

E-Beam Lithography

Many light-based nanotechnology measuring and fabricating tools are limited by the wavelength of light. However, the smaller the wavelength of light, the higher the energy of the light, which can subsequently cause unwanted side effects. One way scientists get around this is to use electrons instead of light. Enter E-beam lithography. Basically, E-beam lithography consists of shooting a narrow, concentrated beam of electrons onto a resist coated substrate. Electrons can induce the deposition of substances onto a surface (additive), or etch away at the surface (subtractive). E-beam lithography is particularly important in micro electronics, which require extremely precise placement of micro sized circuit elements. E-beam lithography allows scientists to design and place elements at the smallest possible scale. Also, electrons can be used to etch a “mask” whose patterns can be later transferred onto a substance using other techniques (think of a stencil you used in grade school). However, with such precision, components can only be made very slowly and only one at a time, greatly increasing the time and cost and prohibiting mass commercial acceptance. Also, because electrons are charged particles, it is necessary to perform E-beam lithography inside a vacuum, further complicating the required equipment and process.

E-beam Components

The process of E-beam lithography is simple, however, the schematics and the parts required are quite complex. Instead of understanding the process of E-beam lithography, it is more efficient to understand some of the important components required for E-beam lithography to work successfully.

Electron Gun: The centerpiece behind E-beam lithography is the electron gun. The specifics of an electron gun could stretch pages, so it is sufficient to know that the electron gun is an apparatus that is able to “shoot” a beam of electrons in a specific direction. Two common E-beam emitters are lanthanum hexaboride crystal and a zirconium oxide coated tungsten needle. The emitter is first heated to produce and excite electrons on the surface. Then, when a high voltage is applied, the excited electrons accelerate towards a structure called the anode. By varying this voltage, the trajectory and the focus of the beam can be manipulated.

Electron Optical Column: The electron optical column is a system of lenses that, by a combination of electromagnetism and optics, has the ability to focus the electrons into a concentrated beam in a desired direction. Two parallel plates inside the column can be electrostatically charged to a precise degree; the resulting electric field is able to bend the beam in a desired direction.

Surface: After the beam is directed and concentrated by the optical column, it is ready to be focused on the surface. As with most lithography techniques, a substance called a photoresist covers the surface. However, E-beam photoresists are not as specific as other types. Technically, high energy electron bombardment will cause bond breakage in any polymer. When the beam hits the surface, either an additive or subtractive reaction takes place. An additive writing method uses

Disadvantages:

Electron Backscattering and Proximity effects: When electrons are subjected directly to a surface, they tend to “scatter” quickly. This phenomenon, known as **electron backscattering**, causes unwanted reactions to take place outside of the focused electron beam. As a result, the resolution of an E-beam is not limited to only the size of the focused beam. In addition to backscattering, the focused E-beam hitting the surface produces secondary electrons, which can expose the resist as much as several micrometers away from the point of exposure. These **proximity effects** can cause critical variations when dealing with surfaces that need to be exact on the sub-micro level.

Efficiency: While E-beam lithography is perhaps the most accurate and precise of all the lithographic techniques, perfection comes at a high price. The complex equipment and slow exposure times makes E-beam lithography impractical as a mass production micro manufacturing method. Also, because electrons are charged particles, E-beam lithography must be performed in a vacuum. Steps are being taken however, in customizing tools such as scanning electron microscopes into having the ability to produce focused electron beams.

References:

Coane, Philip. “Introduction to Electron Beam Lithography” Louisiana Tech University, Institute for Micromanufacturing.

Madou, Mark, J., Fundamentals of Microfabrication. p. 41-43.