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Nanonotes

Nanotech at the University of California Santa Barbara

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In the Winter 1999 issue of Nanonotes we are introducing two tools which add exciting new capabilities to the Nanotech Nanofabrication Facility at UC Santa Barbara. Our E-Beam Lithography and Optical Stepper Systems are now available for use by the UCSB and NNUN research communities. Access information and hourly rates for the Cleanroom and E-beam labs are available on-line at http://www.nanotech.ucsb.edu/.

JEOL JBX-5DII(U) E-Beam Writer at UC Santa Barbara

by Ernie Caine

The JEOL JBX-5DII(U) electron beam lithography system at UC Santa Barbara went "on-line" in April of this year. The UCSB Nanofabrication facility provides full maskmaking and nanometer direct write capabilities to Off-campus and UCSB researchers in engineering, physics and materials science communities.

The machine was originally commissioned in 1986 at Cornell University, (at the then named Micro-Research Fabrication Facility, an early predecessor to NNUN). The machine was transferred to UCSB last year as part of the NNUN site "partnership" and is expected to likewise enhance our research capabilities for the immediate future. Fellow NNUN staff members at Cornell (R. Tiberio, D. Costello (now at DuPont), and M. Rooks (now at IBM-Watson) as well as our JEOL counterparts Paul Maker and Rich Muller at JPL have contributed greatly to this successful transition. This complements existing e-beam lithography tools available at the other NNUN nodes: Cornell (LEICA VB6), Penn. State (Leica/Philips EBPG5-HR) and Stanford (Hitachi HL-700F).

The JEOL is a computer-controlled e-beam lithography system capable of writing complex patterns with dimensions down to 30 nm (with appropriate resist/substrate conditions). This high resolution capability, however, places limits on writing speed, field size and pattern placement. The system hardware features an ion-pumped column and chamber with LaB6 electron emitter, 25 and 50 kV column voltages and turbo-pumped chamber and loadlock. Beam current, which directly impacts resist image resolution through the beam diameter, ranges from approximately 50 pA to ten's of nA's. This in conjunction with the 2 MHz maximum sweep frequency (0.5 usec minimum dwell time) limits speed thereby extending 'write' time.

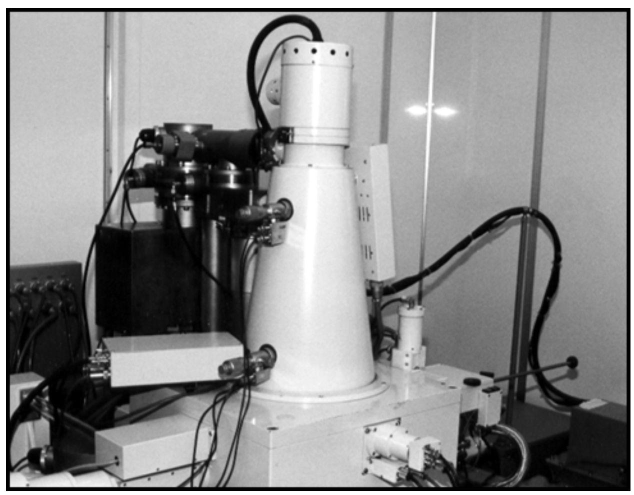

Figure 1. Column as seen in the class 100 cleanroom area of the lab.

Exposure samples can be 3 or 4 inch mask plates, 2 or 3 inch diameter wafers or parts of a wafer (piece parts). Piece parts must fall within specific dimensions due to the limited number of sample chucks we currently have available that use sample front surface referencing. Sample window widths that are allowed include 6, 8.5, 10.5, 16 and 21 mm. Stage travel places a limit on the maximum exposable area with Xmax = 100 mm. and Ymax = 75 mm. Generally wafers or piece parts are used for direct write applications where the pattern to be written registers to a pre-existing pattern on the substrate. This entails the use of registration or mapping and requires two types of registration marks. Additional information on physical dimensions can be found at the Nanotech website http://www.nanotech.ucsb.edu/.

