roughly equal to the electron penetration depth. The penetration depth increases with the energy of the incident electrons. Consequently, the diameter of the exposed area is at a minimum when the penetration depth is equal to the film thickness (positing the requirement that the entire thickness of the film be irradiated). Therefore, a means of obtaining improved resolution is by use of a thinner resist film, such as spin-cast organic polymer films or the Langmuir-Blodgett films described previously. However, ultra-thin organic film resists suffer from a number of problems that include film inhomogeneity (particularly pinholes) and the inability to withstand the vigorous plasma etching processes used to transfer the features of the resist to the underlying substrate.

Optical flood lithographic processes are the most widely employed because they offer the best combination of resolution and throughput. At the present time, the limit of resolution of microcircuitry features that can be produced on a scale practical for commercial production is on the order of one micron. Optical lithography generally involves patterned UV (sub-400 nm) irradiation of semiconductor substrates coated with a spin-cast organic resist film that is usually 300 nm to one micron thick. Principal limitations to attainment of higher resolution are due to a combination of the wavelength of light employed, the film composition, and thickness.

In optical lithography, it is known that resolution varies inversely with the wavelength of the irradiation. Therefore, high resolution is achieved by using radiation of the shortest possible wavelength to which the resist is sensitive. A number of light sources suitable for UV irradiation are available, including mercury lamps, xenon lamps, Nd-YAG lasers, excimer lasers, and fourth harmonic generation. Most of the high resolution photopolymeric resists that are now available are sensitive to near-UV (i.e., 320 to 400 nm) light. Few, if any photoresists are sensitive in the deep-UV (200 to 320 nm) or the vacuum-UV (below 200 nm) regions.

The wave length of ultraviolet radiation is in the 4 to 400 nm range. That range is loosely divided into near-UV (400 to 300 nm), far-UV (300 to 200 nm), and extreme-UV (below 200 nm). Extreme-UV radiation is strongly absorbed by air and therefore extreme-UV is usually used in evacuated apparatus. For that reason, extreme-UV is often refered to as "vacuum-UV".

As discussed above for beam techniques, the spin-coated resist films used in optical lithography must be at least several tenths of a micron thick to avoid pinholes and provide adequate resistance to plasma etching. Other limitations to resolution arise with the use of thick films due to defocussing of the image in the film, the occurrence of standing waves in the film, Rayleigh scattering from film inhomogeneities and from reduced control of the spatial extent of photoreactions. Spin coating tends to produce films that are thicker at the edges than in the center. Variations in the thickness of the film causes loss of resolution during contact mask exposure (i.e., where a patterned mask is in direct contact with the resist-coated substrate). Additionally, spin-coating machines are expensive and the substrates must be coated serially (i.e., one after the other).

Once patterned conventional optical resists generally require chemical development of the image (i.e., removal of the soluble resist material). Solvents employed in development, especially chlorinated hydrocarbons, are known to be environmentally hazardous. Resolution degradation is also induced during development by imperfect dissolution of the resist

Other difficulties encountered with known resist films include imperfect or weak adhesion to the substrate, which can render the piece of work useless if needed resist regions come loose from the substrate. Resist materials often require special care in handling due to their sensitivity to ambient light, moisture and temperature.

Fabrication of conductive paths on a semiconductor substrate can be accomplished in a number of ways Generally, a thin metal coating is applied by vapor or sputter deposition over the entire area of the substrate. Most of the metal is removed in a later step following patterning and development steps. No flood optical lithographic process currently exists whereby high resolution metal patterns can be selectively deposited.

OBJECTS OF THE INVENTION

In Relation To Semiconductor Microcircuitry

The principal object of the invention with respect to the technology of semiconductor microcircuitry is to provide an ultra-thin high resolution resist film that can be patterned by irradiation with an electron beam or by irradiation with light whose wavelength is less than the 320 or 400 nm wavelength of the conventionally employed near-UV light, that does not require chemical development, that is pinhole-free, that is strongly adherent to the semiconductor substrate, that is more tolerant of varying environmental conditions than conventional resists and that retains its integrity under conditions of long exposure (i.e. many minutes) to the reactive ion plasmas now used in fabricating semiconductor microcircuits. In short, the principal objective of the invention is to provide an ultra-thin high resolution resist that does not have the drawbacks associated with the high resolution resists heretofore used in the fabrication of semiconductor microcircuits.

Another object of the invention is to provide a method of making microcircuits using conventional electroless plating technology to produce high resolution patterns on semiconductor substrates.

A further object of the invention is to provide an ultra-thin high resolution, strongly adherent, etch-impervious, positive resist pattern on a semiconductor substrate.

Yet another object of the invention is to provide a method of making microcircuits using standard wet chemistry techniques that avoid the need for complicated or expensive equipment such as the vacuum systems employed in some of the microcircuit fabricating methods now in use.

Another object of the invention is to produce an ultra-thin high resolution resist that remains stable over a wide temperature range and is sufficiently tolerant of high humidity so that specialized atmospheric control equipment is not needed for the protection of the resist.

BACKGROUND OF THE INVENTION

In Relation To Printed Circuitry

In the fabrication of printed circuits, adherent metal patterns are produced on insulative substrates such as organic polymers (e.g., acrylonitrile-butadiene-styrene or polysulfone) and metal oxides (e.g., aluminum oxide). As in the case of semiconductor substrates, metal patterns are generally formed by vapor deposition fol-