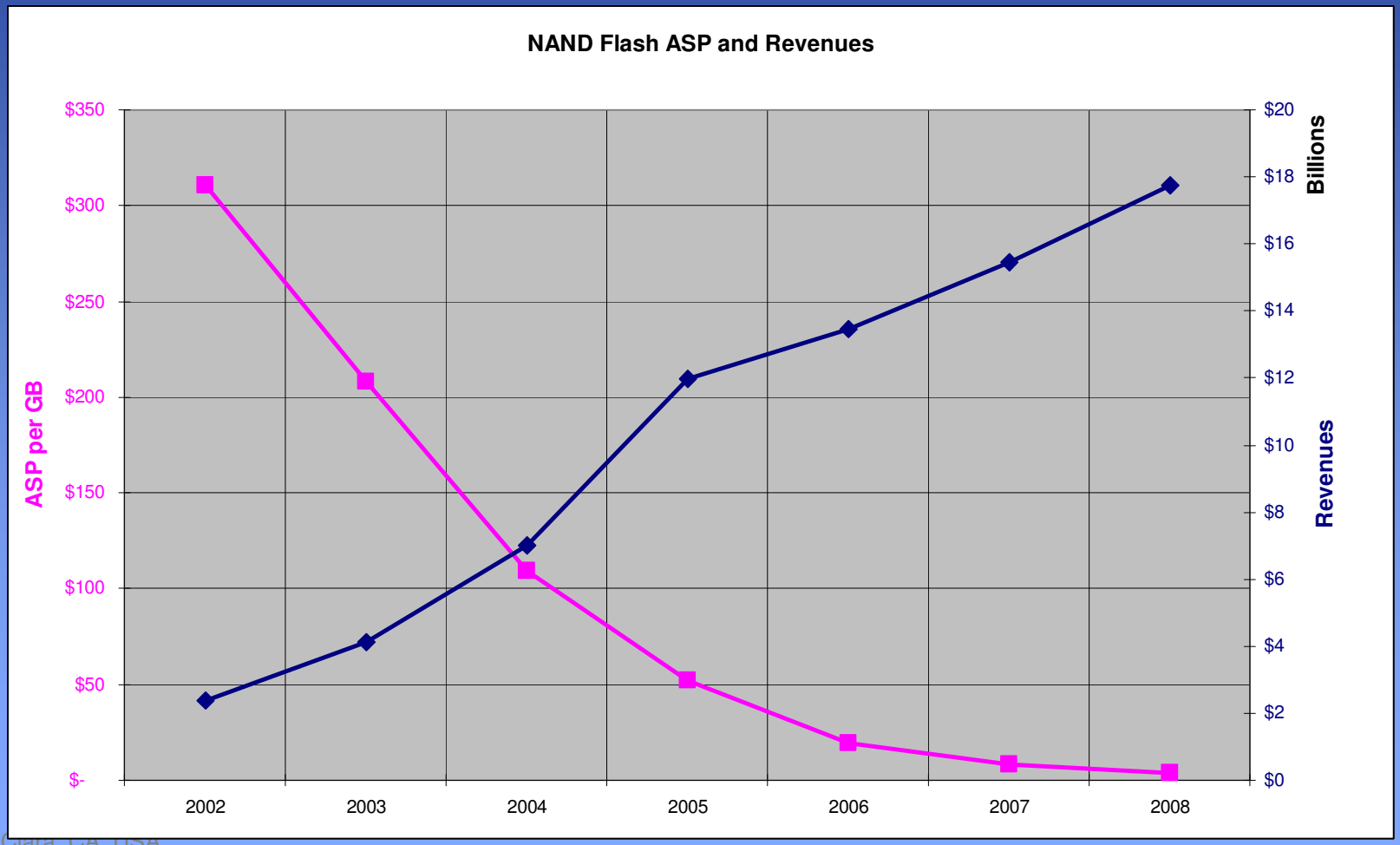
NAND Flash Industry Growth

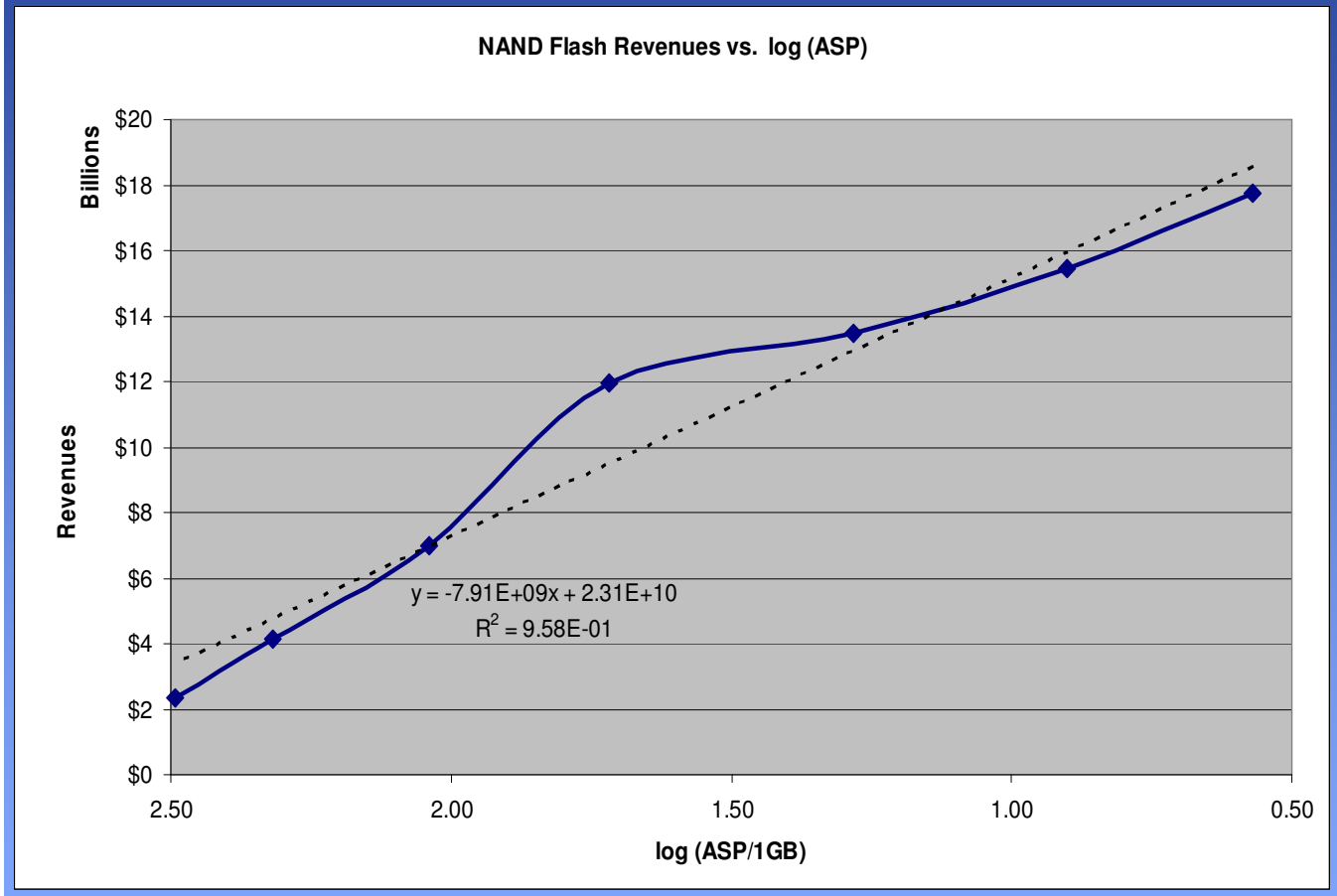


Source: Gartner

What drives cost-per-bit?

- Multiple bit per cell (MLC) technologies
- Economies of scale
- But beyond everything SCALING

