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News and Views
Materials witness: Silicon still supreme
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There is a journalistic template for articles on the future of information technology that is structured something like this:
1. Fundamental limits will imminently prevent the trend in device performance/density/cost of silicon microelectronics from being sustained.
2. So totally new materials/architectures/device principles are needed if our laptops are to go on getting lighter/smaller/more powerful.
3. Molecular electronics/quantum computing/spintronics/bio-nano hybrids will save the day, providing unheard-of computing power.

Those in the microelectronics industry once routinely scoffed at this kind of thing. Today they do something rather more devastating. The 2004 International Technology Roadmap for Semiconductors (ITRS; see http://public.itrs.net) includes a 60-page document on 'emerging research devices' that acknowledges all of these new directions. It appraises each of them coolly and objectively as both memory and logic structures, considering characteristics such as power consumption, switching speed, data retention time, manufacturability and so forth.

Such an assessment is thus a multi-dimensional issue – something that popular articles, keen to promote immense device density or parallel processing or whatever , tend to neglect. But the ITRS finally boils down all of these factors to just two: 'performance potential' and risk.

The final tables then deliver the bucket of cold water. As technologies for logic, all of the exciting new ideas – spintronics, molecular devices, quantum cellular automata and single-electron devices – turn out to have miserable ratios of performance index to risk index. For memory devices, molecule-based schemes fare a little better, but not much. Quantum computing and 'biologically inspired' systems don't even make the tables, since they are too immature to permit a meaningful assessment.

In a sense, no one working on these speculative technologies will be surprised by any of this, even if it is sometimes hard for them to admit it. And it would be foolish and dispiriting to abandon a potential new technology simply because it has a low chance of succeeding. The journalistic attention devoted to these areas might also be excused by the fact that, as the ITRS shows, the most speculative also tend to be the most active in terms of research publications. Quantum computing enjoys 10-100 times as many publications as its competitors (largely because the interest here is as much fundamental as it is practical).

But what is most striking about the ITRS is that it demolishes any suggestion that risky technologies are necessitated by the lack of silicon-based alternatives. As a recent article shows (Ieong *et al.*, *Science* **306**, 2057; 2004), inventive new device architectures may well take silicon electronics comfortably into the regime of sub-10-nm component dimensions by 2016.

What the ITRS highlights is that, from a materials perspective, this need by no means be the boring solution. The problems raised by such silicon devices should keep plenty of people busy. For example, the desired switch from 300-mm to 450-mm wafers challenges existing silicon crystal-growth methods; new insulating materials with very high dielectric constants are needed; defect control on these scales is very tricky; and current methods of materials modeling are inadequate to predict transport properties in nanodevices. There's a lot to be done.