tonic inhibition must be carefully assessed. The source of the increased tonic GABA conductance in the peri-infarct zone also warrants further investigation; pharmacological removal of GAT-3 in the healthy neocortex does not alter tonic inhibition[7].

Again, timing is everything: previous work[8] indicated that increased inhibition at the time of the stroke is beneficial. In addition, when Clarkson *et al.* reduced inhibition too soon after the stroke, they observed a detrimental effect — increase in stroke size. These timing constraints point to overlapping beneficial and detrimental GABA functions and need to be resolved.

Clarkson and colleagues' experimental reductions of GABA-mediated tonic inhibition affected the entire brain, leaving uncertainty as to whether the enhanced tonic inhibition in the peri-infarct zone was the main site of action. Strokes alter the activity of local networks in which the injured zone was involved[9]. Consequently, both local and general alterations in inhibition might help to reconstitute some of these network activities[10] and so improve functional recovery.

All of the benefits that Clarkson *et al.* report for reducing GABA-mediated inhibition had occurred by the time of their first assay of functional recovery — one week after the stroke. Thereafter, both treated and untreated animals recovered at the same rate. This result again raises the possibility that a reduction in GABA-mediated tonic inhibition improves the function of the damaged cortical networks, as opposed to enhancing the long-term recovery of those networks. The latter would increase the rate of improvement in gait, and would persist after the GABA blockers are removed. Of course, it could be that both effects (improvements in immediate function as well as recovery) contribute to the observed improvements in muscle control: Clarkson and co-workers show that discontinuation of GABA blockade removes about half of the improvement in recovery.

Reducing GABA-mediated inhibition enhances alertness. Although Clarkson *et al.* rule out an immediate performance enhancement by treating a subgroup of animals just before each test, stimulants are known to improve stroke recovery in rodents[11], if not humans. So future work should carefully control for effects of GABA manipulations on the level of consciousness.

Strategies to accelerate recovery from stroke not only offer a possible complement to the emergency rescue strategies, but are also much more feasible: they can be used at later times after a stroke. The present study[2] promises one such strategy, subject to further investigation. ■

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ELECTRONICS

A diverse printed future

An approach that entails printing compound-semiconductor ribbons on a silicon substrate offers the means to build nanoscale transistors that can be switched on and off much more effectively than their bulk analogues. SEE LETTER P.286

JOHN A. ROGERS

For applications in electronics, silicon is often referred to as 'God's material'. Characteristics such as high natural abundance, and relative ease in crystal growth, purification and doping, combine with favourable electronic-transport properties to provide unmatched capabilities for commercial integrated circuits. As a result, silicon has held a dominant position in microelectronics since the early days of the industry, with compound semiconductors, used mainly in radio-frequency devices, consistently a distant second.

Sometime in the latter part of this decade, however, fundamental limitations on the switching speed and energy efficiency of silicon transistors may force a shift to a certain level of diversity in semiconductor materials[1,2]. One future approach might involve integrating non-silicon semiconductors onto silicon platforms, to yield heterogeneous systems that exploit different types of materials for different functions. On page 286 of this issue, Ko *et al.*[3] report an intriguing route to this goal, which is based on organized arrays of ribbons of indium arsenide (InAs) delivered to silicon wafers in a type of printing process[4]. Transistors built with such ribbons at nanoscale thicknesses exhibit impressive characteristics, suggesting their potential for enhancing the performance of next-generation silicon electronics.

Compound semiconductors such as InAs are attractive because their extremely high electron mobilities and conductivities lead to transistors that can be faster (up to twice as fast) and more power efficient (up to ten times) than silicon transistors with comparable dimensions[2]. Although poor hole mobilities (where a hole is a 'missing electron') and lack of high-quality, interfacial insulators will probably prevent their exclusive use in large-scale complementary logic circuits[1,2], these materials have potential as strategic additions to silicon-based technologies. The most widely explored means of exploiting compound semiconductors in this fashion involve specialized procedures for growing or bonding these materials on silicon wafers. Although certain research demonstrations are encouraging, such strategies have serious shortcomings, ranging from defects in the materials to challenges in manufacturability. Ko *et al.*[3] present an advanced procedure that avoids these limitations, and they demonstrate their ideas with InAs.

In the first step of the procedure, Ko and colleagues exploit optimized techniques to grow pristine, ultrathin films of InAs on gallium antimonide (GaSb) wafers coated with layers of aluminium gallium antimonide (AlGaSb). Next, the authors pattern the InAs films into narrow, nanoscale-thick strips that they release from the underlying substrate by selectively removing the AlGaSb with a chemical etchant. In a final step, they use a silicone rubber stamp to lift arrays of the nanoribbons from the substrate, and then to deliver them to the silicon dioxide (SiO$_2$) insulator surface of a silicon wafer, in a type of printing process[4] in which the InAs serves as the 'ink' (Fig. 1, overleaf). Because the procedure can be used with different types of material, the authors refer to the resulting structure as 'X' on insulator, or XOI, where X represents a semiconductor, by analogy to the widely used acronym SOI for silicon on SiO$_2$/Si substrates.

