SUMMARY

Laser chemical vapor deposition (LCVD) is a new manufacturing process that holds great potential for the production of small and complex metallic, ceramic, and composite parts. However, the field of LCVD is still in its infancy and the deposition process is not well understood, especially as it relates to the manufacture of three-dimensional objects. Therefore, the current research has focused on (1) designing and developing an advanced gas-jet LCVD system, (2) understanding and modeling the effects of the gas-jet on the deposition process, and (3) using the LCVD system to deposit a ceramic (boron nitride) and a metal (molybdenum).

A major portion of the research was the design and development of a sophisticated LCVD system. The design included several novel features which were advantageous in terms of build time, accuracy, resolution, and flexibility. A high velocity gas-jet was used to deliver reagent gases directly to the substrate surface. Patterned deposits were generated by rotating and translating the substrate in a spiral fashion, which avoided high reversal forces and associated vibrations. A thermal imaging system was used to control the deposition temperature to within 5°C and to document two-dimensional thermal gradients in real time. A laser triangulation distance device was also available to evaluate deposit uniformity and overall shape. This system has demonstrated direct writing and fiber growth mechanisms with carbon on various substrates. Furthermore, the thermal control system permitted the fabrication of uniform multi-layer structures to be used as building blocks for larger three-dimensional objects.

Successful operation of the LCVD system demands that the fundamentals of the process are well understood. Since CVD is a thermally activated process, the most important process variable is temperature. Therefore, a thermal model was developed for the LCVD system, accounting for Gaussian beam laser heating and gas-jet convection cooling. Various substrates and reagent mixtures were evaluated. It was determined that the most significant variable in the laser heating of a substrate for the LCVD process was the substrate thermal conductivity. The forced convection cooling imposed by the gas-jet reagent delivery system was also significant, accounting for a 15 to 20% change in the substrate temperature.

The deposition rate for a given material is not only affected by temperature, but can also be limited by the mass transport of reagent gases to the deposition zone. The gas-jet reagent supply for the LCVD system was designed to remove this limitation, but the need and impact of such a system

has been debated. Therefore, a two-dimensional mass transport model was developed to estimate the effects of a gas-jet with respect to local reagent concentration variations and reaction rates. Across all deposition regimes, the gas-jet was found to be an effective tool for increasing the concentration of reagent gases at the surface of the substrate. The gas-jet also generated higher deposition rates and increased deposit resolution for those processes limited by diffusion.

In the final stage of research, the gas-jet LCVD system was used to deposit boron nitride and molybdenum on various substrates. The ability to deposit boron nitride and molybdenum is essential to continuing LCVD research efforts at Georgia Tech. The fabrication of an advanced thermionic emitter is a long-term goal of the lab. The materials specified in the design of this device are deposits of boron nitride and molybdenum on a tungsten substrate. Demonstrating that both of these materials can be deposited onto tungsten is an important step toward the fabrication of thermionic emitters.

Not only has the current research resulted in material deposits that are required for the development of a thermionic emitter, but a sophisticated gas-jet LCVD system has been designed and constructed that will serve as a focal point of further research on LCVD and for fabrication of advanced electromechanical devices. Furthermore, thermal and mass transport models have been developed that will enable future characterization and analysis of the gas-jet LCVD system.