

**Low Defect SiC Material
by Liquid-Phase Epitaxial Lateral Overgrowth**

Contract No. N00014-94-C-0221

**Progress Report 2
(29 January 1994)**

prepared for:
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The technical approach of the Phase I program may be summarized as follows:

1. SiC epitaxial films are grown on SiC substrates using a relatively low-temperature liquid-phase epitaxy process. Liquid-metals (e.g., lead, tin, germanium, or other metals, or mixtures of these metals) are used as solvents for solution growth of SiC. The targeted growth temperatures are 1000 to 1200 °C. The process is similar to conventional liquid-phase epitaxy as commonly applied to growth of III-V heterostructures.
2. Next, having established a reproducible, low-temperature solution-growth technique for SiC, a process is developed whereby the SiC substrate is first masked prior to growth with a dielectric or refractory metal coating. The masking layer is patterned with stripe openings. A typical stripe pattern has 10-micron wide stripes on 100-micron spacings. The exposed SiC surfaces at the stripe openings serve as sites for preferential nucleation of SiC during a subsequent LPE step.
3. An epitaxial film of cubic silicon carbide is grown on a silicon substrate using a simple vapor-phase epitaxy process. The SiC-on-Si heteroepitaxial layer is used to seed the subsequent growth of a cubic SiC layer by liquid-phase epitaxy as described above.

1. Liquid-Phase Epitaxy of SiC

Based on phase equilibria data, we have selected lead, tin, and Pb-Sn alloys as solvents for the solution growth of SiC. These solvents dissolve a relatively high amount of carbon or SiC in the temperature range of 1000 to 1200 °C compared to other liquid metals for which the available data allows a comparison.

We first applied this technique to Si solution growth from Pb, Sn, and Pb-Sn solvents. Our purpose was to first investigate liquid metals as solvents for high-temperature solution growth without sacrificing silicon carbide substrates. The main differences between SiC LPE and Si LPE are:

1. Silicon is somewhat more soluble in these metals than is carbon or SiC.
2. The silicon substrate is more susceptible to oxidation than is SiC. Surface oxides on the substrate tend to impede epitaxial growth.
3. SiC exhibits polytypism whereas crystalline silicon exists in only the diamond structure.

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Silicon was grown on (111) Si substrates at 1050 to 1100 °C using a standard slideboat technique [CASEY and PANISH, 1978]. Figures 1 and 2 are micrographs of epitaxial growth on silicon substrates from Sn and Pb-Sn solvents. The substrates are masked with a patterned, tungsten coating. It is clear that it is feasible to grow silicon selectively on silicon.

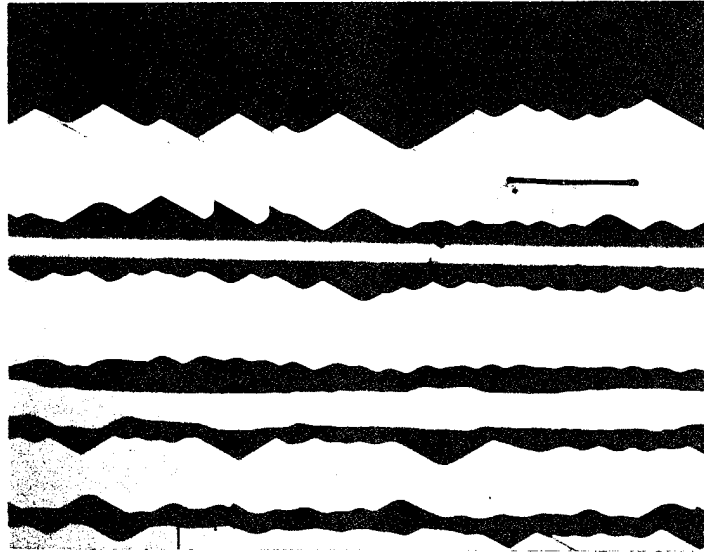


Figure 1: Photomicrograph of silicon selectively grown on a tungsten-masked (111) silicon substrate. The mask is patterned with 10-micron wide stripe openings on 100-micron spacings. The crystals nucleated at each stripe show significant lateral overgrowth of the tungsten mask.

