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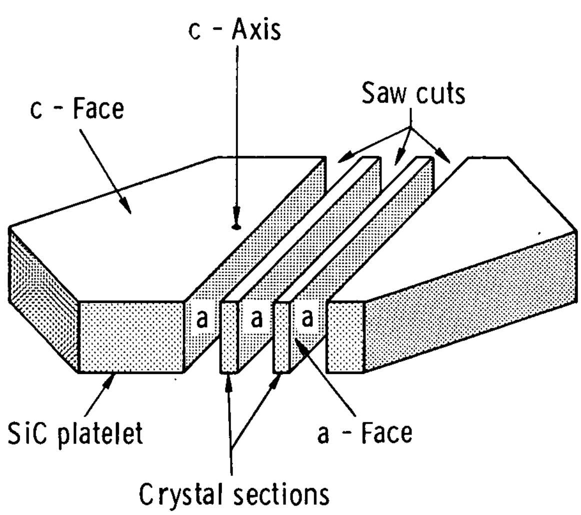
Improved Epitaxial Process for Fabricating Silicon Carbide Semiconductor Devices

The Problem:

Silicon carbide is a semiconducting material with much promise for certain electronic applications. Its wide energy band gap and high mobility should make it a useful semiconductor for temperatures up to 870 K (1110°F) or higher. However, SiC semiconductor devices are very difficult to produce because of the extremely high temperatures required. Present processes require temperatures in the range 1820 to 2900 K (2800 to 4760°F). At these temperatures, the dopant atoms tend to diffuse and blur the boundaries between differently doped regions. There is significant diffusion of dopant atoms (e.g., nitrogen) at temperatures above 1770 K (2730°F). Also, these high temperatures make it difficult to maintain the required degree of system purity.

Another serious problem arises in the preparation of substrates for epitaxial growth. The SiC crystals normally used for substrates grow in the shape of hexagonal platelets. In present procedures, the epitaxial layer is grown on the large face of the hexagonal platelet in the c-axis direction (see figure). In this process, the stacking sequence frequently changes during growth, yielding layers of crystals of different properties which seriously affects semiconductor performance.



The Solution:

An improved process of growing epitaxial SiC layers on SiC substrates so that the epitaxial growth is perpendicular to the c-axis (see figure) by a chemical vapor deposition process at temperatures of 1590 to 1660 K (2400 to 2530°F) which minimizes the variations in stacking sequence and the problems associated with higher temperatures.

How It's Done:

The SiC substrates are prepared from single crystal platelets, cut parallel to the c-axis as shown in the figure, yielding many crystal sections with exposed a-faces. One a-face on each substrate is polished and the substrates attached (polished side out) to the side of a vertical graphite susceptor. The susceptor with the substrates attached is placed in a reaction chamber and outgassed in a vacuum for several hours. Hydrogen is then admitted to the chamber and the susceptor brought up to temperature. A temperature profile is maintained along the susceptor so that the temperature at the top of the susceptor is less than 1470 K (2180°F) and the region of the substrates is in the range of 1590 to 1660 K (2400 to 2530°F).

After allowing approximately a half hour for thermal stability, the epitaxial growth is started by admitting hydrogen mixed with CH_3SiCl_3 (methltrichlorosilane). With a CH_3SiCl_3 concentration of 0.25 to 0.40 molar percent in a total hydrogen flow of 800 to 1800 cubic centimeters per minute, epitaxial layers can be grown at rates of about 0.3 to 0.4 micrometers per minute.

Because of the large radial temperature gradient in the system, large thermal convection currents exist in the reaction chamber. These convection currents carry the gaseous reaction products, mostly hydrogen chloride, back over the substrates. Thus, there is an etching process taking place simultaneously with the deposition at the surface of the substrates. This increases surface mobility of the depositing atoms and results in better epitaxial layers.

With this process, high quality epitaxial layers with thicknesses up to 80 micrometers have been grown.

(continued overleaf)

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Notes:

1. This innovation should be of interest to manufacturers of semiconductor devices for use as temperature, pressure, etc., sensors in high temperature up to 870 K (1110°F) and/or high radiation environments; also as a light emitting material (e.g., luminescent diodes for numerical displays).
2. Further information is available in the following report:

   NASA TN-D-7558 (N74-16462), Epitaxial Growth of 6H Silicon Carbide in the Temperature Range 1320° to 1390°C

   Copies may be obtained at cost from:

   Aerospace Research Applications Center
   Indiana University
   400 East Seventh Street
   Bloomington, Indiana 47401
   Telephone: 812-337-7833
   Reference: B74-10017
3. Specific technical questions may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B74-10017

Patent Status:

Inquiries concerning rights for the commercial use of this invention should be addressed to:

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