The printing process used by the authors[3] represents a recent and increasingly sophisticated method for transferring nanoscale ribbons, wires and sheets of semiconductors (such as silicon, gallium arsenide, gallium nitride and indium phosphide) from substrates on which they are formed to other surfaces, including those of silicon, glass, plastic and even paper and rubber[4,5]. Demonstrated applications of the process include electronics integrated with biological systems[6], hemispherical 'eyeball' and near-infrared imagers[7,8], flexible display and lighting devices[9]

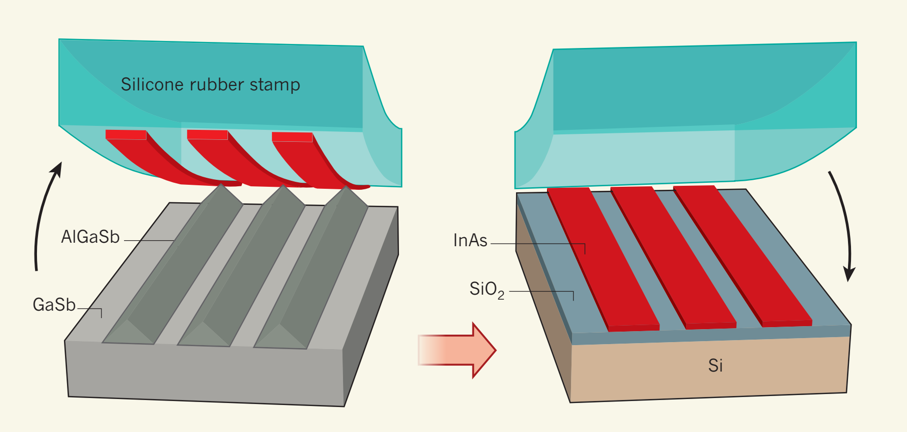

Figure 1 | Heterogeneous electronics by printing. Ko and colleagues' printing technique[3] for making heterogeneous structures for electronic applications uses a silicone rubber stamp to lift nanoscale-thickness indium arsenide (InAs) ribbons from a gallium antimonide (GaSb) wafer coated with a layer of aluminium gallium antimonide (AlGaSb). The nanoribbons are then delivered to a silicon dioxide/silicon (SiO$_2$/Si) substrate in a process in which the InAs acts as the ink.

and photovoltaic modules[8]. In many of these examples, viscoelastic effects[4] and/or specialized relief structures[10] on the stamps enable printing of pristine, unaltered material onto bare substrate surfaces, even without any separate adhesive layers. Yields approaching 99.99% are now possible with highly developed tools that also offer micrometre-scale precision in the positions of the printed parts, and throughputs corresponding to millions of printed structures per hour, or more[8].

These printing methods are presently in use for the pre-commercial manufacture of photovoltaic modules that incorporate sparse arrays of thin compound-semiconductor solar cells and micro-optics for focusing incident sunlight[11]. Although the same methods have been suggested for integrating compound semiconductors with silicon[4,5,12], Ko and colleagues[3] achieve by far the most impressive results in this context, accomplished by using semiconductor-material layers at exceptionally small thicknesses, down to just a few nanometres.

With remarkably clean, adhesiveless interfaces and high-quality, thermally grown oxides, these ultrathin semiconductor layers yield transistors that can be switched on and off much more effectively than their conventional, bulk counterparts. The authors[3] describe systematic experimental studies that capture the essential physics of operation of one such type of device, in which an interesting and gradual transition from three- to two-dimensional electronic transport occurs as the thickness decreases from 50 nm to less than 10 nm. Device simulations not only quantitatively capture these trends, but also explain related improvements in switching properties. This match between theory and experiment provides further evidence of the defect-free, predictable nature of the printed material stacks from which the devices are made.

The transistor's performance parameters are highly promising, with electron mobilities that significantly exceed those of silicon transistors of similar design. The behaviour of the device at high switching speeds, however, must be evaluated to determine the potential for enhancing the performance of state-of-the-art silicon platforms. Exploring aspects of operation in this regime and demonstrating interconnected operation with silicon transistors represent directions for future work. Research of this type is appealing because it advances knowledge in both science and engineering, in the context of potential solutions to problems of practical importance. The increasingly ubiquitous nature of electronics in modern society suggests that successful outcomes will have widespread, positive implications. ■

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NEUROSCIENCE

The split view of motion

In both fruitflies and vertebrates, signals from photoreceptor cells are immediately split into two opposing channels in the downstream neurons. This might facilitate the computation of visual motion. **See Letter p.300**

CHI-HON LEE

Nearly a century ago, the great Spanish neuroanatomist Santiago Ramón y Cajal compared[1] the vertebrate retina with the fly's compound eye and noted similarities in their neural circuits (Fig. 1). He redrew the cell bodies of the fly's monopolar cells, transforming them to vertebrate retinal bipolar neurons. Ultrastructural studies have since revealed that, indeed, both sets of neurons receive inputs from photoreceptor cells at structurally unique junctions called ribbon synapses in their first visual neuropiles, or neural switchboards — namely the fly's lamina and the retina's outer plexiform layer[2]. On page 300 of this issue, Joesch *et al.*[3] further extend the analogy, reporting that, like their vertebrate bipolar-neuron counterparts, fly monopolar cells split photoreceptor signals into ON and OFF channels to encode brightness increment and decrement, respectively.

Two main types of fly monopolar cell — L1 and L2 — receive a similar number of synaptic inputs from the type of photoreceptors that mediate motion detection. Using genetic methods to manipulate the activity of specific neurons, behavioural studies[4,5] have suggested that L1 and L2 have overlapping but differentiable roles in detecting visual motion.

By recording electrical activity from downstream motion-sensitive neurons, Joesch *et al.* provide a physiological basis for the behavioural observations. They find that blocking L1 eliminates the response to a moving bright edge (ON), whereas blocking L2 abolishes responses to a moving dark edge (OFF). In a separate paper[6], the same group directly examines the activity of L2 neurons by calcium-imaging techniques and confirms that L2 encodes the OFF signals. Thus, as for vertebrate photoreceptors, the fly photoreceptor signal is split into ON and OFF channels at the first synapse.

Joesch and colleagues[3] further unexpectedly find that L1 and L2 are electrically coupled through gap junctions — specialized complexes that connect the cytoplasm of