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Gordon Moore and the influence of Intel

The creator of Moore's law and co-founder of Intel has died, leaving behind a unique legacy in the history of electronic technology.

Gordon Moore, whose name is inextricably linked to the advance of electronics, died on 24 March 2023 at his home in Hawaii. He was 94. Together with Robert Noyce, he co-founded Intel, the California chip maker that was central to the development of Silicon Valley and helped bring electronic technology to the wider world.

When *Nature Electronics* launched in January 2018, it was a quote from an article by Moore that opened our first editorial[1]. The article in question was entitled 'Cramming more components onto integrated circuits', published in the trade magazine *Electronics* in 1965 (ref. 2). In it, Moore suggested that the number of components in an integrated circuit would approximately double every year, which he later revised to every two years[3]. The prediction became known as Moore's law and drove progress in the semiconductor industry for decades.

When Moore wrote the paper, he was director of research and development at Fairchild Semiconductor, a business that he helped form in 1957. He left Fairchild Semiconductor in 1968 to establish Intel, initially serving as executive vice president and then president, before becoming chief executive officer from 1979 to 1987. He then continued as chairman until 1997 and then as chairman emeritus, finally stepping down in 2006. (An obituary for Moore will appear in next month's issue.)

Today, Intel remains at the heart of the electronics industry, although it no longer enjoys the leading position it once had due to competition from Taiwan Semiconductor Manufacturing Company (TSMC) and Samsung. The company is also currently undergoing a number of profound changes[4]. It has, in particular, recently taken the decision to become a chip foundry and manufacture chips on behalf of other companies, placing it in direct competition with TSMC[5].

The decisions Intel makes can also influence the direction of the research community. Last year, for instance, the company announced that it was winding down its resistive switching memory manufacturing plant[6]. Such devices – which can be made with phase-change materials, metal oxides and magnetic materials – are a topic of extensive interest in the research community and the decision was a surprise to many academic researchers. In a Comment article in this issue of *Nature Electronics*, Mario Lanza, Gabriel Molas and Ishai Naveh consider what this means for the future of technology based on resistive switching devices. And what industry and academia need to do to find a successful path forward.

The authors – who are based at King Abdullah University of Science and Technology (KAUST) in Saudi Arabia and the company Weebit Nano in Israel – note that the key factor limiting the mass production of standalone resistive switching memories remains costs. They also argue that many academic research articles on resistive switching devices are of little value in the development of industrial applications due to the way the materials and devices are studied.

For example, research articles from academia will typically examine large, isolated devices on a non-functional substrate. But industry work will typically examine small devices integrated at the back-end-of-line interconnections of a silicon microchip. In addition, work from academia may often show data from only one device when evaluating key figures of merit such as endurance and retention time. But industry needs to see data from hundreds of devices to evaluate the potential of a system.

Lanza and colleagues go on to highlight a number of strategies that academic researchers – as well as publishers – should aim to adopt. Ideally, resistive switching should be probed with industrial testing vehicles – that is, silicon wafers containing circuitry – and using small device sizes. This, they explain, is not as difficult or expansive as it may seem, as numerous institutions and agencies offer reduced foundry prices (though Intel isn't currently one of them).

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