CrossMark

https://doi.org/10.1017/S1551929500067389 Published online by Cambridge University Press

Using a SEM to "Write" Sub Micron Structures

Dr. Ralf Jede, RAITH GmbH
George Lanzarotta, RAITH USA

Electron beam lithography is a term well known in the world of microelectronics. It provides an effective but costly solution for producing the smallest electronic devices (transistors, memories, etc.). Many fields of science and research also require small structures below the one micron dimension. The ability to generate these structures "in house" without going to external sources has been a luxury only the largest corporations and universities could afford. Even when a production lithography system is available, the time allocated for research work can sometimes be extremely limited. Those with the need for these small devices are now realizing there is new way to get the most use from their SEM, STM or STEM .

In the past few years, experimental e-beam systems have been developed by making use of the basic capabilities of the scanning electron microscope. Now a variety of home built and commercially available systems are being used throughout the world. The most basic system can take control of the e-beam in the SEM and write a simple pattern on a sample coated with materials sensitive to electrons. The current generation of SEMs is the perfect tool for this technique due to improved performance, ease of use and compatibility with external beam controlling systems.

The basic components to the system are a SEM with external deflection input and preferably a beam blanker, a personal computer, pattern design software, an electronic interface with analog X/Y output, a beam current monitor and, in some cases, an automated stage.

Generally any SEM can be used but, in achieving best performance, there are some characteristics that are important for e-beam writing. Stability of the beam current, focus and shape of the beam, and the linearity of the scan (especially for thin, long lines) are all contributing factors to the quality of the finished structure.

To prevent unwanted exposure between the patterns, a beam blanker should be available. The linearity of the SEM scanning system is also important for avoiding distortion in the structures.

The patterns are designed on the computer, usually a PC or Macintosh. The design software allows the generation of basic shapes and the ability to combine them as component parts of the complete pattern design. Storage on disk and edit functions are carried out by software. In addition to pattern design, a good software package will also include utilities for proximity correction, mark recognition and alignment, exposure control and stage control.

The information of the pattern is transferred to the electronics that decodes and converts it to an analog signal for X and Y deflection. This signal connects to the external beam control input on the SEM and steers the beam across the sample, writing the pattern within the selected field of view. This writing field can be any size, depending only on the magnification of the SEM. The required input voltage for full scale X and Y deflection does not change with magnification. This means that patterns can be written at high magnification resulting in extremely small structures.

The sample, or substrate (typically a Silicon or III-V compound wafer), is spin coated with a thin layer of electron sensitive resist. The most common is PMMA. These films are only a few hundred nanometers thick and, once exposed by an e-beam, hold a latent image in either positive or negative tone analogous to photographic positives and negatives. Just like the photographic film in a camera, the exposure (or dose) is an important parameter. The dose can be controlled by changing the beam current or changing the time the resist is exposed to the beam. After exposure, the resist is developed leaving cleared out areas on the sample that can now receive a layer of metal or any material required for the desired pattern.

Speed is a critical part of the system. If the spot size of the beam is small, the writing field must be divided into many picture points, or pixels, to avoid gaps in the pattern. The number of pixels can, in some cases, be extremely large. It then becomes necessary to dwell in each pixel only a short period of time to avoid overexposure or excessively long writing time. Excessive writing time will allow other factors like beam and stage stability to introduce errors. This puts a demand on the overall speed of the system. A total exposure time of one second for three million pixels is sometimes needed and can be achieved by the most advanced systems.

It may be necessary to carefully place the pattern on top of, or next to, another structure. This alignment is done by using the imaging capabilities of the SEM and the PC (or Mac) to make position corrections to the steering signal before the writing begins. The corrections can be performed by software or additional electronics. The software alignment technique can add excessive processing time when writing and may not be as desirable as the hardware alignment.

Patterns in close proximity will have an effect on its neighbor's dose due to the scattering of electrons passing through the layer of resist (forward scattering) and also within the sample itself (back scattering). This is known as proximity effect. Some systems have the ability to minimize this effect by fracturing the pattern into smaller substructures and assigning corrected doses. Utilities for determining the correct parameters for calculating the corrections are included in some proximity correction software. Not all portions of the pattern will be influenced by this effect and a simulation function is included in the correction software to help determine those critical areas.

Small features in large writing fields cannot always be resolved due to limitations such as spot size, beam stability and inherent electronic noise. This problem is overcome by writing portions of the pattern at higher magnifications and stitching fields together by moving the SEM stage and writing the adjacent fields in succession (similar to a collage of micro graphs). The accuracy of stitching is sometimes very critical and therefore high accuracy in stage movement becomes necessary. Motorized stages with laser interferometers can achieve a stitching accuracy better than 100 nanometers. These accessories are now available and can be added to the SEM in place of the existing specimen stage. Most SEMs can accommodate a stage exchange quite easily so the system can always be returned to its original configuration for normal work.

