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Work by L.A. Kolodziejski and her collaborators is summarized here

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OFFICE OF NAVAL RESEARCH

SEMI-ANNUAL REPORT

for

1 AUGUST 1989 through 31 JANUARY 1990

for

Contract N00014-88-K-0564

"CHEMICAL BEAM EPITAXY of ZnSe"

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OBJECTIVE

The objective of the program is to determine optimum growth parameters for the chemical beam epitaxy of ZnSe. In addition microstructural, optical, and electrical characterization of the material will be performed to assess the material's quality and potential; comparisons will be made with material grown by molecular beam epitaxy.

PROGRESS

The chemical beam epitaxy system has unfortunately not been delivered according to our initial schedule. Following an extensive assessment of the current status of the CBE system the following subassemblies have been completed: The reactor has been completely assembled with the reflection high energy electron gun attached; all ovens and associated shutters have been added; the two high temperature gas injectors for As and Se have been installed. (Figures 1 and 2 show the CBE growth reactor and the reactor with electronics rack layout, respectively as of November, 1989.) The substrate heating station and associated rotation mechanism is completed. The substrate station is undergoing life testing at temperatures of 900 °C and rotation speeds of up to 450 rpm with safisfactory performance. The pumping subsystem is complete with the mechanical pump backed diffusion pump and the ion pump connected to the reactor. The major hurdle left to surmount is in regard to meeting the vacuum specification. The gas manifold, which transfers the metalorganic or hydride gas to the gas injectors on the reactor, has been completed, although it is apparant that a modification is required. The gas injection valve blocks are to be moved directly to the atmospheric pressure side of the gas injectors to facilitate rapid switching in and out of the process gas during the growth. Hydrogen has been flown through the gas manifold with source flow control provided by the mass flow controllers. The hydrogen gas was either directed to the vent line or to the reactor where the gas was pumped out of the chamber by the diffusion pump. The entire routing of the hydrogen was manipulated via computer control of the pneumatic valves and mass flow controllers.

The transfer chamber has been connected to the growth reactor and to the introduction chamber. The rotating robotic arm has been completely assembled and installed in the transfer chamber. The multiple wafer storage elevator is in the transfer chamber in addition to the substrate heating station; satisfactory operation of both has been demonstrated. The robotic arm can transfer samples with the use of a manual operation 'joy stick' to and from the introduction chamber and the reactor. The movement of the robotic arm is currently taking place in a 10^{-9} Torr vacuum environment with no increase in pressure observed in the transfer chamber during the rotation or transfer movement. The introduction and bake chambers have been completed and are connected to the computer to allow complete operation of the pneumatic valves, toxic gas detection devices, and doors.

The final subassembly which is not completed is the sophisticated computer control software which is a major part of the CBE system. The software and hardware connection for control of the various pneumatic valves, shutter actuation, mass flow control settings, etc. have been completed. The PID control of the thermal channels is currently manually performed, although the goal is to have control via the main computer. The epitaxial layer specification software which allows the user to 'write' menus for various sophisticated superlattice configurations is approximately 75% completed.

As of the preparation of this report, the schedule for the CBE system is to have factory acceptance tests performed around 12 February, 1990, followed by shipment. The schedule complements the final work to be completed on the facility. The air handling unit, which is required for the laboratory will be received, installed, and tested the second week of February. The installation of the air handling unit prior to installment of the CBE system guarantees no accidental damage to the CBE system. The facility is complete except for the installation of the air handling unit. The acid and solvent chemical hoods are currently being installed, in addition to the toxic gas detection system. The toxic gas cabinets will be delivered the end of February. The final items necessary to provide for a working laboratory is installation of de-ionized water, hydrogen, liquid and gaseous nitrogen, and coaxial piping for safe transportation of the arsine gas from the toxic gas cabinet to the reactor.

The position of research specialist for the CBE facility has been filled by an impressive engineer with extensive experience in industry supervising the processing of GaAs MMIC devices. He will be responsible for maintenance and repair of all hardware associated with the laboratory. The major engineer in charge of the design and assembly of the CBE system at Emcore Corporation will rotate with Emcore's service engineer every two weeks to spend their time at M.I.T. to train the staff, as well as keep the laboratory running smoothly.

Upon receipt of the epitaxy hardware, experiments will be underway to begin testing procedures of the specially designed, one-of-a-kind instrument to familiarize the research team with the operation of the machine. Following the initial training period experiments will commence in the chemical beam epitaxy of ZnSe using metalorganics of Zn and Se. The use of both visible and ultraviolet laser illumination will be implemented to assist in the growth. Ga and arsine will also be available initially for n- and p-type dopants, in addition to the use of In, Ga, and arsine for the growth of lattice-matched buffer layers of InGaAs to ZnSe, all grown on GaAs substrates.