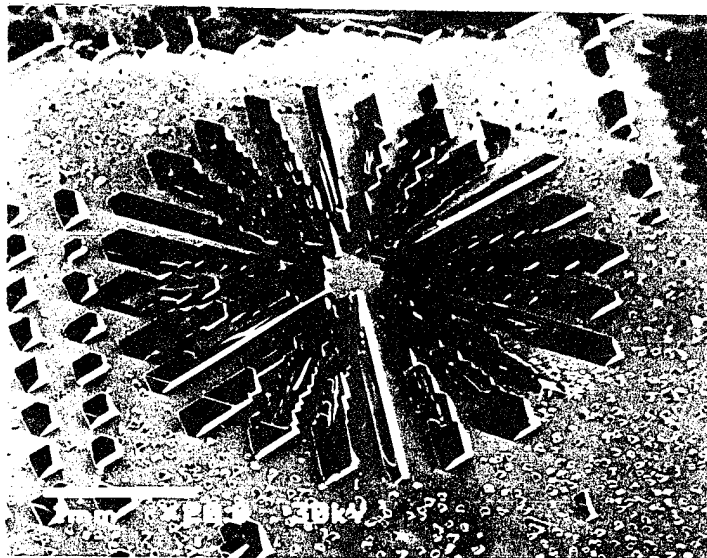


Figure 2: Scanning electron micrograph of silicon selectively grown on a tungsten-masked (111) silicon substrate. The mask is patterned with 10-micron wide stripe openings on 100-micron spacings arranged in a radial pattern. The extent of lateral overgrowth depends on the stripe opening, indicating that the crystallographic alignment of the stripe opening can be optimized to increase the extent of lateral overgrowth.

We are beginning SiC epitaxy experiments using 6H-SiC substrates provided by CREE Research, Inc. The results of these experiments will be given in the Final Report.

2. Chemical Vapor Deposition of SiC with Hexamethyldisilane (HMDS)

TAKAHASHI *et al.* [1992] described the low-temperature growth of 3C-SiC on (100) and (111) silicon substrates by atmospheric-pressure chemical vapor deposition using hexamethyldisilane $\text{Si}_2(\text{CH}_3)_6$ (HMDS) and hydrogen. Epitaxy was achieved at substrate temperatures as low as 1100 °C. Single crystal layers of epitaxial cubic silicon carbide were grown on (111) Si with and without carbonized buffer layers at growth rates as high as 70 nm/min. With (100)Si substrates, a carbonized buffer layer was required for epitaxial growth of SiC on Si. NORDELL *et al.* [1994] reported a very similar technique with the main difference that the growth ambient was a mixture of argon and hydrogen.

This approach is used in the Phase I program to produce SiC-on-silicon surrogate substrates. Figure 3 shows selectively deposited SiC on a (111) patterned, oxide-masked Si substrate. We are presently analyzing this material with respect to crystallinity and purity.

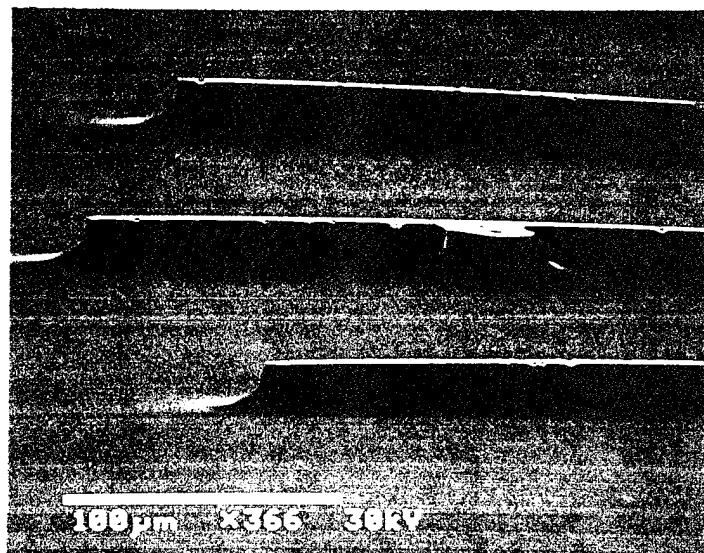


Figure 3: Scanning electron micrograph showing selectively deposited SiC on a (111) patterned, oxide-masked Si substrate.

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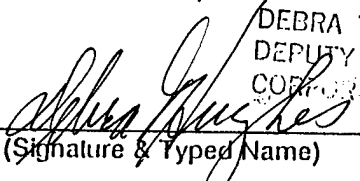
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