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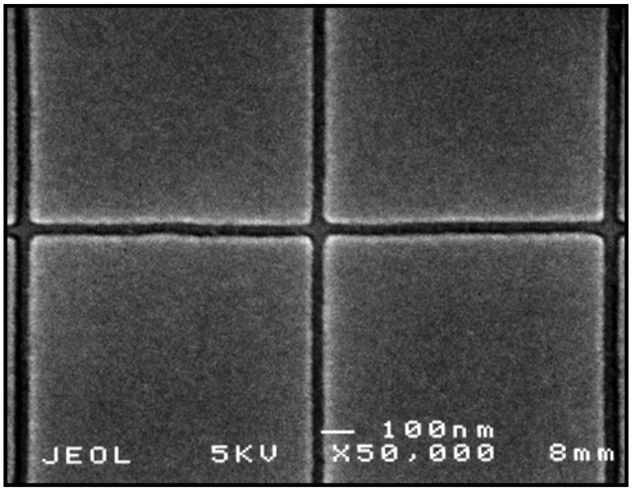


Figure 2. The minimum features obtained with single pass lines written in PMMA at 50 kV with a dose of 1.0 nC/cm. This ultimate linewidth is obtained by exposing single pass (SP) lines. A similar approach can be used for dots.

The JEOL JBX-5DII(U) has proven capabilities:

- 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)
- Minimum feature size: ~35 nm for < 100 nm PMMA resist

There are four basic column exposure "modes" resulting from the combination of the 25 and 50 kV column voltages and the two final or deflection lens, known as the 4th and 5th lens. The lowest resolution mode is at 25 kV with the 4th lens which has the machine's maximum field size of 1600 microns. The minimum beam diameter is ~ 100 nm for 30 pA of beam current. Typical values would be 100 pA to 10 nA. Changing to the 5th lens reduces the field size (and beam step) by a factor of ten to 160 microns and 2.5 nm, respectively. Minimum beam diameter here is ~ 70 nm. 50 kV/4th lens conditions operate with a maximum field size of 800 microns and 25 nm beam step. The last mode, 50 kV/5th lens, has the highest resolution and is used for nanolithography, such as for devices that exhibit quantum effects. Beam currents of 30-100 pA are typical for the 80 micron field size and 10 nm beam diameter. Note that although the machine is capable of doing work at both accelerating voltages, it is generally kept at 50 kV.

Several related areas must be taken into account in doing an exposure, wherein electronically stored "image data" (or patterns) are ultimately transferred to some substrate or work piece with the electron beam. These areas include:

1) CAD layouts, from the simplest of a single layer device with no registration to a multi-level design for a mask with registered direct write layers, this is what is written. We primarily use L-Edit from Tanner Research . Whatever CAD used, the final pattern should be formatted in gdsII/Calma. Layers should have a hierarchial structure to keep memory requirements low. We currently do not have automatic proximity correction software, therefore corrections must be done manually at the CAD stage using the 'data typing' option. This is important for pattern features of less than ~3 microns including isolated shapes and gaps.

2) Pattern data conversion to machine language code. This fractures or 'parses' individual pattern layers into fundamental shapes that the machine can work with. The stitched field size must be declared at this time along with the gds layer numbers and pattern size. Also the electron beam current must be determined which in turn fixes the beam diameter and sweep time. (A general rule is that the diameter should be ~1/5 of the CD or smallest feature to be written). Simple pattern manipulations such as tone reversal and mirroring can be done here.

3) Exposure files that "direct" the beam and stage. This program, along with a pattern generator, drives the electron optics which combines with x-y servo-locked stage movement to write the pattern. Other information needed here includes: location of registration marks, mark detection parameters, area and line doses and pattern array placement.

4) Sample preparation which is primarily a resist coating steps; a resist that will then allow for an image transfer via subsequent additive (eg. metallization) or subtractive (eg. etching) processing. We currently have baseline processes using various PMMA, SAL-601 and EBR-9 resists.

5) Machine calibrations and sample registration. This calibrates the working surface for proper field size, correction for rotation and exact location of registration marks. One must provide a layout showing relative spacing and location of marks and relative placement of the exposable pattern center.

6) Proper exposure conditions and doses. One generally starts by determining the beam diameter needed, which when combined with column conditions and dose determine the allowable beam currents.