PUBLICATIONS

a. Papers Published in Refereed Journals

- Q. -D. Qian, J. Qiu, M. Kobayashi, R. L. Gunshor, L. A. Kolodziejski, M. R. Melloch, J. A. Cooper, J. M. Gonsalves, and N. Otsuka, "Low Interface State Density at Pseudomorphic ZnSe/Epitaxial GaAs Interface," *Materials Research Society Symposium,* Vol. 45, pp. 423-428, 1989.

b. Invited Presentations at Topical or Scientific/Technical Society Conferences

- L. A. Kolodziejski, "Semimagnetic Semiconductor Superlattices: MBE Growth and Characterization," to be presented at the *European Materials Research Society Meeting* in Strasbourg, France, May, 1990.

- L. A. Kolodziejski, "Modern Growth Technologies of Semimagnetic Semiconductors," to be presented at the *International School on Physics of Semiconducting Compounds*, in Jaszowiec, Poland, April, 1990.

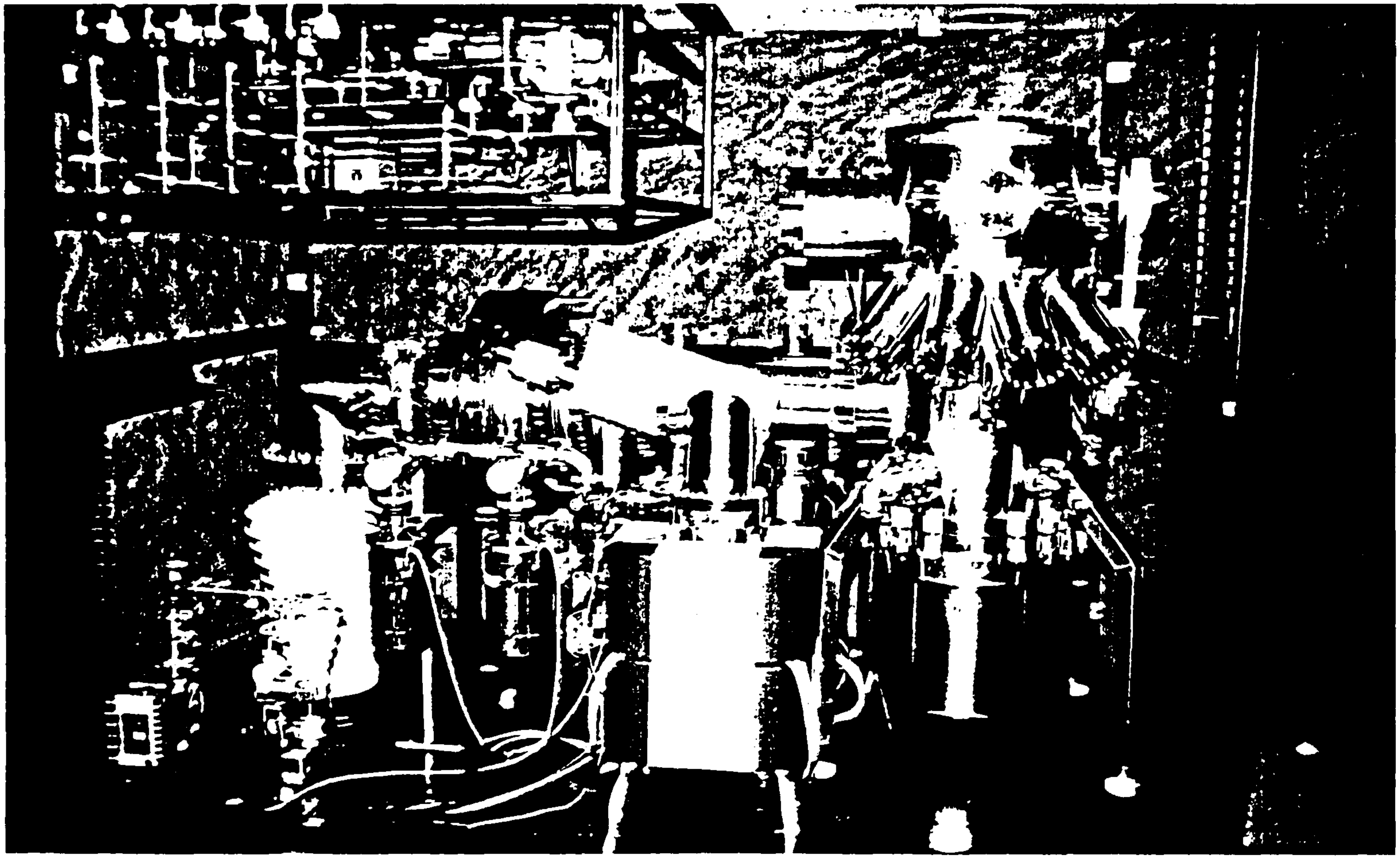

Figure 1. Frontal view of the reactor, vacuum pumping subsystem, and gas manifold.