Stage movement can sometimes lead to a defocused beam if the sample is not level. To prevent this, a leveling platform is built into the stage. The sample is positioned under the beam in three different locations. Each location is then brought into focus by adjusting the sample platform, not the beam, until all points remain in focus whenever the stage is moved.

The range of applications of experimental electron beam lithography has become wide spread in the past few years. This is mainly because of the flexibility of this approach, allowing one to write large areas (at low SEM magnification), or very small areas with extremely fine features (at high SEM magnification). With this technique, important work has been done in:

- Study of quantum effects
- Study of superconductors
- Research in integrated optics
- Fabrication of diffraction gratings and zone lenses
- Testing of electron sensitive resists
- Fabrication of computer generated holograms
- Performance testing of single ICs and components by dimensional down scaling
- Electron induced metal deposition
- Production and testing of micro mechanical components

Experimental e-beam lithography has worked out to be a suitable tool for small laboratories to perform almost all types of research based, micro patterning applications. Its main benefits are the flexibility, the ease of operation and the low cost of investment and ownership. Applying SEM technology, the minimum feature size can be scaled down to well below the 100 nm range, making this approach ideal for all research and development work in the upcoming "nanotechnologies". ■

40th National AVS Symposium Short Course Program

The American Vacuum Society will be offering the following 40 short courses in conjundtion with their 40th National Symposium and Equipment Exhibition, Novermber 15-19, 1993 in Orlando, FL. Extended course information can be obtained from Margaret Banks, AVS: (212)661-9404.

Vacuum Technology

Basic Technology of Diffusiŏn Pumps.
Controlling Contamination in Vacuum Systems.
Cryopump Technology.
Gas Flow in Vacuum Systems.
Operation and maintenance of Vacuum Pumping Systems.
Partial Pressure Analyzers: Analysis and Applications.
Pumping Hazardous Gases.
Total Pressure Gauging Techniques.
UHV Design and Practices.
Vacuum Sealing and Joining Techniques.
Vacuum System Design.
Vacuum Technology.

Materials, Thin Films & Coatings: Processing & Characterization

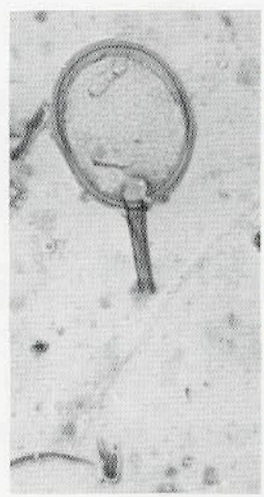
Adhesion of Polymeric and Metallic Thin Films.
Basics of Radio Frequency (RF) Technology.
CVD of Films for Microelectronics.
Deposition and Processing of High-Tc Thin Films.
Electro-Optical Characterization of Semiconductors.
Fundamental Mechanisms of Semiconductor Film Growth from the Vapor Phase. (Evaporation, MBE, CVD and Sputter Deposition)
Hard Coatings by PVD Methods.
An Introduction to Ellipsometry and Interferometry.
An Introduction to Ion Sources: Principles and Technology.
Ion-Beam Techniques for Thin-Film Coating Deposition.
Mass Flow Controllers: Fundamentals, Techniques, and Applications.
Mechanical Properties of Thin Films.
Monitoring/Controlling Techniques for Thin-Film Deposition Processes.
Optical Diagnostic Techniques for Plasma Processing.
An Overview of IC Processing.
An Overview of Thin-Film Deposition and Etching Techniques.
Plasma-Enhanced CVD: Fundamentals, Techniques & Applications.
Plasma Etching and RIE.
Semiconductor Contacts: Science, Fabrication, and Characterization.
Semiconductor Microlithography.
Sputter Deposition.
Structure-Property Relations in Thin Films.
Surface Preparation for Thin-Film Deposition.
Thin Films for Optical Recording Applications.
Transparent Conducting Oxides: Their Science, Fabrication, Properties, and Applications.
Understanding Thin-Film Optics.

Surface Analysis and Materials Characterization

Auger Electron Spectroscopy.
A Comprehensive Course on Surface Analysis Techniques
Depth Profiling.
Fundamentals of Surface Science.
Materials Microcharacterization.
Scanning Tunneling Microscopy: Instrumentation and Practice.
Secondary Ion and Neutral Mass Spectroscopies (SIMS, SNMS, SALI)
X-Ray Photoelectron Spectroscopies (XPS/ESCA).

TENNIS, ANYONE?

When we pry with our
Electron microscopes
Into the realm of
elves and gnomes and pixies,
They take umbrage
At the flagrant
Loss of privacy - -
Then they'll show us
Just who's boss,
With wandering apertures,
Defocused lenses,
Interlocks
That won't unlock - -
Yet to show us
There's no harm intended,
They take charge,
But offer us a game - -
Tennis, anyone?



By:
Murray Vernon King
William A. Samsonoff
Wadsworth Center for Laboratory and Research
NYS Department of Health