United States Patent [19]

Varker

[11] 3,772,520

[45] Nov. 13, 1973

[54] METHOD FOR THE INVESTIGATION OF THIN FILMS ON A SEMICONDUCTOR SUBSTRATE IN A SCANNING ELECTRON MICROSCOPE

[75] Inventor: Charles J. Varker, Scottsdale, Ariz.

[73] Assignee: The United States of America as represented by the Secretary of the Air Force, Washington, D.C.

[22] Filed: Mar. 21, 1972

[21] Appl. No.: 236,595

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 716,659, March 27, 1968, abandoned.

[52] U.S. Cl. .... 250/307, 250/310, 250/311, 250/371, 324/54, 324/71 EB

[51] Int. Cl. H01j 37/26, G01n 23/22

[58] Field of Search .... 250/49.5 PE, 49.5 A, 250/49.5 R; 324/54, 71 EB

[56] References Cited

UNITED STATES PATENTS

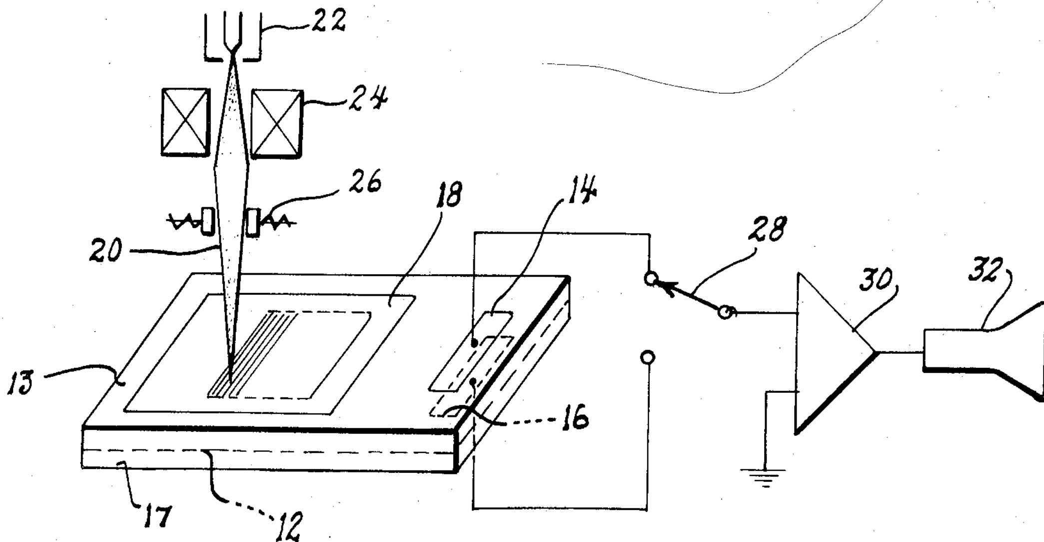
3,373,353 3/1968 Harris 324/54

Primary Examiner—William F. Lindquist
Attorney—Harry A. Herbert, Jr. et al.

[57] ABSTRACT

A method of investigating thin films where the film is mounted on semiconductor substrate containing a p-n junction and the film is scanned with an electron beam. The resulting current produced at the p-n junction by the penetrating electrons modulates the brightness of an associated display tube.

1 Claim, 3 Drawing Figures



PATENTED NOV 13 1973 3,772,520

FIG. 1

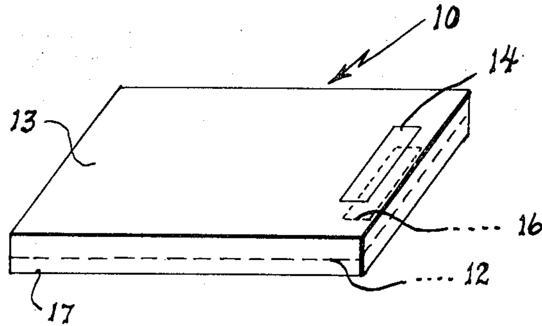
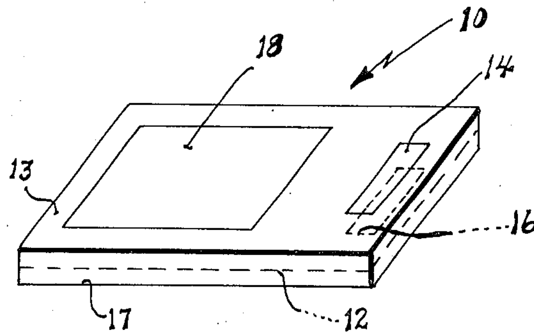