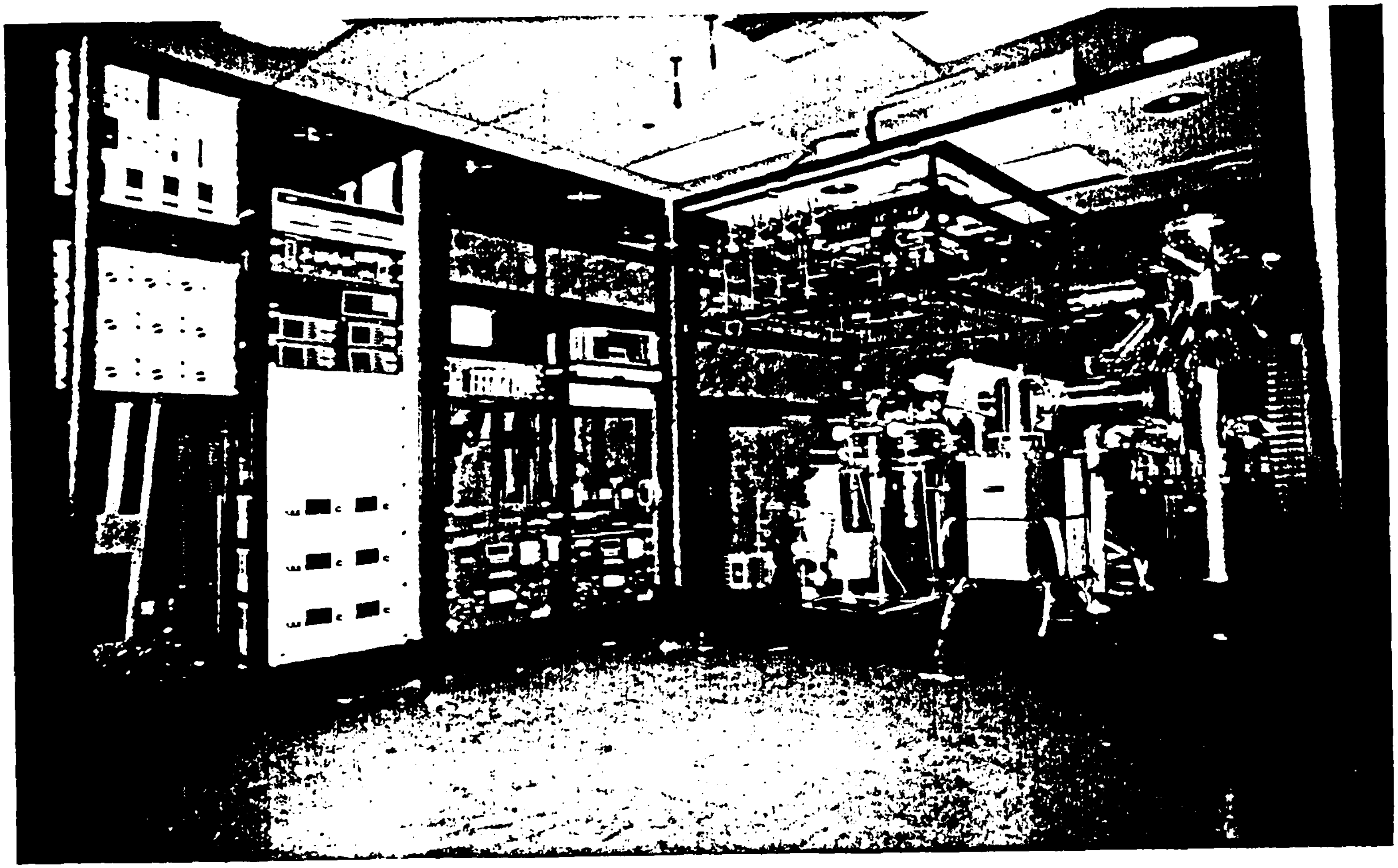

Figure 2. Layout of the reactor cabinet and associated electronics panel once installed in the laboratory.