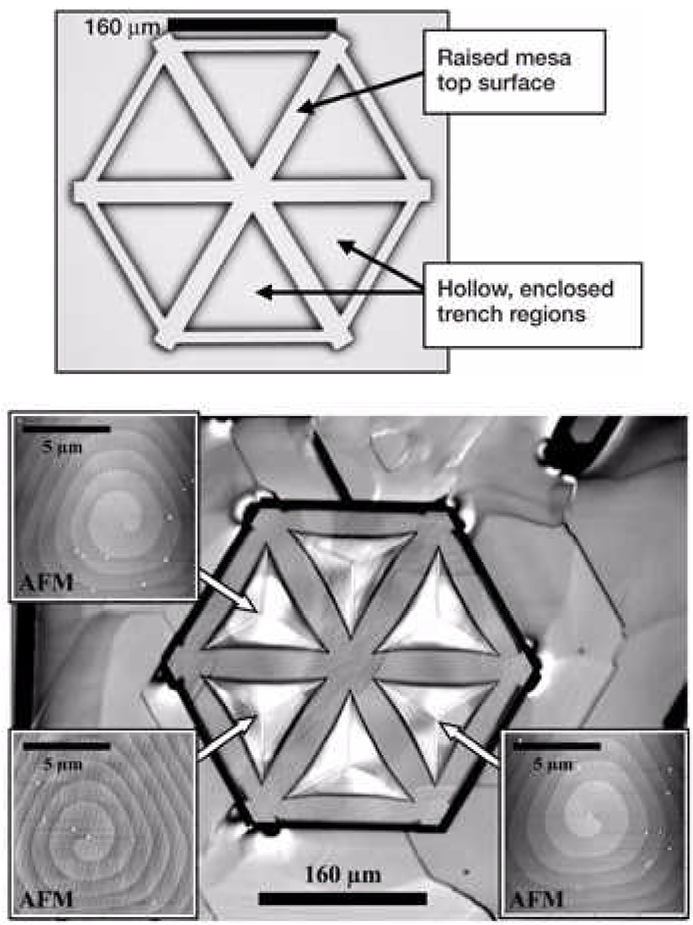
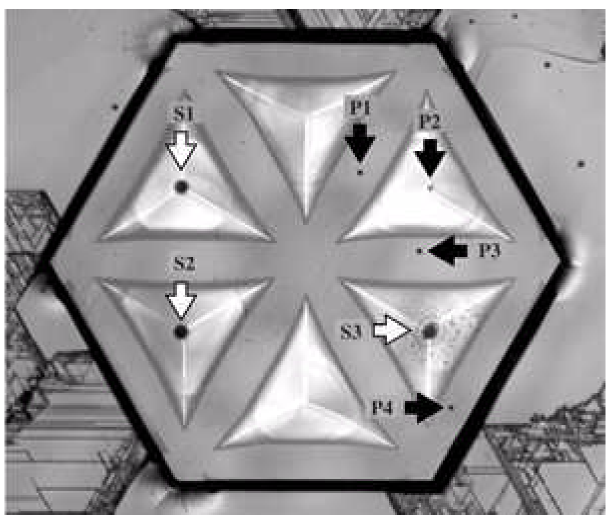
Web Growth Used to Confine Screw Dislocations to Predetermined Lateral Positions in 4H-SiC Epilayers

Silicon-carbide- (SiC-) based power devices could enable substantial aerospace electronics benefits over today's silicon-based electronics. However, present-day SiC wafers contain electrically harmful dislocations (including micropipes) that are unpredictably distributed in high densities across all commercial 4H- and 6H-SiC wafers. The NASA Glenn Research Center recently demonstrated a crystal growth process that moves SiC wafer dislocations to predetermined lateral positions in epitaxial layers so that they can be reproducibly avoided during subsequent SiC electronic device fabrication.



Top: Pregrowth mesa etched into SiC wafer surface with enclosed trench regions. Bottom: Homoepitaxial web growth carried out on the mesa of the image on the left. Insets show AFM measurements of screw dislocation spirals where cantilever films coalesce.

The process starts by reactive ion etching mesa patterns with enclosed trench regions into commercial on-axis (0001) 4H- or 6H-SiC substrates. An example of a pregrowth mesa geometry with six enclosed triangular-shaped trench regions is shown in the microscopic image in the top figure. After the etch mask is stripped, homoepitaxial growth is carried out in pure stepflow conditions that enable thin cantilevers to grow laterally from the tops of mesas whose pregrowth top surfaces are not threaded by substrate screw dislocations (ref. 1). The image in the bottom figure shows the postgrowth structure that forms after the lateral cantilevers expand to coalesce and completely roof over each of the six triangular trench regions. Atomic force microscope (AFM) measurements of the roof revealed that three elementary screw dislocation growth spirals, each shown in the AFM insets of the bottom image on the previous page, formed in the film roof at three respective points of cantilever film coalescence. The image above shows the structure following an etch in molten potassium hydroxide (KOH) that produced surface etch pits at the dislocation defects. The larger KOH etch pits--S1, S2, and S3--shown in this image correspond to screw dislocations relocated to the final points of cantilever coalescence. The smaller KOH etch pits are consistent with epilayer threading edge dislocations from the pregrowth substrate mesa (P1, P3, and P4) and a final cantilever coalescence point (P2). No defects (i.e., no etch pits) are observed in other cantilevered portions of the film surface.



Etch pits formed on the structure in the preceding image on the following KOH etching reveal that all dislocations are confined to the pregrowth mesa region and to points of final cantilever coalescence.

On the basis of the principle of dislocation Burgers vector conservation, we hypothesize that all vertically propagating substrate dislocations in an enclosed trench region become combined into a single dislocation in the webbed film roof at the point of final roof coalescence. The point of final roof coalescence, and therefore the lateral location of a webbed roof dislocation, can be designed into the pregrowth mesa pattern. Screw dislocations with predetermined lateral positions can then be used to provide the new growth steps necessary for growing a 4H/6H-SiC epilayer with a lower dislocation density than the substrate. Devices fabricated on top of such films can be positioned to avoid the preplaced dislocations.

Find out more about this research:
A formal technical paper describing this work in more detail:
http://www.grc.nasa.gov/WWW/SiC/publications/MRSPGN2002.pdf
SiC electronics research: http://www.grc.nasa.gov/WWW/SiC/SiC.html

Reference

1. **Neudeck, Philip G.: Improved Silicon Carbide Crystals Grown From Atomically Flat Surfaces. Research & Technology 2002, NASA/TM-2003-211990, 2003, p. 75.
http://www.grc.nasa.gov/WWW/RT2002/5000/5510neudeck.html**

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