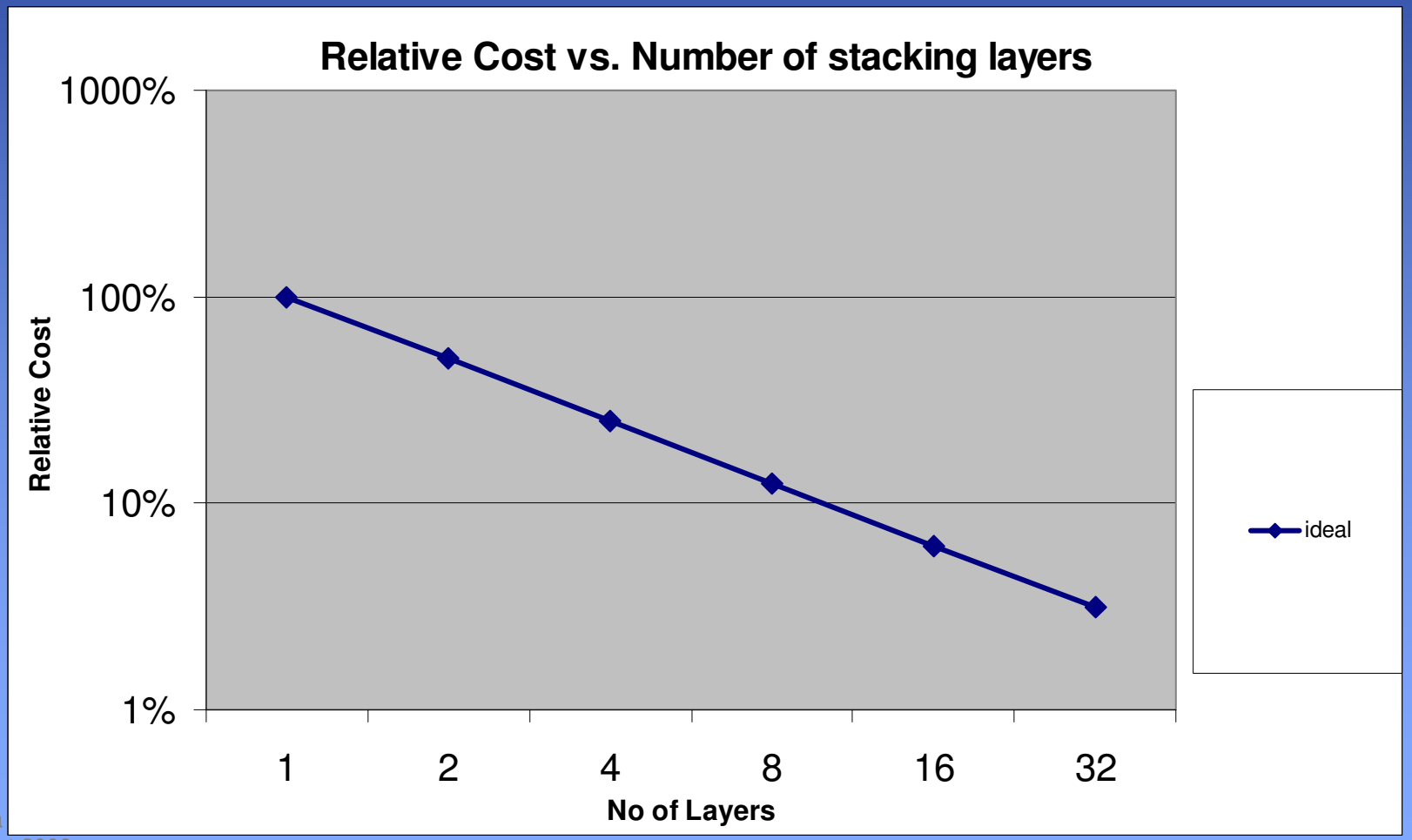
Flash Revenues vs. ASP



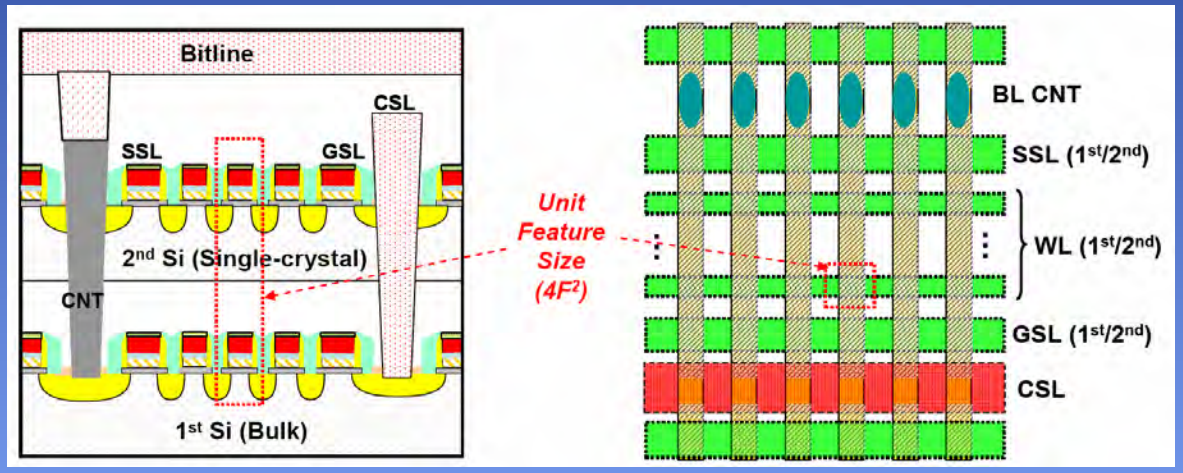
- "If we build it (at the right price), they will buy it"
- Exponential ASP reduction needed to drive industry growth
- We need to continue scaling

Rev = $23B – 7.9 x log (ASP/GB)

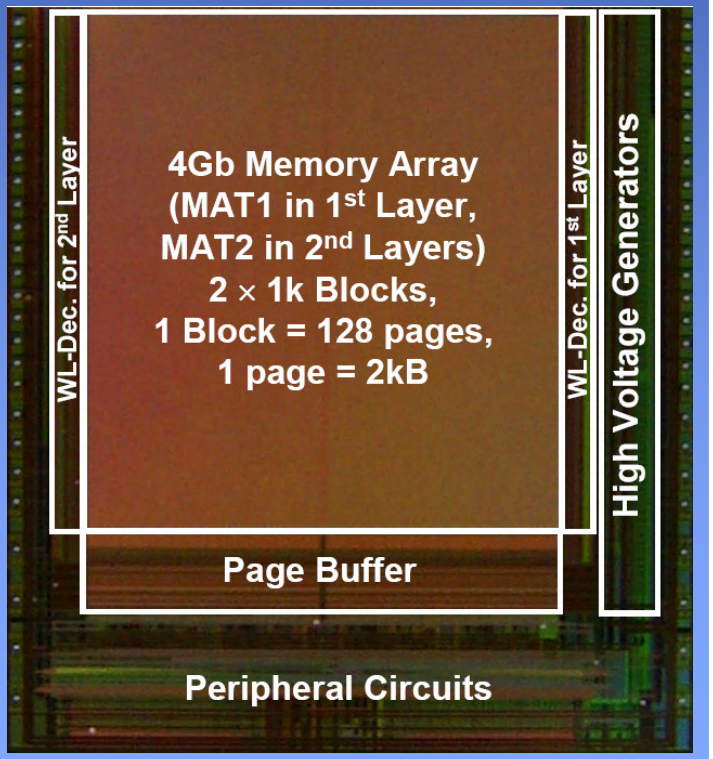
Can stacking layers of memory solve our scaling problem?

