1. AGENCY USE ONLY (Leave blank)
2. REPORT DATE
   1 Oct 00
3. REPORT TYPE AND DATES COVERED
   Final Tech Report  1 Mar 98 to 31 Aug 99
4. TITLE AND SUBTITLE
   Equipment for Multivariate Control, Simulation, Optimization, and Signal Processing for the Microlithographic Process
5. FUNDING NUMBERS
   F49620-98-1-0263

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
   Air Force Office of Scientific Research
   AFOSR/NM
   801 N. Randolph Street, Rm 732
   Arlington, VA  22203-1977

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
    F49620-98-1-02630

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
    Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
    This report summarizes the results associated with instrumentation purchased under DURIP contract F49620-98-1-0263 in support of AFOSR/DARPA MURI Program on "Multivariable Control, Simulation, Optimization, and Signal Processing for the Microlithographic Process". This project is generally concerned with the application of systems techniques to the lithographic sequence used for patterning integrated circuits at very small dimensions (less than 250 nanometers). This complex sequence is comprised of photoresist processing, mask design, and optical illumination steps. Lithography is a major technological area that may impede the continued increase in integrated circuit density (Moore's Law).

14. SUBJECT TERMS

15. NUMBER OF PAGES
   4

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
    UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE
    UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT
    UNCLASSIFIED

20. LIMITATION OF ABSTRACT
    UL
Final Technical Report

Equipment for Multivariate Control, Simulation, Optimization, and Signal Processing for the Microlithographic Process

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Submitted to:
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AFOSR/PKC
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Arlington, VA 22203-1977

Contract Number
F49620-98-1-0263, P00001

October 1, 2000
Summary

This report summarizes the results associated with instrumentation purchased under DURIP contract F49620-98-1-0263 in support of AFOSR/DARPA MURI Program on "Multivariable Control, Simulation, Optimization, and Signal Processing for the Microlithographic Process". This project is generally concerned with the application of systems techniques to the lithographic sequence used for patterning integrated circuits at very small dimensions (less than 250 nanometers). This complex sequence is comprised of photoresist processing, mask design, and optical illumination steps. Lithography is a major technological area that may impede the continued increase in integrated circuit density (Moore's Law).

The equipment purchased in this program was used primarily for the development of an advanced thermal processing station for manufacturing integrated circuits utilizing acid catalyzed photoresists for deep-ultraviolet photolithography. This process is quite sensitive to temperature (ranging from 2 to 10 nanometers per degree Celsius). Consequently, stringent temperature control is required. We have developed temperature control algorithms and patented gear for conducting these most thermally sensitive steps. This technology has been transferred through a licensing arrangement with Stanford University to a company APT Systems, that has transitioned it into a commercial-grade product. The first productized system was successfully delivered in July, 2000, to a major manufacturer of photomasks with several follow-on orders scheduled for delivery later this year. The purpose of the technology is to place stringent controls on the photomask processing temperature trajectories, thereby enabling highly sensitive photoresists to manufacture advanced photomasks. The basis for the system was an analysis of the thermal characteristics of large volume substrates to show that nonuniform local heating was needed to achieve uniform heating at the substrate plane. Further analysis showed that decoupling the heating modes into independent rapidly responding units was required to achieve fast response times with minimal out-of-plane stress-induced deformation. The resulting technology is a major departure from conventional heating systems since it utilizes high dimensional multivariable spatial control to manipulate the temperature field over a small grid. The system is nearly two orders of magnitude faster than conventional equipment (response times of 20 seconds versus 2000 seconds) and provides an order of magnitude improvement in spatial controllability (625 mm² local heating fields versus 18,000 mm² fields). Further, the system provides an in-situ quench capability that had never been achieved in the industry. This adds-up to a system with extreme temperature control capabilities, providing advantages in yield, throughput and across-substrate electronic performance. This precise method of temperature control may also find use in other areas, such as independently controlling all linear in-plane distortion modes for precision overlay.

The instrumentation purchased under this program was used in demonstrating the thermal array concept. It included the fabrication of the unit, the implementation of computerized data acquisition and thermal sensors, and the addition of a robot to test the repeatability of the system. The overall system was stationed at ETEC Systems in Hillsboro, OR,
from 6/99 - 12/99 for application on photomask processing. This system is shown in Figure 1. The temperature control results taken at ETEC are shown in Figure 2.

*Figure 1: Picture of the thermal cycling system in operation in a cleanroom at ETEC Systems in Hillsboro, OR.*

*Figure 2: Temperature uniformity at steady-state as measured by 16 RTD’s positioned in a quadrant of a 6-inch square quartz photomask.*
## 2DTA432 Summary of Expenses

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