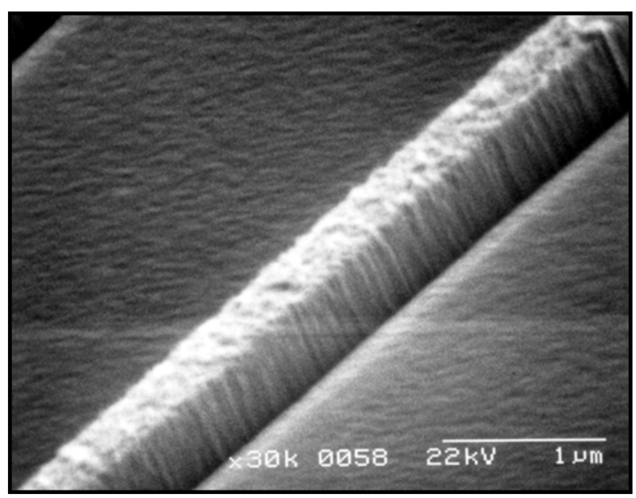


Figure 3 E-Beam defined 0.4 µm line in GaAs etched with Cl2 in Radical Beam Ion Beam Etcher (RBIBE). The mask material was nickel.

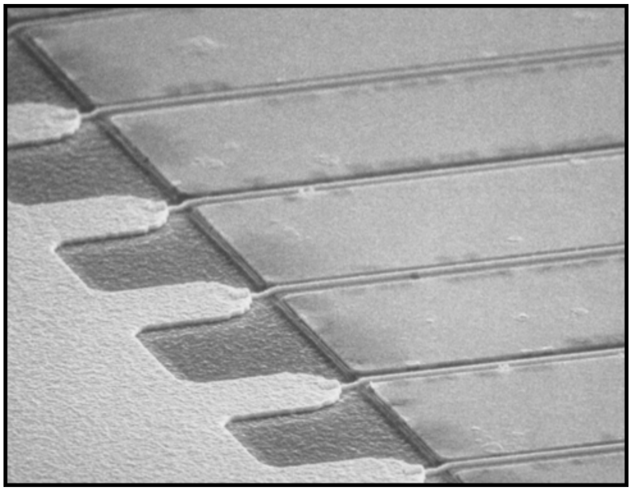


Figure 4. A multi-gate GaAs on Insulator (GOI) FET. The gate length is 0.4 microns.

7) Proper resist developing conditions. Considerations here include: post-exposure bakes, developer type and concentrations, time and temperature, etc.

It is possible for a NNUN researcher to get user training on the machine in order to do on-site/independent work. Our E-Beam lab currently has several on-site users (graduate students from various campus departments). These individuals constitute the UCSB E-Beam User Group that meets periodically to exchange ideas and discuss questions and problems that users might have.

If you would like to inquire about the JEOL E-Beam lithography system, or information regarding the processing capabilities at the UCSB Nanofabrication Facility visit our web site at http://www.nanotech.ucsb.edu/. E-Beam users who would like information regarding starting a project, hourly rates, and E-Beam access can contact Ernie Caine at (805) 893-8489 or Mike Anzlowar at (805) 893-7975.

Lithographic Step and Repeat Photocamera

by Mike Anzlowar

A step and repeat photocamera, or optical stepper, is now fully operational in the Nanofabrication Facility at the University of California at Santa Barbara. Features down to 0.5 micron have been resolved in both positive and negative photoresist. The I-line stepper has a mercury lamp source utilizing an exposure wavelength of 365 nm, and a 5X reduction lens which yields superior performance, resolving features down to 0.5 microns. The lens is an Olympus 2142, with a maximum field size of 21 mm diameter, or 14.5 mm square (at the wafer plane), and a numerical aperture of 0.42.

