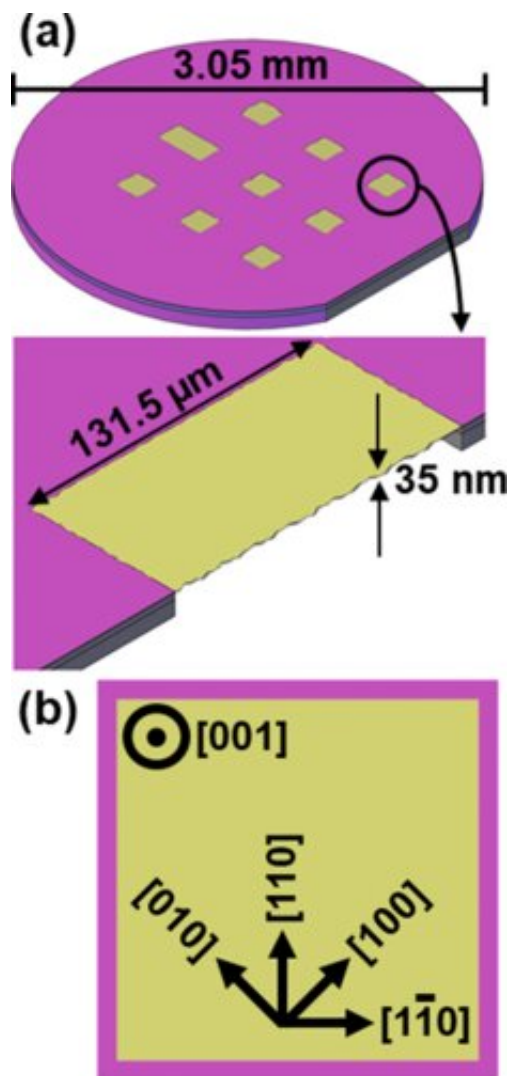


Research produces record levels of strain in single-crystal silicon

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Schematic drawing showing (a) grid and membrane dimensions and (b) crystallographic directions. 3.05 mm corresponds to standard transmission electron microscope (TEM) grid size, while window dimensions and crystal directions are a result of the anisotropic wet etching of silicon-on-insulator (SOI)

wafers. Credit: DOI: 10.1103/PhysRevMaterials.5.124603

University of Surrey researchers have developed a single-step procedure to put single-crystal silicon under more strain than has been achieved before. The discovery, which has a patent pending, could be crucial to the future development of silicon photonics, which underpins the technologies behind the internet-of-things, and is currently constrained by the lack of cheap, efficient, and easily integrated optical emitters.

Now, the Surrey-based researchers are transferring the same procedure to germanium. If successful, they will open the door to creating germanium lasers, which are compatible with silicon-based computers, and could revolutionize [communications systems](#) by means of new opto-[electronic devices](#). This would address the problem of overheating, which is becoming a threat to development in silicon-based computer systems, and would eliminate the need to develop expensive and difficult to integrate III-V devices, a popular area of research to try to overcome overheating.

Moving photonics fully onto silicon has been a long-held goal, and while there have been many successes in developing passive silicon photonic devices, a laser that is CMOS-industry compatible, using elements from the same group of the periodic table, has remained elusive until now. The team were recently awarded an EPSRC New Horizons project grant to exploit their innovation and progress their work.

The new approach is also an important step towards creating near-infrared sensors that could pave the way towards developing more sophisticated smartphones—fitting them with fire alarms and carbon monoxide sensors.

A new paper published in *Physical Review Materials* describes how the team generated strain via ion implantation in suspended membranes in a similar manner to tightening a drum skin. The effect is created by a downward bowing of the implanted region because of a still crystalline layer underneath the implanted top region in a mechanism analogous to a bi-metallic strip submitted to a temperature change.

The team from the University of Surrey's Advanced Technology Institute and Department of Physics demonstrate that up to 3.1 percent biaxial strain and up to 8.5 percent uniaxial strain can be generated but point the way to even larger strains, achievable by varying the implant species and by exploiting the underlying crystal direction.

The method far exceeds previous records using more complex approaches. In the Group-IV semiconductor germanium, an indirect-to-direct transition in the electronic bandgap occurs at much lower [strains](#) than silicon, where this new method offers huge potential.

Although the procedure is relatively simple and points the way to a versatile, fast, generally applicable, and widely available technique for strain control, its development required the use of two national facilities: the Surrey Ion Beam Centre, which allows users to undertake a wide variety of research using [ion implantation](#), ion irradiation and ion beam analysis, and which also has extensive processing and characterisation facilities; and the National Physical Laboratory, the UK's National Metrology Institute, which develops and maintains national primary measurement standards and which ensures cutting-edge measurement science has a positive impact in the real world.

Dr. David Cox, senior research fellow at the Advanced Technology Institute at the University of Surrey, said, "What excites me about this is the simplicity of the method and that it can easily be transferred to production methods. It will be exciting to see if this can have as

significant an impact on Group-IV semiconductor photonics as Alf Adam's long-standing legacy on the development of the strained-layer III-V based quantum-well lasers. Photonics will be to the 21st Century what electronics was to the 20th Century: revolutionary."

Mateus Masteghin, Ph.D. student and the lead author of the study, said, "Seeing the wrinkles annihilation and the flattening of the membranes in real time was astonishing. This new technique promises to be highly disruptive to the field of photonics, and I am looking forward to continuing developing new devices based on this proposed technique."

More information: Mateus G. Masteghin et al, Stress-strain engineering of single-crystalline silicon membranes by ion implantation: Towards direct-gap group-IV semiconductors, *Physical Review Materials* (2021). [DOI: 10.1103/PhysRevMaterials.5.124603](https://doi.org/10.1103/PhysRevMaterials.5.124603)

Provided by University of Surrey

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