Many techniques for growing metallic and semiconducting nanowires have been developed, but most are slow, complicated or material specific. A new approach based on creating and then filling nanosized cracks in a thin film could enable horizontal nanowires to be made more quickly and easily, and from a wider range of materials.

The fabrication process developed by Adelung and co-workers is a template-based approach that lies in the second of these categories, but without the need for high-precision equipment. The process begins by forming nanoscopic cracks in a continuous but brittle thin film that has been grown on a flexible substrate. The cracks are formed by inducing mechanical stresses.
in the film, either by differential thermal expansion with the substrate (generated by heating), swelling the substrate in an appropriate chemical environment, or through simple mechanical bending (Fig. 1). The direction and geometry of the cracks can be controlled by the direction and size of the induced stresses, and by deliberately introducing discontinuities into the surface (through a low-precision patterning step) from which cracks can initiate. (The induced stresses can be determined by, for example, choosing the appropriate direction and extent of bending.) Once formed, these cracks can be used as templates for horizontal nanowire formation. By depositing material into the cracks (using techniques such as evaporation) and then removing the brittle film in which they were formed, nanoscale structures that mimic the cracks are left behind.

Although conceptually simple, fabricating well-defined nanoscopic structures by Adelung’s approach is more challenging than it might at first seem. For example, cracks formed in films grown through predominantly elastic bending of the substrate will tend to close again once the substrate is allowed to relax (Fig. 1d, e). Owing to unavoidable roughness of the crack walls, this would cause significant along-length variation in the width of subsequently formed nanowires, and could even result in discontinuities at points where opposing walls touch. To avoid such problems, either some bending of the substrate must be maintained or some plastic deformation be allowed to occur (through appropriate choice of substrate material, degree of bending and processing temperature; Fig. 1f, g). Although the details are not explicitly discussed, the authors make use of both.

To avoid constraints on the fabrication approach arising from the preferential growth of cracks along specific crystal directions in crystalline materials, the authors have focused their efforts on amorphous films and substrates. However, the use of single-crystal
templates could confer substantial benefits in terms of uniformity and alignment, owing to the greater ease of forming atomically sharp and straight cracks along the well-defined lattice planes of such materials. Another intriguing possibility would be to use highly strained single-crystal films, such as 'strained silicon', which can be grown with significant tensile strains of around 1% (ref. 4). These strained silicon layers are promising candidate materials for future micro/nanoelectronic devices because of their enhanced strain-induced carrier mobility.

The potential attraction of using such pre-strained crystalline layers is illustrated in Fig. 2. As well as increasing the likelihood of crack formation, relaxation of strain at the free surfaces of such films would result in cracks that are more accessible to subsequent deposited materials (Fig. 2B). Moreover, by heating the template above the glass transition temperature of the underlying substrate (here an oxide layer on a silicon wafer), viscous flow of this layer could allow the strained layer around the crack to relax and provide a means to increase the diameter of subsequent nanowires (Fig. 2C). Their diameters could be tuned still further by either oxidizing the crack walls (to narrow them) or oxidizing and subsequent etching of the oxide (to widen them).

In order for the full potential of Adelung’s technique to be realized, it will be necessary to find better ways of controlling the position and structure of the crack templates; further exploration of the techniques shown in Fig. 2 should also prove fruitful. Nevertheless, the elegant simplicity of Adelung’s approach is indisputable, and it should allow the growth of nanowires of almost any composition, using cheap and widely available materials.

References