Center for X-ray Lithography

'inal Phase I Technical Report
NRL Contract No. N00014-89-J-2017
April 25, 1989 to February 28, 1991

Prepared for:

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By:

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FINAL PHASE I TECHNICAL REPORT
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This is the final Phase I Technical Progress Report prepared by the University of Wisconsin-Madison Center for X-ray Lithography under the Naval Research Laboratory contract N00014-89-J-2017. This report covers the period from April 25, 1989 to February, 28 1991.

1 Tasks

Three principal tasks have been assigned by the NRL to the University of Wisconsin-Madison Center for X-ray Lithography. The first task involves the integration of the SVG Lithography (originally Perkin-Elmer Corp.) vertical-stage stepper to the synchrotron X-ray source, Aladdin. This task involves the design and construction of the beamline optics, electronics, vacuum, and mechanics to deliver stable and uniform X-ray flux over a 25 mm by 50 mm field to the SVG Lithography stepper. Incorporated in this task is the development of the instrumentation from the beamline to SVG Lithography stepper, i.e. flux information, scan rate and position sensors, etc., and the appropriate in-situ monitors to the beamline, e.g. vacuum information, mirror contamination status, etc. The final aspect of this first task involves the installation and characterization of the SVG Lithography Stepper and beamline systems in the clean room at the CXrL. The second and third tasks involve the design and construction of two clean rooms: a stepper clean room to house and support the vertical-stage stepper and its instrumentation; and a process clean room facility, which will be used to perform X-ray resist processing, resist cleanup, and inspection. A task not foreseen at the initiation of the NRL contract, and subsequently added, involves the characterization and format study of X-ray masks. Because this task is related to the SVG Lithography stepper, it is reported as a sub-task under stepper–beamline integration and subsystems. In the mask format task the CXrL at the University of Wisconsin-Madison has provided important information to SVG Lithography and a number of U.S. companies who are involved in the XRL program about the mechanical rigidity and stability of various X-ray mask designs and mounting techniques.

2 Final project status

Activities and schedules of the SVGL stepper delivery have modified our development during the Phase I activities. The ES-2 and ES-3 beamlines and beamline cleanroom will be continued and finished during Phase II funding. Most of our tasks are complete. Several of our tasks are dependent upon information from SVGL and cannot be completed until it is supplied. See the topics mentioned in the following section which state the status of the respective tasks at the end of Phase I of the DARPA/NRL program.

2.1 11.010 – Vacuum and Mechanical Studies

Task Summary

Responsible:	E. Brodsky
Description:	Vacuum and Mechanical Studies
Purpose:	Design of vacuum and mechanical systems for the stepper beamline (ES-3)
Date Begun:	1 January 1990
Completion:	75%

Detail

The beamline has been, for the most part, designed. Many of the components have been fabricated by the Physical Science Laboratory(PSL). Remaining major sections are in the PSL workshop queue. Components are being stored until the remaining sections are available for assembly.

During the design process we were in contact with the Grumman Corporation. They are interested in acquiring beamline technologies. We have provided information and support for their engineering efforts in beamline design. During the year they have had a number of engineers at CXrL to observe and understand our beamline design procedures.

There are a number of issues that are yet to be resolved in our beamline. Work will continue on the acoustic delay line and related equipment. We are doing some experiments to try to understand the problems that might arise due to the breaking of a beryllium window. These experiments are not completed yet and will continue in Phase II.

2.2 11.030 — Design Reviews (SPDR, PDR, CDR)

Task Summary

Responsible:	S.Palmer and P.Anderson
Description:	NRL Design Review of CXrL Program
Purpose:	To present current progress and review the plans and the integration of the CXrL Program to the DARPA/Navy Program
Date Begun:	29 January 1990
Completion:	100%

Detail

We had a number of design reviews of our program and attended all three of the SVGL reviews. Presentations were made of our progress, and information was shared to expedite the integration.

2.3 11.090 – Optics Procurement

Task Summary

Responsible:	R. Cole
Description:	Beamline Figured-Optics Procurement
Purpose:	Vendor selected in task 11.080 will fabricate the optical components to be used as grazing incidence mirrors in the ES-3 stepper beamline.
Date Begun:	1 Mar 90
Completion:	95%

Detail

Continental Optical Corp., of Hauppague NY was chosen to fabricate the mirrors for the stepper beamline (ES-3). At the end of the reporting period the mirror order was outstanding.

2.4 11.110 – Optics (Scanning)

Task Summary

Responsible:	R. Cole
Description:	Beamline Scanning-Optics Procurement
Purpose:	Fabricate the optical components to be used as grazing incidence scan-mirror in the stepper beamline.(ES-3)
Date Begun:	16 Mar 90
Completion:	95%

Detail

The results of the bids for the scanning (flat) mirror were received on 16 Mar 90. The low bidder for the mirrors as specified was Muffoletto Optical Co, Inc. The order was still in progress at the end of Phase I.

