Transistor reporting under test

The assessment of emerging transistor technologies is a challenging task. What can be done to help improve the reporting and benchmarking of devices?

Transistors are the central building block of modern electronics. Currently, transistors based on silicon, germanium and compound semiconductors (such as silicon carbide) are the dominant technologies. But the ever-increasing demands of society create new challenges for the electronics community. And while systems, architecture, packaging and a range of other engineering advances have helped deliver a stream of performance enhancements — particularly as lithography-based scaling has slowed — the development of new transistor technologies is still needed.

Since the launch of *Nature Electronics* in January 2018, we have published around 30 primary research articles on transistors in which the work focused solely on device-level developments. The advances in these papers typically involved new fabrication methods, a better understanding of mechanistic properties, improvements in device performance, or the suitability to new applications. Notably, all but a handful of these articles considered devices based on emerging materials, such as organic, oxide and two-dimensional semiconductors.

As this brief analysis suggests, the search for new materials that can provide novel functionality in transistor devices — or overcome the physical limits of current semiconductors — continues at pace. The International Roadmap for Devices and Systems (IRDS) introduced an *Emerging Research Materials* report in its 2017 edition[1] and the potential value of such materials is considered in numerous elements all across the current edition of the IRDS[2]. However, the use of new materials — often with poorly understood physical properties — in transistors brings new challenges, particularly when trying to assess their performance and thus their potential value in practical applications. The complexity of transistor analysis, the interdisciplinary nature of the research community and, at times, a fixation on a narrow set of benchmarks has, for instance, led to the mischaracterization of devices in the past[3,4]. What then can be done to improve the reporting of research on such transistors?

In a Perspective in this issue of *Nature Electronics*, Zhihui Cheng, Aaron Franklin, Curt Richter and colleagues explore the issues surrounding the characterization of field-effect transistors based on emerging materials and propose guidelines for the reporting and benchmarking of these devices. The researchers — who are based at institutes from across academia and industry, and from across the United States, Europe and China — first note that the physical architecture of a transistor plays a key role in determining its eventual performance. And with this as a starting point, they suggest a range of device parameters and benchmarking plots that should be reported in order to ensure transistors are clearly evaluated. These include structural parameters, measured characteristics and derived characteristics, as well as parameters that might be specific to certain applications such as highly scaled devices.

To illustrate the reporting and benchmarking approach, Cheng and colleagues use transistors based on monolayer molybdenum disulfide (MoS_2) — a material that has received considerable attention in recent years — as an example, highlighting some of the challenges faced with these devices. They also note that caution is needed when benchmarking such work — which is often preliminary — against the future performance requirements set out in the IRDS. A key focus of the Perspective article is appropriate benchmarking of emerging field-effect transistors against more mature technologies, and many of the suggested parameters and methods could also be applied more broadly when assessing other transistor technologies.

Transparent reporting and the reproducibility of results are, of course, central requirements of publishing in *Nature Electronics*. But what specific steps can the journal take to help improve the reporting of research on transistors? The Nature Portfolio journals already have an editorial policy checklist for all papers, as well as an additional code and software submission checklist for relevant work. Reporting summary documents — which are made available to editors and reviewers during manuscript assessment and published with an accepted manuscript — have also been developed for research articles in the life sciences and for work on solar cells and on lasing. The development of a related reporting summary for work on transistors is a potential option. Either way, we hope that the Perspective article will be the start of a discussion and exploration of what can be done to improve the reporting and benchmarking of transistor research. Any comments and suggestions from researchers on these ideas — and the development of a reporting summary for transistors, in particular — are welcome via e-mail at electronics@nature.com or via submission of a Correspondence article to the journal. ❐

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