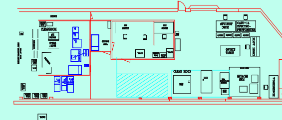
NanoTech Wisconsin

Masks & Metrology

Annex, view to the SW

- Masks and metrology comprises the equipment that gives CNTech the capabililty to create masks for both the EUV and X-ray sources. This includes:
  - Create mesa mask blanks with a KOH etching system
  - Coat mask blanks with a variety of resists
  - Write masks with an E-Beam lithography tool
  - Develop patterned resists
  - O2 Plasma etch to de-scum masks
  - Coat absorber masks with gold for either plate-through or lift-off processes
  - Characterize masks for CD, thickness of layers and elemental mapping to check for fidelity of the mask
  - Measure the results of lithography on wafers from the various exposure facilities
- The masks and metrology functions of CNTech are primarily housed in the Annex facility immediately adjoining the North side of the Synchrotron Radiation Center of the University of Wisconsin on the Kegonsa Research Campus. The Annex is a total area of 2900 square feet, with 2 clean rooms.
- The E-beam Clean room is 360 square feet of class 100 space.
- The Metrology Clean Room is 450 square feet of class 1000 space.
- Flow hoods are approximately 500 square feet of space.
- In addition to the masks and metrology functions the Annex also serves as a multipurpose development, staging, repair, and storage area for all of CNTech. Included in this is in-house developed mechanical and vacuum components and systems including components designed and built by CNTech personel.

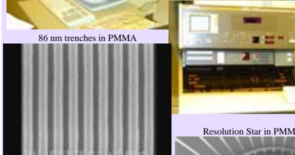
Annex, layout



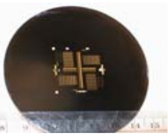
JEOL JBX-5DII (U) E-Beam

- Received from JPL on 2-21-02, First test pattern written 5-30-02
- Capable of writing complex patterns with dimensions down to 30 nm.
- Beam current ranges from approximately 50 pA to ten's of nA's.
- Exposure samples can be 3 or 4 inch mask plates, 2 or 3 inch diameter wafers.
- Sample window widths that are allowed include 6, 8.5, 10.5, 16 and 21 mm.
- Stage travel Xmax = 100 mm. and Ymax = 75 mm.
- Field stitching accuracy: Spec 0.1 µm/ Actual 0.038 µm (3-sigma).
- Overlay accuracy: Spec 0.1 µm/ Actual 0.053 µm (3-sigma).
- Four basic column exposure "modes":
  - Lowest resolution is at 25 kV with the 4th lens, maximum field size of 1600 microns and 50 nm step size. The minimum beam diameter is ~ 100 nm for 30 pA of beam current. Typical values would be 100 pA to 10 nA.
  - 50 kV/4th lens conditions operate with a maximum field size of 800 microns and 25 nm beam step. Minimum beam diameter is ~ 50 nm.
  - 25 kV and the 5th lens reduces the field size to 160 microns and step size of 2.5 nm. Minimum beam diameter here is ~ 70 nm.
  - 50 kV/5th lens. Beam currents of 30-100 pA are typical for the 80 micron field size and 25 nm beam step. Minimum beam diameter is ~ 10 nm .

86 nm trenches in PMMA

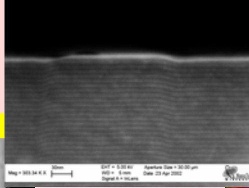


Resolution Star in PMMA at CNTech

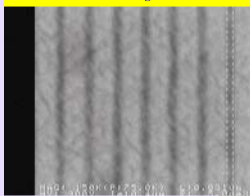


Sub 60 nmTrenches in PMMA written at CNTech

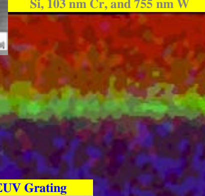
LEO SEM of 2 nm layers of Si and Mo



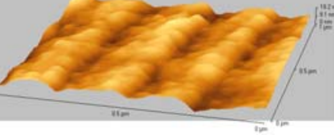
JEOL E-Beam Patterning of 31 nm trenches



