Project Title: FLOAT ZONE SILICON SHEET GROWTH
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Reported By: CARL E. BLEIL, Principal Investigator
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During this period continued attention has been paid to task number 8 as cited in the proposed statement of work. Progress in the final assembly (task No. 8) and the relevant changes in tasks numbered 4 and 7 have occupied more than 80% of the time. Preparations have also been made for the completion of the final report.

Task No.1 Heat Pipe Construction:
Objective: Finalize the design, construct and test the five heat pipes required to provide the stable thermal environment for the crystal growth system.

Progress: Stable thermal leveling has been accomplished. All of the special BORALECTRIC heaters with the graphite thermal levelers have had their final testing completed. The thermal leveling of the heater-graphite assembly is comparable to the previous results with stainless steel heat pipes at 1200K. The heater-graphite system shows no loss in leveling above 1200K.

Task No.2 Heat Pipe Heater and Heat Extraction System:
Objective: Provide the heaters and controls for maintaining the preset heat pipe temperature and controlled heat extraction.

Progress: The new system has been installed. The initial testing has been successfully completed. The system will successfully remove the heat of fusion corresponding to a growth rate of 0.5 gms/sec. Task No. 8 has not been completed to permit a final evaluation.

Task No. 3 Optical Temperature Monitoring System
Objective: Integrate the several optical sensors for
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temperature monitoring with the optical sensing of the solid-melt growth interface.

Progress: The multiplexing network previously built for the germanium photodiode array is being used for operating the new units. Water cooling for the photodiodes is functional. The new high temperature coax lines have been reinstalled after finding and removing some shorted terminations.

Task No.4 Replenishment Source Development:
Objective: Finalize the design, assemble and test the RF heater coil, coupling network and ancillary heater to provide the controlled replenishment of the melt.

Progress: The two kilowatt, 13.56 MHz, RF generator with its matching network has passed the preliminary tests. New tests with the preheater in place, the chamber at or above atmospheric pressure and the thermal levelers operating, have been conducted. Power dissipation of the preheater may have to be modified in the final operating mode. The drive mechanism for controlling the displacement of the replenishment source has been installed and tested. Modifications of the source geometry have been completed to assure the proper feed conditions for the source material.

The melt level monitor to control the melt thickness directly has not performed adequately. Because of the changing coupling of the RF to the source during ramp up, the overall ramp time must be controlled and the melt thickness monitor switched on only after the melt is stabilized. Modifications of this coupling to the power supply has not been completed.

Additional testing of the 2KW replenishment heater produced an unexpected but significant complication. As contact was made between the melting silicon and the ground plane representing the melt zone of the ribbon, the capacitance between the silicon source and the rf coil changed abruptly. This was undoubtedly the cause of the earlier failure of the matching network. To rectify this problem a Faraday shield was incorporated in the RF coil design. One successful system demonstrated that the approach was correct. However, that system used tantalum for the shield and after several high temperature tests the shield oxidized and failed. Residual oxygen in the chamber at 1686K must be reduced further or the Faraday shield must be protected. A copper Faraday shield was under test when the 2KW power supply lost power. Presumably a circuit in the power amplifier failed. The system is being returned to COMDEL for
repairs. Better initial vacuum conditions and oxygen free inert gas or additions of hydrogen to the inert gas are possible solutions to this problem. Other solutions are being investigated.

**Task No. 5 RF Electrode Assembly:**
Objective: This task is to assemble the RF electrode ensemble to assure that the spacing, dielectric coupling, thermal and mechanical stability and correct geometrical properties are secured.

Progress: The properties of silicon nitride appear to provide a very favorable dielectric layer. Silicon nitride has been deposited on six four inch wafers and they have been prepared for electrode assembly. Another system to provide the desired dielectric layer is also under investigation. Final electrode assembly has been completed and is under test. Failure of the 2KW power supply has delayed this task.

**Task No. 6 Solid-Liquid Interface Monitors:**
Objective: Complete the development of the optical sensors required to sense the three principal solid-liquid interfaces: a) The sloping growth interface, b) the nucleating edge and c) the growth termination edge.

Progress: An optical system for magnifying and monitoring the edge of the sloping solid-liquid interface has been constructed and tested. The analysis of an alternate system for monitoring the horizontal growth termination edge has been completed. This system should also complement the current optical system for monitoring the horizontal nucleating edge. Testing of this new system has been delayed.

**Task No. 7 Ribbon Seed Preparation (Proprietary)**
Objective: The Task is to acquire, clean and etch the crystal seed for the initial ribbon growth.

Progress: Some suitable three inch wafers have been prepared as ribbon seeds. Tests of the three element heater assembly below the melt zone were successful. Analysis of the system has been completed but verification of the initial seed-melt stability has not been completed. Further seed-melt stability tests have been delayed.
Task No. 8  Overall System Assembly

Objective: The task includes the overall assembly and testing of the growth processor.

Progress: The progress with this task has been severely interrupted by the problems of the replenishment source Rf coil design and the failure of the 2KW power supply. Nevertheless, work has continued on other tasks as time permitted. Even though this is the last quarterly progress report, progress that is completed prior to the submission of the final report will be included therein. The status at this time is as follows:

1. The vacuum chamber is complete and functions well
2. All feed through connections are operational
3. The five BOROELECTRIC heaters with their pyrolytic graphite work well and provide thermal leveling with a lateral thermal gradient smaller than 0.03K/cm.
4. The system for the extraction of the heat of fusion will allow growth rates exceeding 0.5 gms/sec. (ie. Ribbons 10 cm wide, 0.0375 cm thick pulled at 30 cm/min)
5. The temperature monitoring system will accommodate 14 GE photodiodes and four fully shielded Pt-Pr 10% Rh thermocouples. Nine photodiodes are installed with the high temperature coax lines and the multiplexing network. Three shielded thermocouples are installed.
6. The replenishment power with the RF coil modifications functioned as expected. The lifetime of the first Faraday shields proved unsatisfactory but new materials and system changes should resolve this problem.
7. The replenishment drive mechanism functioned properly. It should be replaced in future processor designs where continuous rather than batch processing is desired. The preheating of the replenishment source should be retained in future systems.
8. The melt level monitor with the direct feedback to the RF power supply needs a voltage conditioning interface or a secondary melt level control. New processors may require both.
9. The primary RF electrode assembly functioned as expected. The results did suggest future modifications that would simplify the overall configuration of the system.
10. The optical systems for observing the solid-melt interfaces were adequate. Good control of these features will be realized when combined with the electrical monitoring of the nucleating tip and the exit meniscus.

11. The proprietary techniques for the preparation of the silicon seed were found to work as expected. Several seeds have been prepared successfully. The stability of the melt zone has not been fully tested. Primary concerns are at high level pulling speeds.

12. During the development of this project it was determined that all but two of the parameters could be controlled by feed back systems that did not require computer control. The remaining two can be managed manually in this laboratory prototype. In the commercial version of this processor, especially for high pulling rates, a computer control of the pulling speed and the heat of fusion extraction will be required. Computer monitoring of the other parameters will also be required. Computer control features have been considered but not implemented.