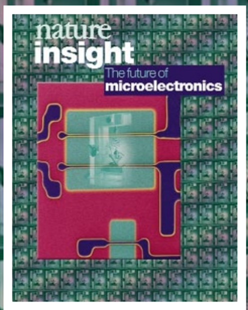
nature insight

The future of microelectronics



Cover illustration
Set against repeated images of the world's first transistor, developed by Brattain and Bardeen in 1947, is a scanning electron microscopic view of phase-shifted 0.12-μm gates in one of today's state-of-the-art digital signal processors. (Images courtesy of Lucent Technologies' Bell Labs.)

The remarkable success of the semiconductor industry is well described by 'Moore's law', essentially a prescription for future progress made back in 1965, which has held to the present day: every three years will see a new generation of memory chips and microprocessors, in which the device size will reduce by 33%, the chip size will increase by 50%, and the number of components on a chip will quadruple . This has fuelled a thirst for cheaper electronic memory and increasingly powerful microprocessors that has yet to be satisfied.

But such a trend cannot continue indefinitely; indeed, it is surprising to many that it has been sustained for as long as it has. For example, if the present miniaturization trend continues, the narrowest features on microelectronic circuitry will be only a few atoms across by the end of this decade. This collection of reviews will therefore focus on some of the most pressing technological and fundamental problems that are — or will be — faced by the semiconductor industry if it is to continue to satisfy the relentless consumer demand for speed and computational power.

On page 1023, Paul Peercy provides an overview of some of the economic and technical challenges that the semiconductor industry will encounter in the next few years as it attempts to follow Moore's law. As he points out, for many of these challenges there are at present no known solutions. One of the most pressing barriers to the fabrication of ever-smaller devices stems from the process that has long been used to pattern the component devices and circuitry: optical lithography. Ito and Okazaki on page 1027 describe the scope for further enhancing the power of this technique, before discussing the alternative lithographic techniques that are available to the industry. Looking slightly farther ahead, Angus Kingon and colleagues on page 1032 anticipate the need to replace silicon dioxide — a mainstay material for both memory and logic devices — with dielectrics of higher permittivity, emphasizing the magnitude of the technology shift and resources that will be required. As device dimensions approach the nanometre scale, quantum effects will have an increasingly important role in determining device properties, and may eventually necessitate the use of conceptually new device architectures. Using the single-electron transistor as an example, Devoret and Schoelkopf on page 1039 describe how these quantum effects can be harnessed to achieve new and improved device functionality. Finally, no such collection would be complete without a speculative look to the distant future. On page 1047, Seth Lloyd puts practical issues firmly to one side and investigates just how far (in terms of computational power) the laws of physics will let one go. The answer is very far indeed, if you are prepared to consider such possibilities as laptops that operate at stellar temperatures or are constructed from a black hole.

Although this collection is not intended to be comprehensive, we hope that it provides a flavour of the intellectual challenges faced by the semiconductor industry and illustrates the multidisciplinary nature of the endeavour. And by exploring issues of both a practical and fundamental nature, we hope that this collection offers something to pure and applied scientists alike.

Karl Ziemelis **Physical Sciences Editor**

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