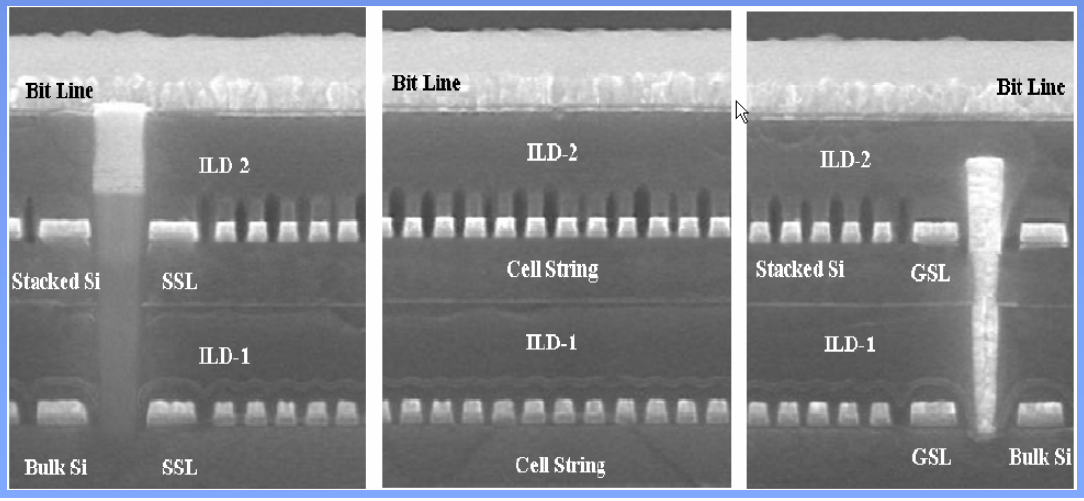


Examples of stacked memories: 3D NAND



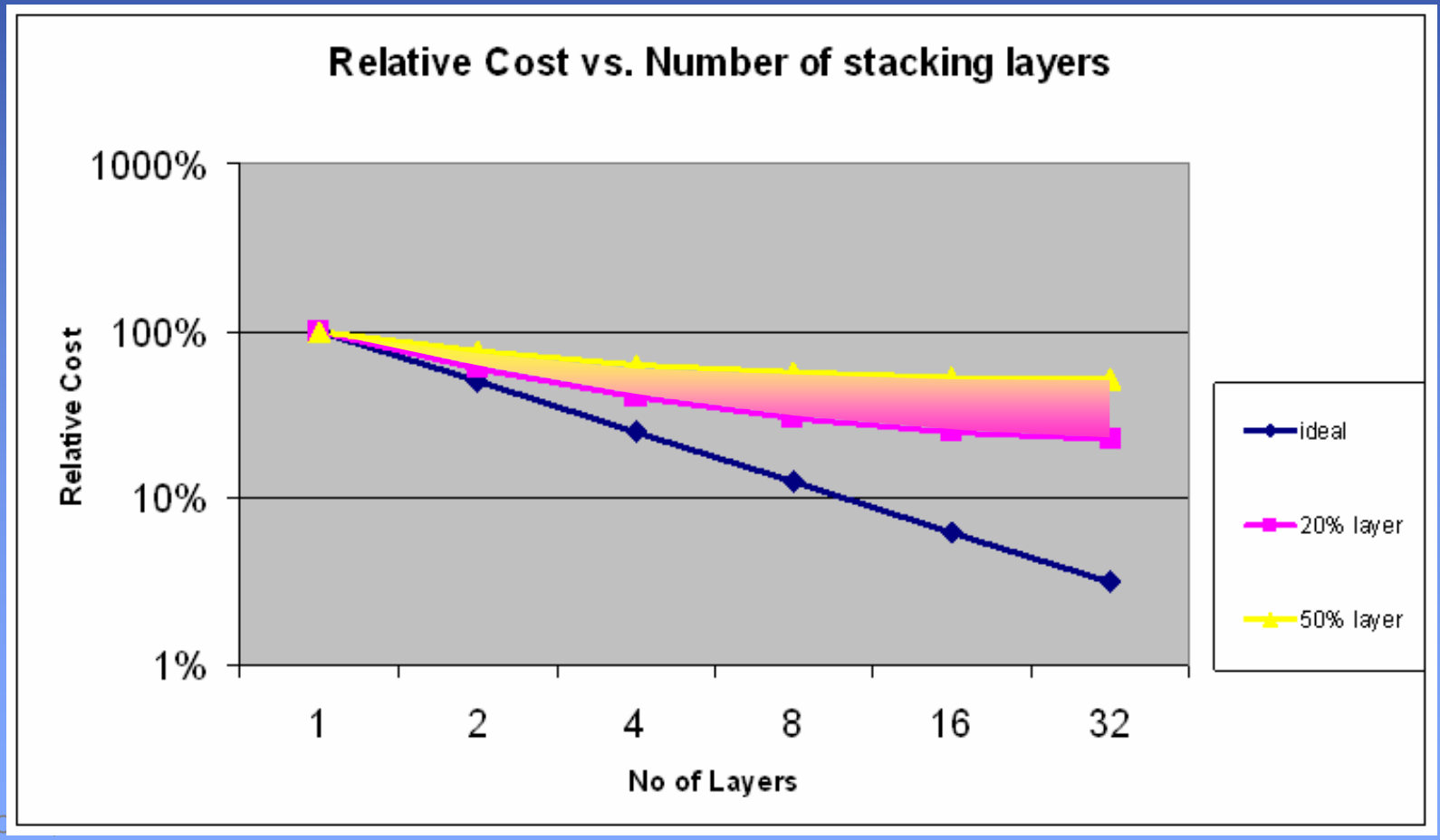
Samsung, IEDM '06, ISSCC '08





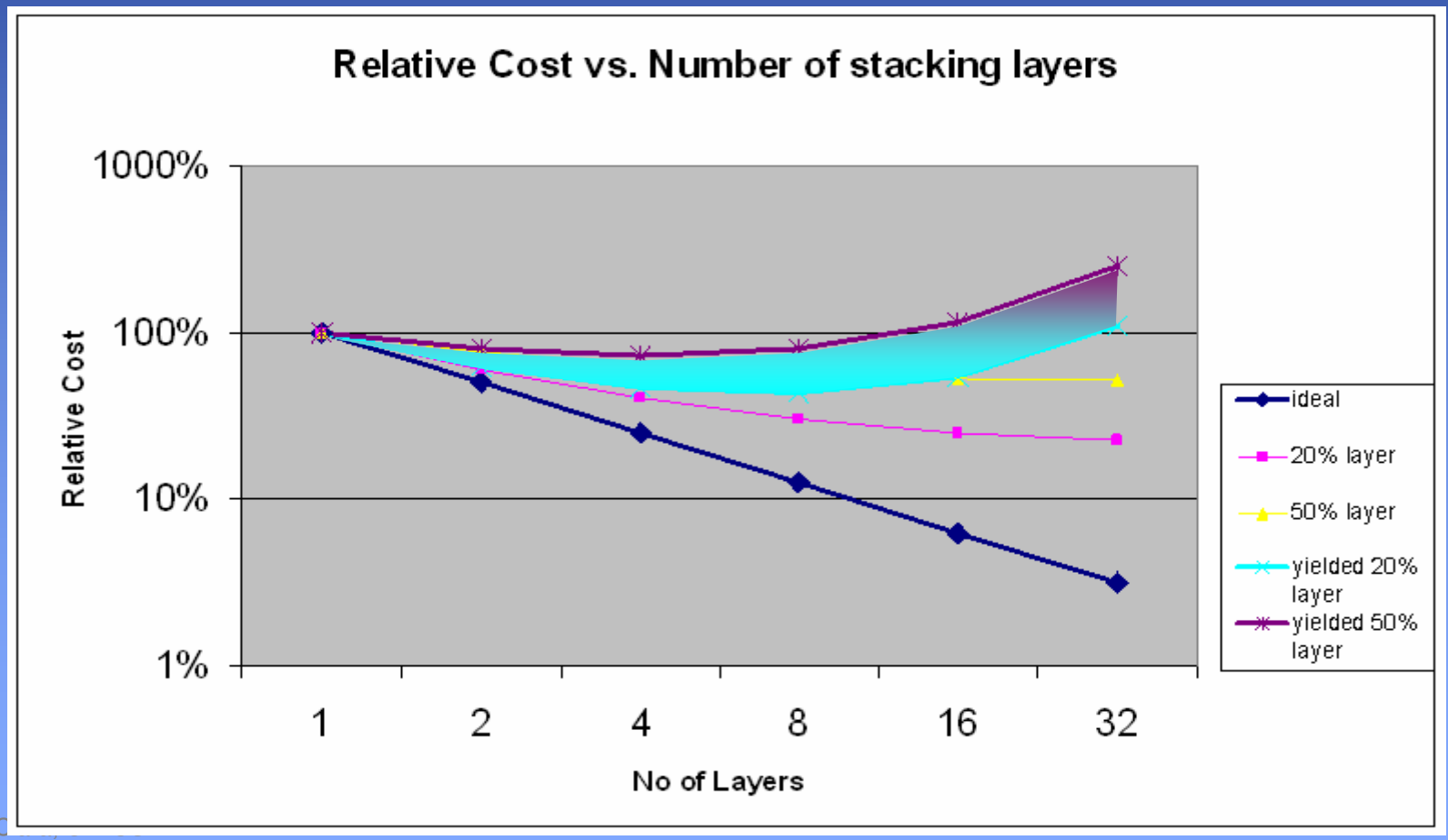
Additional Layers are not free

- **Die size overhead and additional process steps increase cost**



…and yield of each layer is <100%

- **Stacking may provide one-time cost benefits, but it alone is not a replacement for scaling**

