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SPECIFICATION

AN ARTEFACT-FREE SCANNING TECHNIQUE FOR CHARGING SAMPLES IN CHARGED PARTICLE BEAM SCANNING APPARATUS

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AN ARTIFACT-FREE SCANNING TECHNIQUE FOR CHARGING SAMPLES IN CHARGED PARTICLE BEAM SCANNING APPARATUS

FIELD OF THE INVENTION

The invention relates to a new scanning technique for the charged particle beam scanning apparatus which significantly reduces the occurrence of specimen charging. The invention utilizes modulation of the charged particle beam. The invention also employs variable scanning patterns for the charged particle beam in order to reduce charging artifacts caused by prior charge deposited on the specimen being analyzed. The invention performs analysis of specimen signal data to detect the onset of specimen charging. The implementation involves computer-based scanning software which controls the operation of the system hardware. The hardware consists of a charged particle beam modulator, scanning elements and signal acquisition and processing unit. The software incorporates adaptive algorithms to vary the scanning parameters in order to reduce charging artifacts.

BACKGROUND OF THE INVENTION

Charged particle beam-based apparatus have greatly revolutionized the study of microscopic matter. These apparatus offer very high resolution of up to 500,000X compared to optical-based units, which only give magnifications of up to 2000X. To date, such apparatus have been extensively used in the areas of semiconductor failure analysis and biological research. These devices operate by scanning the particle beam over the specimen in a raster pattern in order to

build up an image of the specimen under view. The charged particle beam apparatus require that the specimen be placed in a vacuum chamber during the scanning process in order to avoid scattering of the particle beam by air molecules. In addition, the charge profile on the sample as it is irradiated by the particle beam must remain constant in order to obtain a consistent and reliable information. Any artifact caused by variations of this charge profile in time on the specimen information obtained is given the generic term "charging."

Control of this charging phenomena has been commonly achieved by conductor-coating the specimen. This method essentially prevents charge build-up by providing an escape path for excess charges. Other methods include using a lower vacuum (European Patent 0,324,213), spraying the specimen with neutralizing charges of the opposite polarity (US Patent 3,919,553) and using particle beams at low energies. These methods have significant drawbacks. The first method (conductor-coating) reduces charging considerably but possesses the disadvantage of being destructive to the specimen. Moreover, certain analysis techniques cannot subsequently be used on specimens that have been coated. Conductor coating is also not compatible with semiconductor metrology applications. The second method provides charging-reduction via charge-compensation from the low vacuum. However, resolution is severely reduced by the poorer vacuum, and magnifications in excess of 10,000X are difficult to obtain. The third method usually contaminates the sample due to the formation of foreign substances as a result of the neutralization process. The fourth method is dependent upon the emission characteristics of the material which restricts its application in many cases. Furthermore, low energy methods require the use of higher brightness sources of charged particles to maintain image quality which in turn involves higher cost.

DISCLOSURE OF THE INVENTION

It is the object of the invention to produce a technique that addresses the problems discussed above. In this invention, charging control is achieved by controlling the amount, the placement as well as the time for successive doses of the charge for a given pixel. Reducing the amount of charge used while maximizing the signal derived from the dose is the principle at work at the front-end of the invention, i.e. at the point or pixel level. Selective deposition of the charge based on the charging behavior of the sample is used at the frame data level. Variable scanning patterns are utilized that are derived based on real-time analysis of the sample signal, as opposed to static raster scan and continuous irradiation of conventional techniques. This has resulted in the development of a technique consisting of the following main features: (i) a beam modulator for controlling and minimizing the charge dose, (ii) a noise control processor for Signal-to-Noise

(S/N) ratio maximization, (iii) variable scanning based on the detection of charging, and (iv) all digital control, processing and information output.

SUMMARY OF INVENTION

The invention is a novel method for controlling charging artifacts in charged particle apparatus. This results in the capability to analyze specimens with little or no specimen pre-processing such as decapsulation of IC packages or conductor-coating. Hence, analysis can be performed without significantly altering the fundamental state of the specimen.

