University of Glasgow

School of Computing Science

Hardware Trends and their Implications

Advanced Operating Systems (M)

Tutorial 2

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Review

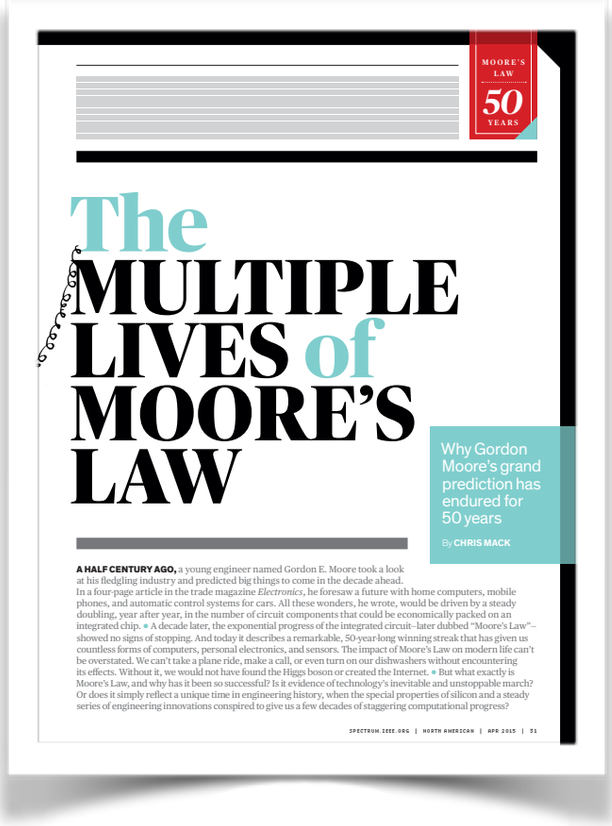
- Moore's Law
- Dennard Scaling
- Increasing heterogeneity
- Increasing storage → solid state
- High performance networking
- Implication of these changes

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Moore’s Law

- C. Mack, “The Multiple Lives of Moore’s Law”, IEEE Spectrum, Vol. 52, Num. 4, April 2015. DOI: 10.1109/MSPEC.2015.7065415

- Discussion:
  - History: Gordon Moore, Fairchild Semiconductor → Intel
  - Moore’s “law” based on very little evidence → succeeds because the industry wants it to succeed; not automatic
  - Economics: “sweet spot” of number of transistors it makes sense to integrate, for a given fabrication technology
  - Dennard Scaling: less well known, but critical to performance and the speed increase associated with Moore’s law
  - Limits of integration – how far can we go with existing designs, while still being able to power enough transistors to make it worthwhile? Is integrating heterogenous components on the device a good alternative?
  - Are we nearing the end of Moore’s law?


MOORE'S LAW 50 YEARS

The MULTIPLE LIVES of MOORE'S LAW

Why Gordon Moore's grand prediction has endured for 50 years

By CHRIS MACK

A HALF CENTURY AGO, a young engineer named Gordon E. Moore took a look at his fledgling industry and predicted big things to come in the decade ahead. In a four-page article in the trade magazine *Electronics*, he foresaw a future with home computers, mobile phones, and automatic control systems for cars. All these wonders, he wrote, would be driven by a steady doubling, year after year, in the number of circuit components that could be economically packed on an integrated chip. • A decade later, the exponential progress of the integrated circuit—later dubbed “Moore’s Law”—showed no signs of stopping. And today it describes a remarkable, 50-year-long winning streak that has given us countless forms of computers, personal electronics, and sensors. The impact of Moore’s Law on modern life can’t be overstated. We can’t take a plane ride, make a call, or even turn on our dishwashers without encountering its effects. Without it, we would not have found the Higgs boson or created the Internet. • But what exactly is Moore’s Law, and why has it been so successful? Is it evidence of technology’s inevitable and unstoppable march? Or does it simply reflect a unique time in engineering history, when the special properties of silicon and a steady series of engineering innovations conspired to give us a few decades of staggering computational progress?