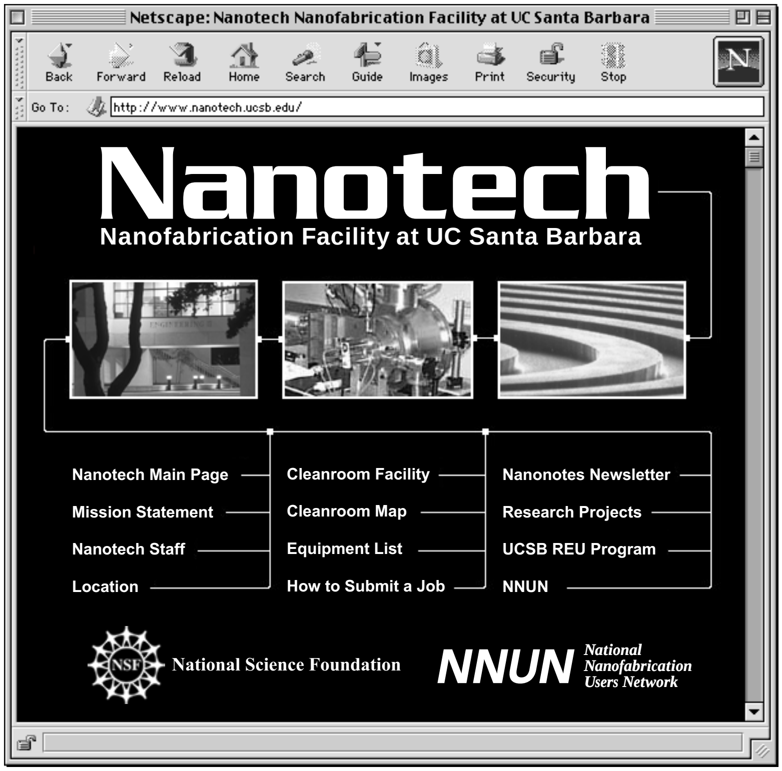
Consistent alignments to within +/- 0.15 micron are achievable using local (die by die) alignment, and +/- 0.35 micron using global alignment. Masks are stepper specific, 5”x5” x 0.090 quartz. High resolution images are obtainable using relatively inexpensive, low resolution masks, a benefit of the 5:1 reduction lens.

The stepper expands UCSB’s lithographic capabilities in a number of ways. The tool bridges the resolution gap between our electron beam writer (< 0.5 micron - see elsewhere in this issue) , and contact lithography (>1.0 micron). It may be used with these other tools in a “mix and match” mode, taking advantage of each techniques strengths, as is common in industry. The stepper operates by projecting an image through the lens onto the substrate, which eliminates the photoresist edge buildup problem . A unique feature of our stepper is that it is not limited to exposing a single wafer size, such as 4 or 6 inch diameter. A patented stage/chuck assembly allows substrates of varying dimensions to be exposed. Current chucks accommodate 2 cm x 2 cm, 1/4 of a 2” wafer, and full 2” wafers. Substrate thickness is limited to a range of **+/-** 300 µm about a standard thickness for each chuck, due to the system’s auto focus feature. A modified chuck could compensate for especially thick or thin substrates. Chucks may also be fabricated for substrates up to 6” diameter if needed.

The stepper has already proven its usefulness on numerous projects. It’s resolution and alignment capabilities have enabled fabrication of very high frequency (820 GHz) devices. The 5X reduction lens also enabled the imaging of very smooth curved wave guides for an optical crossbar switch. Previous attempts at smooth edged wave guides failed using 1:1 contact lithography as the radius of curvature desired conflicted with the MEBES written mask field size. This produced an unacceptable mask with a “jagged” step along the curved wave guides. The stepper has also exposed resist up to 30 µm thick, albeit with lower resolution. These are a few examples of many successful projects using the new stepper.

To learn more about accessing the new stepper, please contact :
Mike Anzlowar at (805) 893-7975.

Figure 1. Photo of Lithographic Step and Repeat Photocamera



Nanotech on the web: http://www.nanotech.ucsb.edu/

For information regarding Nanotech at UC Santa Barbara, users can now access Nanotech on the web. Nanotech's Web Site has up-to-date information about the UCSB Nanofabrication Facility and E-Beam Laboratories. Our new address is http://www.nanotech.ucsb.edu/

Nanotech
Nanofabrication Facility at UC Santa Barbara

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NNUN National Nanofabrication Users Network

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