2.5 12.010 – Vacuum RFQ's

Task Summary

Responsible:	E. Brodsky
Description:	Vacuum RFQ's
Purpose:	Purchase of capital items that require bidding
Date Begun:	1 January 1990
Completion:	95%

Detail

Most of the commercial components for the stepper beamline have been ordered and are here at CXrL or anticipated to be here soon.

2.6 12.020 – Vacuum Procurement

Task Summary

Responsible:	E. Brodsky
Description:	Vacuum Procurement
Purpose:	Purchase parts and fabricate beamline
Date Begun:	1 January 1990
Completion:	80%

Detail

The UW Physical Sciences Laboratory is fabricating components for the ES-3 beamline. We are assembing the custom components with the commercial to check for compatibility.

2.7 14.000 – Beamline Electronics

Task Summary

Responsible:	*P.Anderson*
Description:	Beamline Electronic Equipment and Design
Purpose:	To design the electronics necessary to implement a control system for the beamline.
Date Begun:	1 December 1989
Completion:	50%

Detail

This task has been proceeding on schedule. The motor drives for the mirror and the large linear motor will be here at the end of December. I have been reviewing all the remaining equipment that is needed for the control system.

2.8 15.000 – Beamline Software Design

Task Summary

Responsible:	P.Anderson
Description:	Beamline Software Design
Purpose:	To define the overall software design of the beamline control system.
Date Begun:	1 December 1989
Completion:	50%

Detail

After an extensive presentation to Grumman Instrumentation and Control system engineers I started to work on the details of the software design. I have a half time graduate engineering student coding sections of the control systems. The work was still in progress at the end of Phase I.

2.9 16.000 – Beamline Documentation

Task Summary

Responsible:	P.Anderson
Description:	Beamline Documentation
Purpose:	To document the overall design of the beamline.
Date Begun:	1 January 1990
Completion:	80%

Detail

This task has been proceeding on schedule. This task has expanded since the SVGL PDR. We distributed our findings to more members of the lithography community for their input and comments.

2.10 21.000 – Stepper Cleanroom

Task Summary

Responsible:	S.Palmer
Description:	Stepper/Beamline Cleanroom Design and Installation
Purpose:	To define, design engineer, and construct the beamline cleanroom and facility required to house the SVG-L stepper.
Date Begun:	24 December 1989
Completion:	90%

Detail

The beamline cleanroom construction phase task has begun following the approval of the cost and task summary package by CXrL director F.Cerrina. The request for quotations for the ULPA filter fan units, which will be used in the construction of the cleanroom, have been issued to the U.W. purchasing department. Construction will be done during Phase II.

2.11 22.000 – Process Clean Room

Task Summary

Responsible:	S.Palmer
Description:	Process Clean Room Design and Installation
Purpose:	Develop and install the Class 10/100 cleanroom facility to perform sub-$1/2\mu m$ lithography processing on integrated circuits and research capabilities for x-ray lithography
Date Begun:	July 1989
Completion:	100%

Detail

The process cleanroom task can be considered complete. Only minor tasks such as installation of facilities and safety features remain. A final certification will be performed on the cleanroom with all equipment in place (late July) to determine the cleanroom classification. The "empty" cleanroom particle measurements show that the cleanroom meets Class 1 specifications at the 0.5 μm particle range, and approximately class 10 for the 0.35 μm range. We estimate the cleanroom to be better than class 100 for 0.1 μm size particles.

2.12 31.000 – SEM and Linewidth Metrology System

Task Summary

Responsible:	S.Palmer
Description:	SEM Procurement, Installation, and Qualification
Purpose:	Install and characterize SEM/Metrology tool for use in qualifying $1/4\mu m$ lithography
Date Begun:	3 July 1989
Completion:	100%

Detail

The installation of the SEM is complete. Minor problems caused the delay of the certification, i.e. vacuum leak and poor image resolution due to contaminated Wehnelt and gun assembly.

2.13 32.000 – Process Instrumentation/Equipment

Task Summary

Responsible:	S.Palmer and D.Plumb
Description:	Beamline and Process Clean Room Equipment
Purpose:	Selection and installation of process and inspection equipment to perform and characterize x-ray lithography at 0.25 μm
Date Begun:	3 July 1989
Completion:	100%

Detail

The first phase of the installation of the process cleanroom equipment is complete. All of the instruments which were ordered on the first phase of the contract have been installed with the exception of the acid hood. The scrubber system and holding platform were installed during the month of September, and system checkout is underway. The acid hood is due for delivery in November. The plumbing to the acid hood station will be in place before the system is delivered.

2.14 34.0.020 – ES-0 Procurement

Task Summary

Responsible:	R. Cole
Description:	Procurement of ES-0 Beamline components.
Purpose:	To acquire the components not currently on hand that will be installed on the ES-0 beamline.
Date Begun:	1 Mar 90
Completion:	90%

Detail

ES-0 will require only a few new components to ensure operation after the move. These include a longer straight section, new Be-window assembly, a functional Front-End assembly, and a molecular sieve for the roughing pump. These will be completed in phase II.