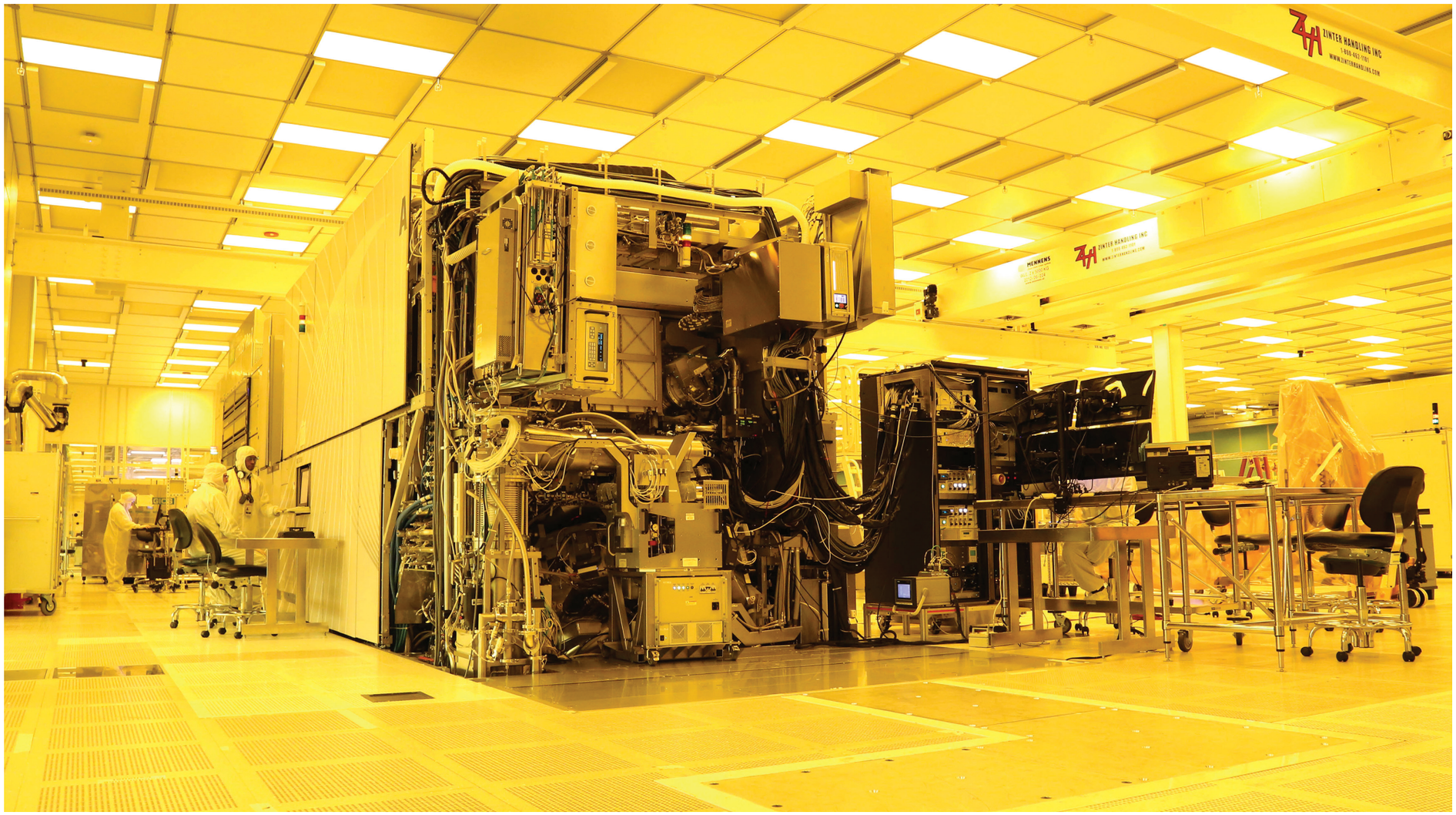
SPECTRUM.IEEE.ORG | NORTH AMERICAN | APR 2015 | 31

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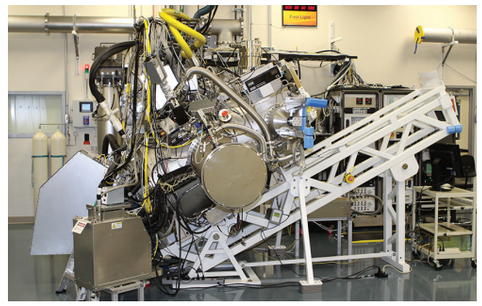
The Molten Tin Solution

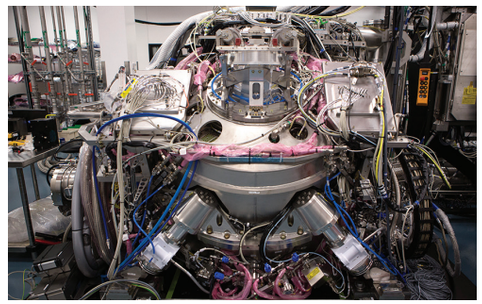
BY RACHEL COURTLAND

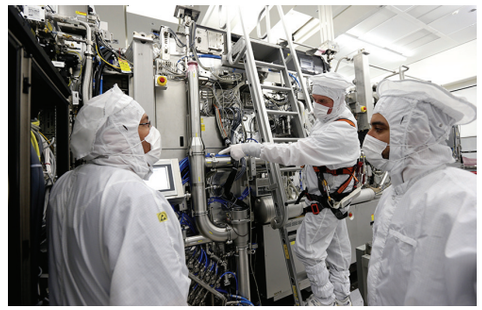
After a 30-year journey, EUV chip-printing technology is now poised to help keep Moore's Law on track



PUTTING EUV TO THE TEST: This EUV scanner (an ASML NXE:3300B) is used to print chip features at a SUNY Polytechnic Institute facility in Albany, N.Y. The EUV light needed to expose wafers is created near the bottom of the scanner, on the side visible in the foreground of this photograph. The far end of the machine is attached to a "track" that coats the wafers before exposure and processes them once they are done.







INSIDE THE MACHINE: To generate EUV, pulses of CO_2 laser light are sent into a vessel [top and middle] where they collide with tiny tin droplets to create plasma. This partially assembled EUV scanner [bottom] at ASML's headquarters in Veldhoven, Netherlands, is one of the company's more recent models.

- Complexity and expense of semiconductor fabrication
- Vacuum, x-ray lasers, $100M, delivered by a Boeing 747, 1.5MW power consumption → what's the limit before this become infeasible?

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