FIG. 2



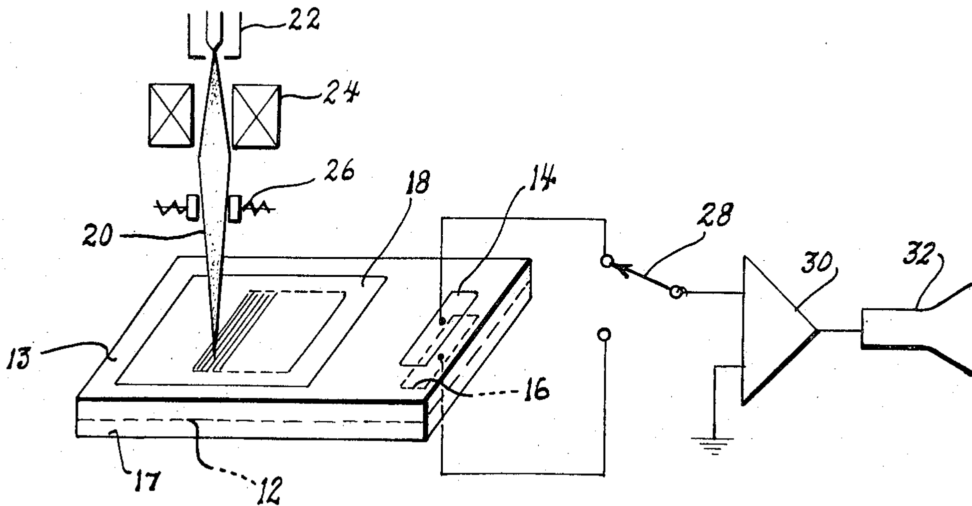


FIG. 3

INVENTOR.
CHARLES J. VARKER
BY Harry A. Herbert Jr
ATTORNEY
Henry S. Miller Jr.
AGENT

METHOD FOR THE INVESTIGATION OF THIN FILMS OR A SEMICONDUCTOR SUBSTRATE IN A SCANNING ELECTRON MICROSCOPE

CROSS-REFERENCE TO RELATED APPLICATION

The present patent application is a continuation-in-part of U.S. Patent application Ser. No. 716,659, filed Mar. 27, 1968 entitled "METHOD FOR THE INVESTIGATION OF THIN FILMS WITH HIGH RESOLUTION IN THE SCANNING ELECTRON MICROSCOPE" by Charles J. Varker and now abandoned.

BACKGROUND OF THE INVENTION

The investigation of organic and inorganic thin films in the electron microscope presents problems in sample preparation and handling which often requires specialized skills and techniques for mounting and handling prior to the actual investigation. Techniques presently employed, when electron transmission is utilized, often require the use of film stripping and surface replication methods in which the deposited films are grown on soluble substrates for ease of removal and subsequent transfer to a supporting structure for examination. The aforementioned method of sample preparation often introduces damage subsequent to the deposition and requires a high degree of manual dexterity in preparation.

Thin films grown on solid substrates can be examined in the scanning electron microscope by utilizing the secondary electrons emitted at the film surface. This technique is, however, highly inadequate when insulating thin films are investigated which introduce surface charging effects. Secondary electron emission techniques also require the use of an external secondary electron collector. The close proximity and large size of this collector imposes geometry considerations in the design of the microscope and often restricts the minimum target to lens spacing, thereby reducing the effective resolution of the instrument. A further disadvantage occurs when using large area target structures, in that there is a practical requirement that the target surface be inclined to the direction of the primary electron beam for the efficient collection of secondary electrons, resulting in a foreshortened image and increased target to lens spacing which will further reduce the instrument resolution.

SUMMARY OF THE INVENTION

This invention provides generally a method wherein thin films can be examined directly in a scanning electron microscope. More specifically, this invention utilizes electron beam induced currents generated at a p-n junction to examine thin films.

In the instant method a thin film is deposited directly onto the surface of a semiconductor substrate containing a p-n junction planar with that surface. The entire substrate is then transferred directly to the scanning electron microsope for the investigation without any additional preparation being required. In addition, another feature of this invention is to provide a method wherein thin films may be investigated simultaneously by an electron beam and visually wherein the surface illumination for auxiliary optical system can be utilized during the scan without affecting the video signal.

