Lightning and the Electron Microscope

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The chain of events that led to the invention of the electron microscope is an interesting story by itself. This chain has a common theme, namely electrons, and its first link is a natural phenomenon: lightning.

A flash of lightning generates a stream of electrons with a potential energy difference of 100 to 200 megavolts between clouds acting as electrodes. Benjamin Franklin envisioned this as a source of energy and tried to snatch electricity from the skies, but this proved to be too dangerous.

At the beginning of the century, lightning was a problem for electrical utilities because it produced surges that disrupted the steady flow of electricity along high tension lines. For this reason, in 1929 a high tension laboratory was founded in Germany with the sole aim of finding a way to test electrical transmission lines so as to make them capable of withstanding the lightning surges.

The first approach to the problem was to design equipment that could simulate the effect of lightning on transmission lines. The test equipment already existed: cathode ray oscillographs, the precursors to modern commercial oscilloscopes. The cathode ray oscillograph used a beam of electrons in a high voltage chamber, a set-up similar to an electrical transmission line being affected by lightning's high voltage. There was a difference when comparing lightning and transmission lines to oscillographs with their voltage and electron beam. The oscillograph could maintain a continuous high voltage on its electron beam, while lightning gives a series of voltage discharges on electrical lines lasting a fraction of a second each. The steady voltage in the oscillograph was more suitable for experimentation than a series of short voltage surges. In addition, the electron beam in the oscillograph could record any induced voltage disturbance affecting it by writing on a fluorescent screen.

Cathode ray oscillographs constitute the second link in the chain of events being followed here. The next step was to modify the oscillograph and its recording media in order to improve the resolution of the output signal recorded by the electron beam. The first modification was to pump the cathode tube chamber to a vacuum. The second modification was to improve the resolution of the electron beam by focusing it to a smaller spot.

Max Knoll and Ernst Ruska in the German high tension laboratory then turned to Hans Busch's theory developed in 1929. Busch's theory postulated that a current circulating in a coil wrapped around a magnet had the same effect on a collimated beam of electrons as a glass convex lens on a light beam. Busch had, in effect, postulated the electromagnetic lens and Ruska decided to apply it to focusing the electron beam in the oscillograph in order to optimize its recording resolution on the fluorescent screen.

The application of Busch's theory to the electron beam focusing in the oscillograph constitutes the third link in the chain of events that led to the invention of the electron microscope.

Since Busch postulated that the electromagnetic lens should behave like a convex lens in an optical microscope, Ruska speculated he could apply the theory both to focus the electron beam in the oscillograph to improve the recording of voltage effects on the electron beam, as well as for constructing a magnifying microscope. He designed an arrangement of two electromagnetic lenses that would be capable of focusing the electron beam and in addition giving a magnified image of an object placed in front of the first lens. He placed the lenses in the vacuum inside the oscillograph chamber. Thus Ruska obtained a focused electron beam as well as the first electron microscope. The first three micrographs recorded were from bronze and platinum mesh grids at x4.3, x17.4, and x13 magnifications[1].

The electromagnetic lenses are the fourth link in the chain of events that started with lightning and led to the invention of the electron microscope. ■

1. Martin M. Freundlich, "The History of The Development of The First High-Resolution Electron Microscope", MSA Bulletin, Vol.24, No.1 (1994).

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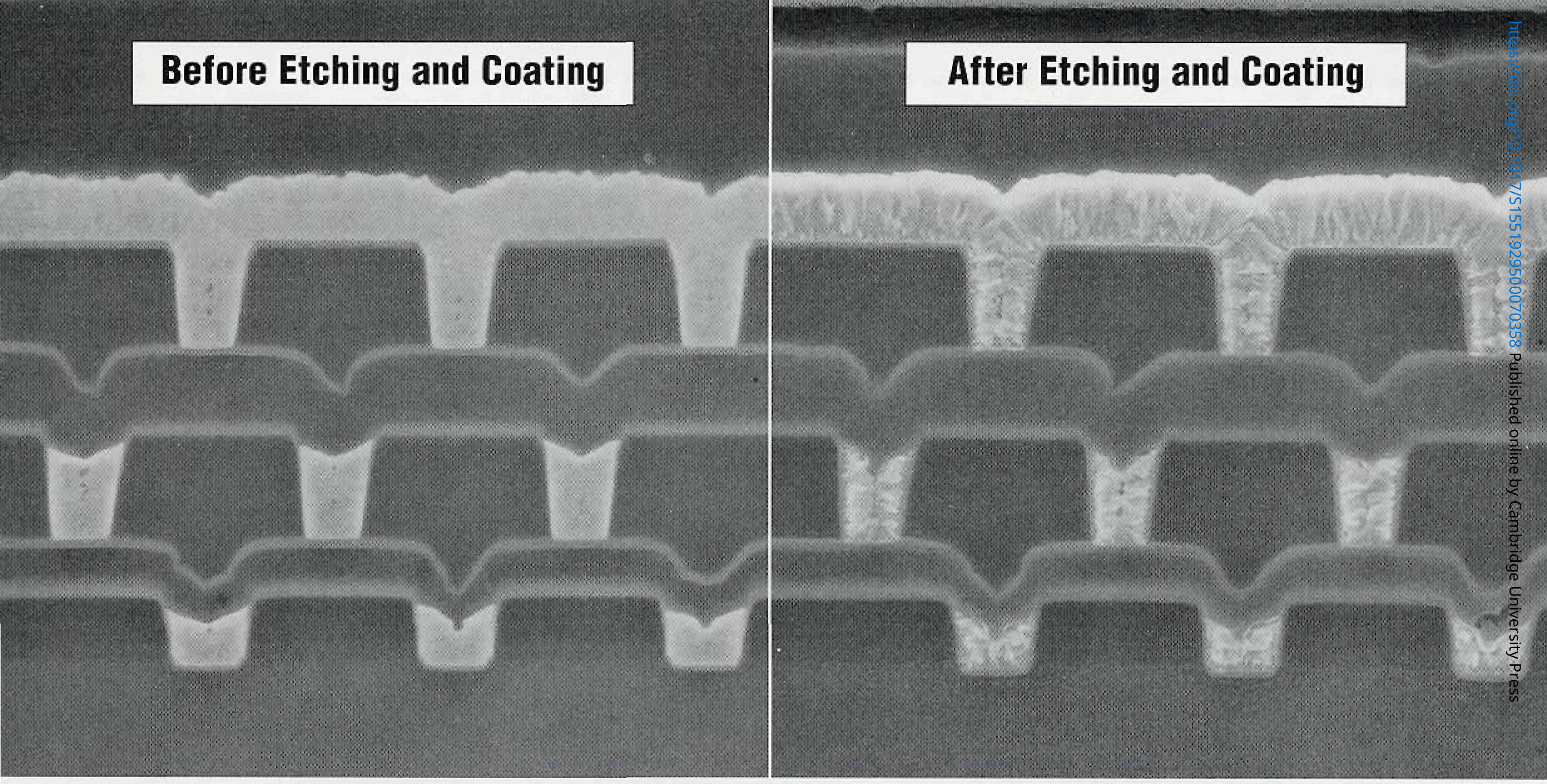

Before and after images showing the polished cross-sectional view of a typical semiconductor device. The sample was etched for 5 minutes at 6 kV and coated with Au/Pd. In the etched image, the detailed grain structure of the tungsten plugs are plainly visible.