NORAN EDS Composite map of Si, 103 nm Cr, and 755 nm W



Thermo Microscope M5 AFM Plot of EUV Grating

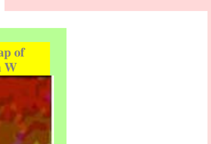


LEO 1550VP SEM and NORAN Quest EDS

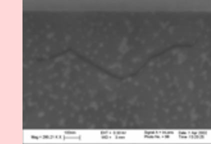
LEO 1550VP SEM

- **LEO 1550VP SEM:**
  - The LEO 1550 is an ultra-high resolution field emission SEM. It is capable of a variety of applications due to is versatile specimen chamber and large capacity cartesian stage.
  - The stage of the LEO 1550 is motorized in all five of its axes of movement and accommodates bulky or irregular specimens or large planar specimens at steeper angles.
  - The LEO 1550 VP variable pressure technology allows the chamber pressure to be set to any value in the pressure range to suit the specimen. Optimum secondary electron imaging is always available. In-lens detection at high vacuum, patented VPSE detection in VP mode. This allows X-ray analysis on completely insulating specimens.
  - Optional NORAN Quest 2 EDS Imaging Microanalysis System
  - **Key Features**
  - Superb resolution and image quality at low operating voltages - 2.1nm at 1kV.
  - Wide operating voltage range, with minimal readjustments required - 100V to 30kV.
  - High probe current and stability better than 0.5% per hour for fast X-ray analysis and EBSP pattern acquisition. In-lens detector for clear, bright surface-specific imaging.
  - Short working distance of 8.5mm for simultaneous high resolution SE or BSD imaging and X-ray analysis.
  - Elemental and Spectral analysis of the specimen via QUEST Energy Dispersive Spectroscopy.

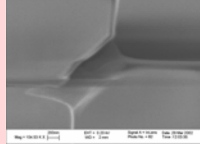
LEO image of features and cracks on mask



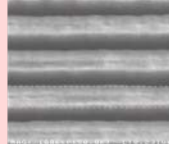
LEO image of cracks on mask



LEO Image of fracture zone in PMMA



Hitachi Image of grating



Hitachi CD SEM

- The Hitachi CD SEM measures CD on a variety of wafers and masks.
- Measurement range 100 nm to 100 microns, reproducibility 20 nm or 1%
- 8 nm image resolution — Magnification 100 to 450X, 500 to 150,000X.
- 700 to 1300 V accelerating voltage. — X and Y motion 200 mm.

KOH Etch Oven

- KOH Etch Oven used for:
  - Creating mesa masks
  - Backside etching to create membrane windows

Mask Process Bench

- Mask Process Bench used for:
  - Gold plating for creating absorber masks and structures
  - Cleaning and drying of masks and mask substrates

Plasma Therm RIE Etcher

- Plasma Therm RIE Etcher is used for:
  - RIE O2 etching for plasma descum and surface prep.

These facilities were provided by DARPA directly and through BAE Systems and are administered through the College of Engineering by DARPA Grants MDA 972-99-1-0013, MDA972-00-1-0018, MDA792-01-1-0039, and N00019-01-C-0004. The Synchrotron Radiation Center storage ring is funded by the National Science Foundation under Grant DMR-0084402. Intel provided funds for both the EUV station and the Hitachi CD SEM.

Image of MELCO - MEL3 mask

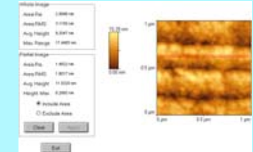
CNTech standard mesa mask on NIST Format Glass Ring

Topometrix AFM Scan of mask with Nanotube tip

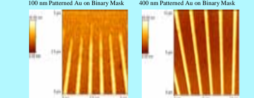
Topometrix Explorer AFM with Nanotube Tips

- Stage handles samples up to 400mm x 400mm x 15mm
- Stage Movement X, Y – 200 mm, Z – 5 mm
- Modes:
  - Contact
  - Intermittent Contact
  - Non-Contact
  - NanoProbe option

M5 AFM Scanning of EUV grating with measurement statistics



AFM Non-Contact Scanning of Patterned Gold on Binary Mask

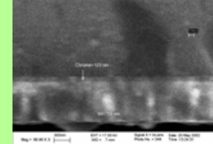


AFM Thermal Scanning of Patterned Resist

Thermo Microscope M5 AFM

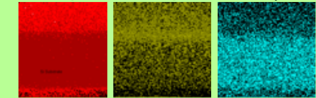
- Stage handles samples up to 400mm x 400mm x 25mm
- Stage Movement X, Y – 200 mm, Z – 25 mm
- X, Y – Scan Movement – 100 µ, Resolution 0.025 nm
- Z – Scan Movement – 8 µ, Resolution 0.0025 nm
- Modes:
  - Contact – Lateral Force – Intermittent Contact – Non-Contact
  - Scanning Thermal – Phase Modulation
  - Force Modulation Microscopy – Electrostatic Force Microscopy
- Options:
  - Nanolithography Option – Materials Analysis Package
  - Scanning Thermal Microscopy – AutoProbe Extended Signal Access
- Enables:
  - Characterization of Resists – Patterning Resolution
  - Patterning Registration – Mask Verification
  - Potential to rework masks with Nanolithographic techniques

LEO 1550 SEM of 755 nm W and 103 nm Cr on Si substrate



NORAN Quest EDS

NORAN elemental mapping of a portion of the above left image:
Si Map — Cr Map — W Map



- **NORAN Quest EDS System:**
  - The NORAN Quest EDS system uses the LEO 1550 SEM as a source of electrons to stimulate sample atoms to emit X-rays. These are detected in a Lithium drifted Silicon detector with a low Z window that allows detection of elements down to Boron.
  - **Key Features**
  - Low atomic mass capability (Boron) — Automatically identifies elements in a scan
  - Capable of creating point, line and area scans — Individual and composite 2D maps of selected elements

University of Wisconsin
Center for NanoTechnology

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