It is therefore an object of this invention to provide a new and improved method of investigating thin films with the electron microscope.

It is another object of this invention to provide a new and improved method of examining organic and inorganic thin films without using the special sample preparation techniques required heretofore.

It is a further object of this invention to provide a method and means of scanning thin films with the electron microscope which does not require the use of large secondary electron collectors.

It is still another object of this invention to provide a new and improved method of scanning with the electron microscope which provides higher resolution than heretofore known.

These and other advantages, features and objects of the invention will become more apparent from the following description taken in connection with the illustrative embodiment in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a semiconductor substrate with a p-n junction and electrical contact pad;

FIG. 2 is a perspective view of a semiconductor substrate having a thin film deposited thereon; and

FIG. 3 is a schematic of a system which may be utilized in the method of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1 there is generally shown a semiconductor substrate **10**. The substrate contains a planar p-n junction defined by the dashed line **12**. Located on the first surface **13** of the substrate is an electrical contact pad **14**. A second electrical contact pad **16** may be optionally located on the second surface **17** of the semiconductor substrate.

A thin film **18** is deposited on the substrate **10** and is arranged generally as shown in FIG. **2**. A variety of configurations are possible and it is to be understood that the configuration of the thin film in no way limits the scope of this invention. The thin film is deposited on the substrate by a method well known in the art and may be considered a conventional method. The thin film may be of a metallic or dielectric nature such as those used in microelectronics or any other thin film which can be placed on a semiconductor substrate and containing planar p-n junction. It is also seen where this method has the capability of being utilized for biological investigations of tissue sections without requiring thin sections and special preparation and handling techniques.

The system shown in FIG. **3** illustrates one way in which the method of this invention may be performed. After the film is deposited on the semiconductor substrate, it can be examined directly in situ in the electron microscope by utilizing the electron beam induced currents generated at the p-n junction as a result of electron-hole pair generation in the depletion layers adjacent the junction.

In a scanning electron microscope, an electron beam **20** is emitted from the electron gun **22** and focused by the lens **24** onto thin film **18**. A deflecting lens **26** is mounted above the film surface to deflect the beam **20** and effect scanning of the specimen surface. The scan of the specimen is synchronized with the scan in the CRT **32** by the scan syncronize circuit **27**. During the scan, as the beam shifts from one position to another, the primary beam of electrons **20** penetrating the film **18** will vary in both number and in energy resulting

from absorption and scattering mechanisms in the film. As a result of this, both the number and the energy of the electrons penetrating into the underlying semiconductor immediately under the focus spot will depend on the physical properties of the film at that point.

The signal induced by the penetrating electrons at the p-n junction **12** as a result of electron-hole pair generation is then detected at the electrical contact **14.** The current is then amplified by amplifier **30** and the resulting signal is fed into cathode ray tube **32** where it modulates the brightness of the display tube in a conventional manner.

The cathode ray tube being scanned in synchronism with the primary beam of the electron microscope will then provide complete information relative to the thin film. The video display will reveal the point by point fluctuation of this junction current and consequently will reveal the topography of the surface film in terms of electron penetration and energy dissipation in the layer.

One of the novel features included in this invention is that the substrate containing the film constitutes an integrated structure which functions as the substrate for the deposition and mechanical support for the film and also comprises the electron collector and information signal source during the scanning.

In addition, another feature of this invention is to provide a method wherein thin films may be investigated simultaneously by an electron beam and visually wherein the surface illumination for auxiliary optical systems can be utilized during the scan without affecting the video signal.

Although the invention has been described with reference to a particular embodiment, it will be understood to those skilled in the art that the invention is capable of a variety of alternative embodiments with the spirit and scope of the appended claim.

I claim:

1. A process for investigating thin conductive and insulating films deposited on the surface of a semiconductor substrate containing a planar p-n junction parallel with the surface, comprising the steps of; depositing a thin film on said surface of the substrate; affixing an electrical contact to said surface of the substrate; placing the substrate in a scanning electron microscope; connecting the electrical contact to the intensity control circuit of a cathode ray tube; bombarding the film with an electron beam to cause an electric current to be generated at the p-n junction; imparting a sweeping motion to the electron beam while causing a synchronous sweeping motion in the beam of the cathode ray tube; and modulating the intensity of the cathode ray beam with the current generated at the p-n junction in the semi-conductor substrate and identifying irregularities in the film according to intensity and location of the cathode ray beam on the screen of the cathode ray tube.

* * * * *