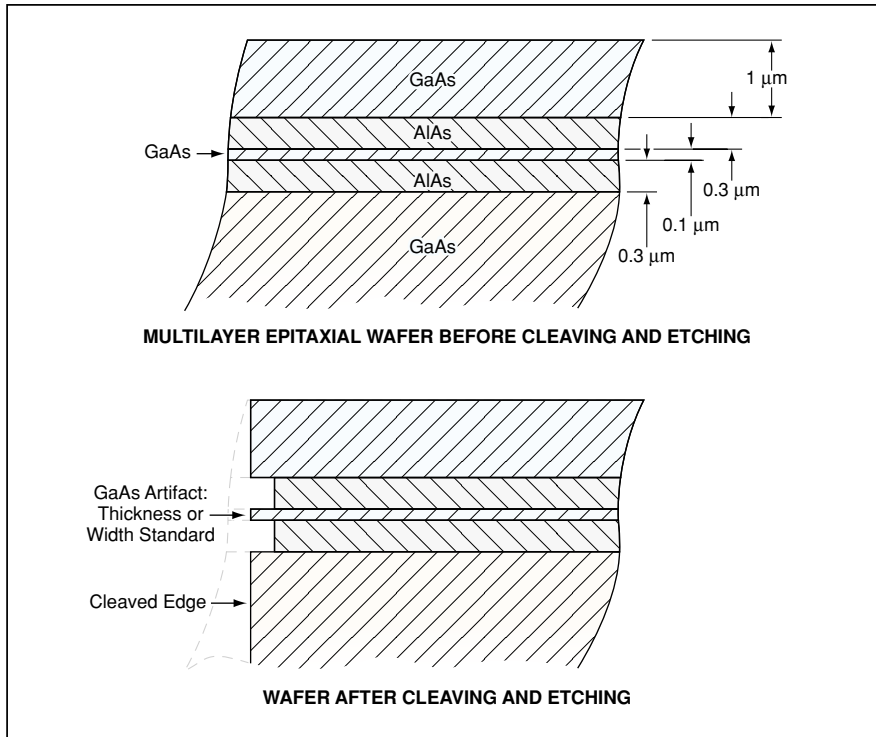


## Artifacts for Calibration of Submicron Width Measurements

Dimensional tolerances as small as 1 nm should be possible.

NASA's Jet Propulsion Laboratory,  
Pasadena, California



An **Artifact With a Reproducible Thickness of 0.1 μm** is made by MBE of GaAs and AlAs followed by differential etching. The basic concept is not limited to the GaAs/AlAs material system: other semiconductor material systems amenable to MBE and differential etching could be used.

Artifacts that are fabricated with the help of molecular-beam epitaxy (MBE) are undergoing development for use as dimensional calibration standards with submicron widths. Such standards are needed for calibrating instruments (principally, scanning electron microscopes and scanning probe microscopes) for measuring the widths of features in advanced integrated circuits. Dimensional calibration standards fabricated by an older process that involves lithography and etching of trenches in (110) surfaces of single-crystal silicon are gener-

ally reproducible to within dimensional tolerances of about 15 nm. It is anticipated that when the artifacts of the present type are fully developed, their critical dimensions will be reproducible to within 1 nm. These artifacts are expected to find increasing use in the semiconductor-device and integrated-circuit industries as the width tolerances on semiconductor devices shrink to a few nanometers during the next few years.

Unlike in the older process, one does not rely on lithography and etching to define the critical dimensions. Instead, one

relies on the inherent smoothness and flatness of MBE layers deposited under controlled conditions and defines the critical dimensions as the thicknesses of such layers. An artifact of the present type is fabricated in two stages (see figure): In the first stage, a multilayer epitaxial wafer is grown on a very flat substrate. In the second stage, the wafer is cleaved to expose the layers, then the exposed layers are differentially etched (taking advantage of large differences between the etch rates of the different epitaxial layer materials).

The resulting structure includes narrow and well-defined trenches and a shelf with thicknesses determined by the thicknesses of the epitaxial layers from which they were etched. Eventually, it should be possible to add a third fabrication stage in which durable, electronically inert artifacts could be replicated in diamondlike carbon from a master made by MBE and etching as described above.

*This work was done by Frank Grunthner and Paula Grunthner of Caltech and Charles Bryson III of Surface/Interface, Inc., for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP [see page 1].*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to Intellectual Property group  
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## Navigating a Mobile Robot Across Terrain Using Fuzzy Logic

This strategy is modeled on the actions of a human driver.

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A strategy for autonomous navigation of a robotic vehicle across hazardous terrain involves the use of a measure of traversability of terrain within a fuzzy-logic conceptual framework. This navigation strategy requires no *a priori* information about the environment. Fuzzy logic was selected as a basic element of this strategy because it

provides a formal methodology for representing and implementing a human driver's heuristic knowledge and operational experience.

Within a fuzzy-logic framework, the attributes of human reasoning and decision-making can be formulated by simple IF (antecedent), THEN (consequent) rules

coupled with easily understandable and natural linguistic representations. The linguistic values in the rule antecedents convey the imprecision associated with measurements taken by sensors onboard a mobile robot, while the linguistic values in the rule consequents represent the vagueness inherent in the reasoning processes to