2.15 34.1.010 – ES-1 Optics Redesign

Task Summary

Responsible:	R. Cole
Description:	Redesign of ES-1 Beamline Optics.
Purpose:	To redesign the ES-1 beamline optics to provide scanning and high-energy filtering capabilities.
Date Begun:	17 JUL 89
Completion:	100%

Detail

Optical design completed in OCT 89.

2.16 34.1.050 – ES-1 Move and Modifications

Task Summary

Responsible:	M. Hansen
Description:	ES-1 Move and Modifications
Purpose:	To move the ES-1 beamline to port 122
Date Begun:	01 February 1990
Completion:	100%

Detail

The ES-1 beamline move has been completed as of 4/1/90. Testing and certification of the beamline was completed 4/15/90. The beamline has been operating successfully for routine experimentation since 4/9/90. The beamline modifications that remain constitute the final 5% of the task and will be implemented in the coming months without interruption to ongoing experimentation.

2.17 34.1.060 – ES-1 Connection

Task Summary

Responsible:	M. Hansen
Description:	ES-1 Connection
Purpose:	To connect the new ES-1 beamline vacuum, signal and utility lines to SRC/Aladdin support systems and controllers.
Date Begun:	01 March 1990
Completion:	100%

Detail

The ES-1 beamline has been connected to Aladdin port 122. The beamline has been certified. It has been operational since 4/9/90.

2.18 34.1.070 – ES-1 Testing and Certification

Task Summary

Responsible:	M. Hansen
Description:	ES-1 Testing and Certification
Purpose:	To test the new ES-1 beamline and modifications.
Date Begun:	10 March 1990
Completion:	100%

Detail

The ES-1 beam has been characterized using our Scientech model 365 calorimeter. X-ray beam shapes and flux values for both 800 MeV and 1GeV beams have been determined. Photoresist exposures were made to characterize the new Be window graininess. The stage scanner code (modified for the new stage encoder system) was tested and is working properly. Stage position repeatability tests were conducted. Twenty-five field exposure tests were run to check the scanning code. The beamline is fully operational, characterized, and certified. The beam characteristics have been modified only slightly by the move. The beamline stage movement and pump/vent systems have been improved markedly.

2.19 34.2.010 – ES-2 Optics Procurement

Task Summary

Responsible:	R. Cole
Description:	Procurement of ES-2 Beamline Optics.
Purpose:	Vendor fabrication and delivery of custom designed optics.
Date Begun:	3 OCT 89
Completion:	95%

Detail

Vendor : Continental Optical, Haupaggue, NY. The order is scheduled for delivery in February 1991.

2.20 34.2.020 – ES-2 Beamline Design

Task Summary

Responsible:	R. Cole
Description:	Design of beamline components for ES-2.
Purpose:	To develop a comprehensive vacuum system and supporting electronic hardware to house the optics and deliver the x-rays where intended.
Date Begun:	1 May 90
Completion:	70%

Detail

Design work will draw upon existing sketches and proven technologies successfully implemented on existing beamlines. The workload associated with acquisition and fabrication will be delegated to the UW Physical Sciences Laboratory.

2.21 40.000 – Stepper Characterization/Qualification

Task Summary

Responsible:	S.Palmer
Description:	SVG Lithography Vertical Stage Stepper Characterization
Purpose:	Develop and implement characterization and qualification procedures for SVG-L vertical stage x-ray stepper
Date Begun:	14 January 1991
Completion:	30%

Detail

We designed a proposed screening experiment (using Plakett-Burmann statistics) to determine the influence of temperature, dose, humidity, and resist thickness variance on resolution and alignment capability of vertical stage stepper. We proposed these procedures to the NRL and SVG-L at our October meeting on stepper qualification. A tape was generated with a mask description containing Prometrix electrical resolution data base. A corrected CXrL pattern generation data diskette was issued to IBM Burlington for x-ray mask generation. We completed a proposal for list of tests to be performed on the stepper and the tools which will be used in performing the measurements.

2.22 60.000 – Mask Standardization

Task Summary

Responsible:	R.Engelstad and S.Palmer
Description:	Mask Modeling and Characterization
Purpose:	Perform modeling and mask analysis of proposed mask formats by National X-ray Mask Standard Committee
Date Begun:	September 1989
Completion:	95%

Detail

The CXrL has continued work with outside groups by providing calculations and ANSYS modeling of the distortion of x-ray masks and the distortions of x-ray masks due to different mounting techniques. This effort was directed under the leadership of NIST in an effort to define an x-ray mask standard. The 3-dimensional ANSYS analysis of vertical and horizontal supported mask frames was modified in August to include the net distortion result of transfer of the mask from one kinematic mount to the other. This was done to simulate the e-beam mask holding distortion effects with vertical clamping during the x-ray exposure. These results will be presented at the UW-Madison SCoE review on October 3.