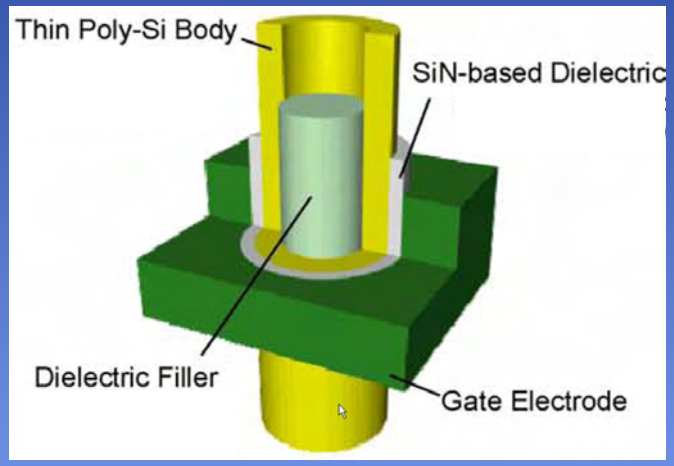


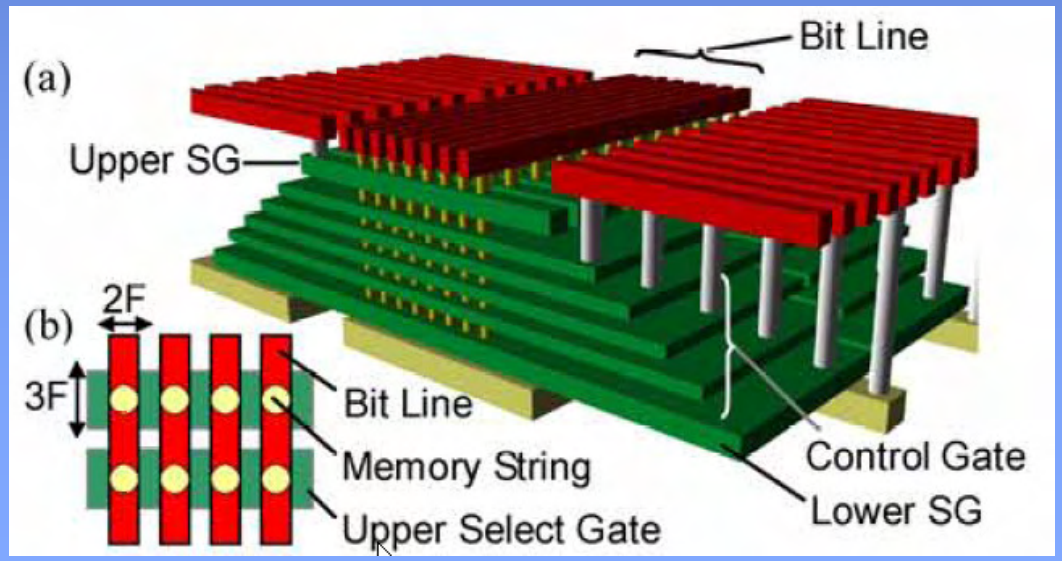
3D: Vertical Devices

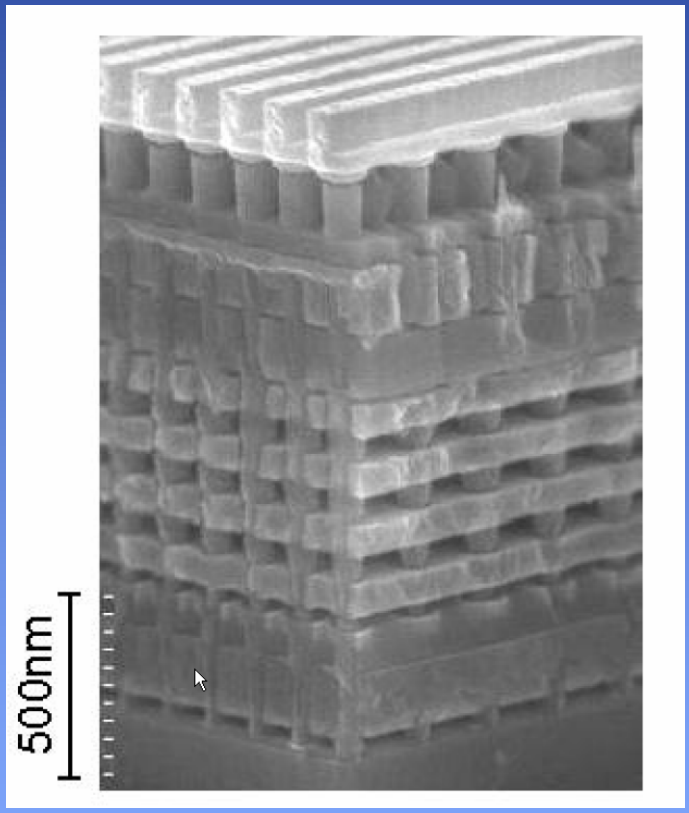
- Another perspective of 3D:

Can we build memory devices in the vertical dimension that are easier to scale?