Briefly, a beam modulator and scanning element are used to control the amount and location of the charge dose. A noise control processor is used to maximize the signal collected. The control and data acquisition is performed by a computer which is linked to the apparatus electronics. The scanning pattern is varied upon detection of charging. Dosage is reduced for areas of the sample that exhibit relatively more charging artifacts. Time intervals between dosages are also modified for severely charging areas. Distances between consecutive irradiated points are also varied to reduce particle beam deflection artifacts for severely charging areas of the specimen.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

Fig. 1 describes the main components of a typical charged particle beam scanning apparatus. There exists a source of charged particle 1. Deflection of the primary particle beam 2 is achieved by the scanning elements 3. The particle beam is conditioned by the lens arrangement 4 before it impinges on the specimen 5. In this invention, an additional component, the beam modulator 6 is used to provide control of the charged particle beam.

Fig. 2 describes the main components of the new invention. 11 shows the charged particle apparatus' main housing. The beam modulator driver 12 generates the signals for modulating the particle beam via a beam modulator 13. Manipulation of the beam position is performed by the scanning element 14 which are driven by the scan generator 15. The resultant analog signals from the specimen are enhanced by the noise control processor 16 which is connected to a computer 17. The entire sequencing of these processes is performed by the scanning algorithm 18 running on the computer. The desired specimen information is displayed on the output device 19.

Fig. 3 shows the scanning grid that is used in the scanning algorithm. The specimen is divided into a grid of X_{res} in the horizontal direction and Y_{res} in the vertical direction. Each square represents a pixel which a set of parameters are stored to characterize the pixel's charging properties.

Fig. 4 depicts the scanning algorithm used in the invention. In this algorithm, the scanning mode is initialized 31 at the start. The sample is then scanned 32. The sample being scanned is continually analyzed for charging 33. If charging is detected, the scanning parameters are modified accordingly 34 and scanning proceeds on. With this algorithm, the particle beam will scan in a manner that will minimize charging of the specimen.

CLAIMS

What is claimed is:



1. Scanning beam apparatus adapted to control charging artifacts, whereby the amount and location of the charged particles deposited varies according to the charging properties of the specimen, comprising a beam modulator, scanning element, noise control processor, data storage and algorithms for overall system control and data analysis and data processing running on a computer.
2. Scanning beam apparatus as set forth in claim 1 wherein control of charging artifacts is achieved through digital control of the scanning apparatus, from the modulation of the charged particle beam, the position of the charged particle beam, the processing of the specimen information obtained, display of the specimen information collected and performed under control of the software residing on the computer.
3. Scanning beam apparatus as set forth in claim 1 wherein control of the amount of the charged particles is achieved by the use of a beam modulator or similar thereof, and the modulation of charged particles involves controlling the width, intensity as well as the shape of the pulse.
4. Scanning beam apparatus as set forth in claim 1 wherein control of the location of the charged particle beam is achieved by controlling the scanning signal applied to the scanning elements.



5. Scanning beam apparatus as set forth in claim 1 wherein the specimen information is processed by the noise control processor to maximize the information content while reducing the effects of noise and other interference, so as to enable further reduction in charging artifacts through minimal use of charged particle during exposure.
6. Scanning beam apparatus as set forth in claim 1 wherein specimen data is stored in digital form in the computer to facilitate analysis of the specimen for the presence of charging.
7. A system for charging artifact-free operation wherein the nature of the scanning varies according to the charging artifacts exhibited by the specimen, and where the scanning pattern varies in time and space, said variation being stored in the form of a scanning look-up table which is used by the algorithm running on the computer, and said scanning table containing information describing the charging properties of the specimen in time and space.
8. A system as set forth in claim 7 wherein scanning occurs in a variable manner where selective charge deposition occurs depending on the charging attribute of the current pixel, with consecutive pixels being modified to reduce particle beam artifacts caused by previous pixels.
9. A method of charging detection of the specimen at both frame and pixel data level, using analysis of the information contained in the multiple frame-store, in which absolute and relative analysis of the frames stored are performed.
10. A method of charging analysis as set forth in claim 9 wherein analysis of the frames stored are performed using the amplitude and spectral information of the frames, the source of the amplitude information being any time and frequency domain analysis and computation method.
11. Scanning beam apparatus adapted to control charging artifacts as well as facilitate studies in the properties and mechanisms of charging in such a manner that all fundamental functions and operations of the scanning apparatus resides under programmed control and can be altered by the operator, said programmed control being achieved by the use of analog as well as digital means with the use of third party parts and devices of electrical as well as mechanical nature.