Example of Vertical Devices in a 3D stack: Bit-Cost Scalable Flash

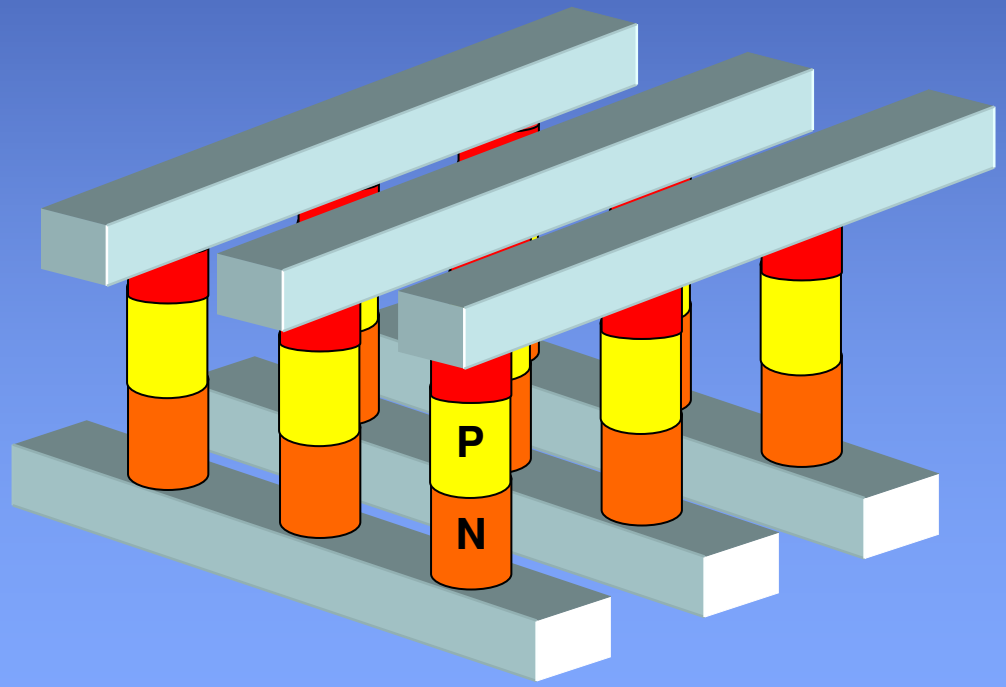






Toshiba, IEDM '07

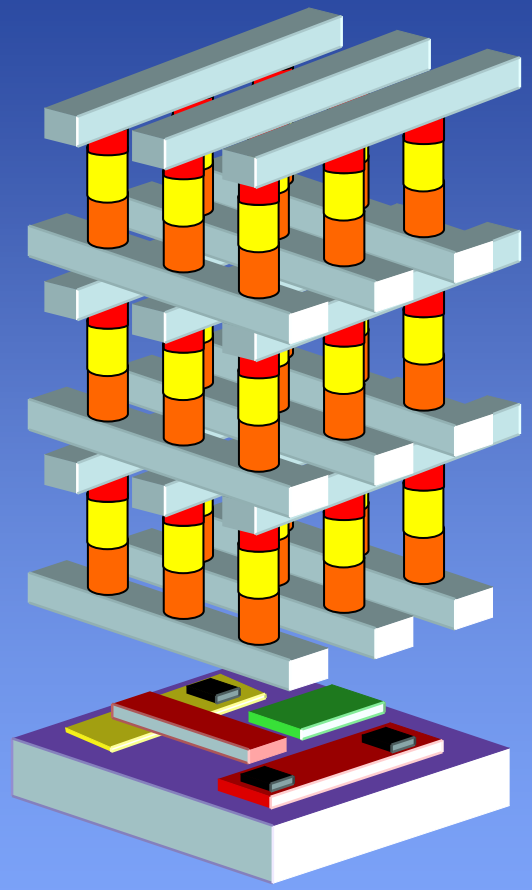
Ultimate 3D Memory - Scalable and Stackable Cross-Point Diode Array

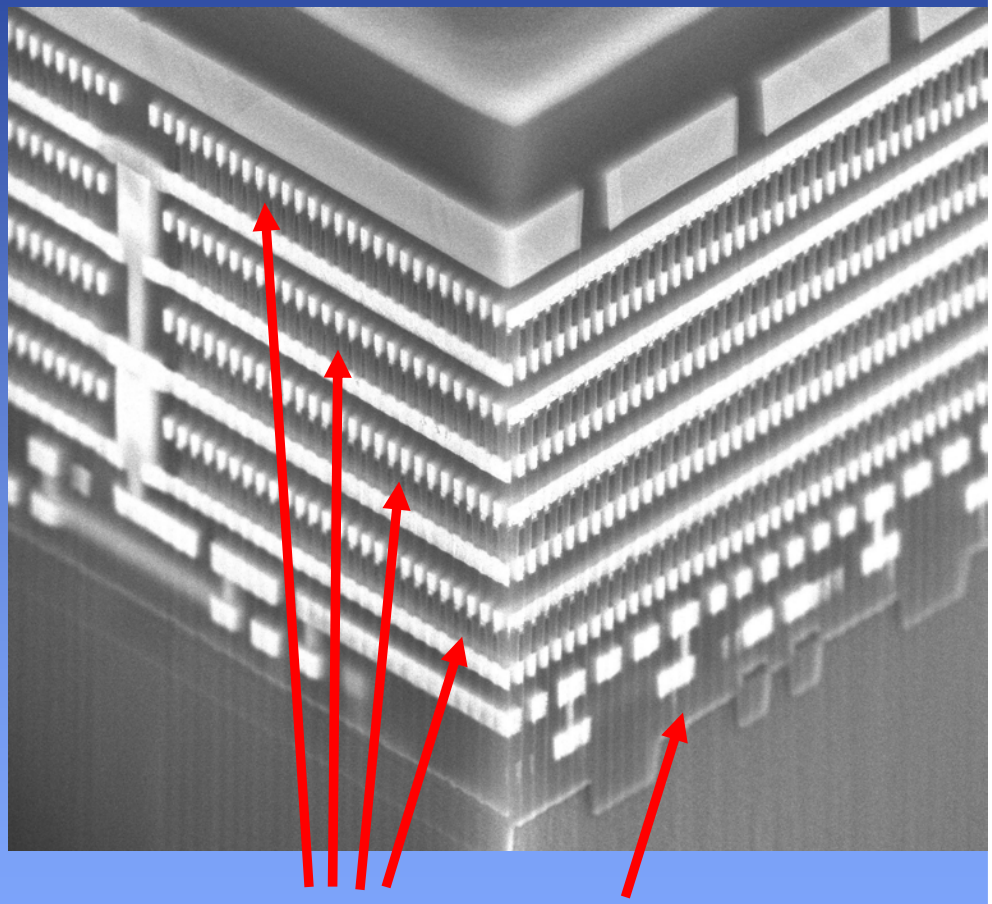


Resistance Change Materials

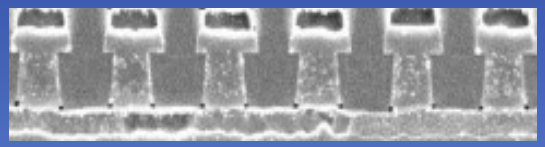
Chalcogenides (PCM)
Metal Oxides
Solid Electrolytes
Magnetic materials
and others…

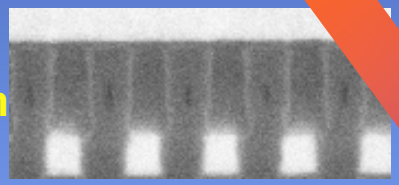
Ultimate 3D Memory - Scalable and Stackable Cross-Point Diode Array

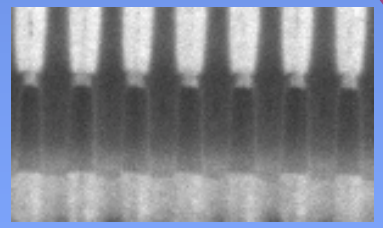


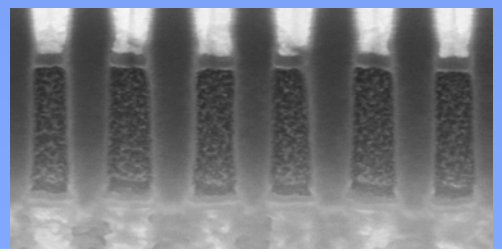


Five Generations of 3D Diode Arrays

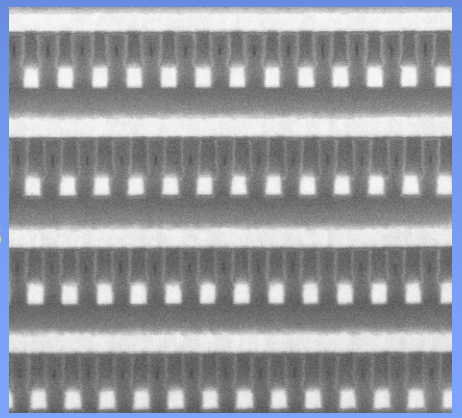


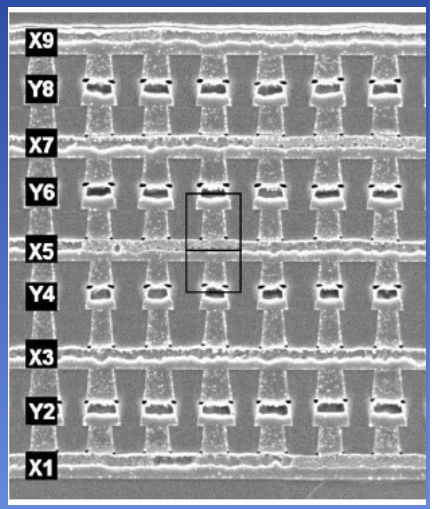






SCALABLE
&
STACKABLE





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Bold Predictions

- NAND Flash will continue scaling beyond current predictions through not only process and device but also system-level innovation
- Investment in alternative technologies that do not have a long-term scaling path will have limited returns
- 3D diode arrays with the right switching material will replace Flash