Hitachi S-6000 Field Emission CD-Measurement SEM

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ABSTRACT

We have developed the Model S-6000 for critical dimension measurement of circuit patterns on VLSI wafers utilizing a filed emission electron source. This instrument has been designed to handle up to a 6" wafer. Measurements are made under low voltage operation, at a high resolving power and at a flicker-free TV-scan rate. Minimum dose feature protects the wafer under measurement from electron beam damage. The S-6000 is a state-of-the-art CD measurement SEM for quality control of in-process wafers.

INTRODUCTION

Recently, integrated circuit technology has made significant advancements through higher integration and density. Micro-electronis circuit pattern requirements have moved into the sub-micron rules of 1.2 to 0.8μm in the 1M to 4M bit DRAMs from 2 μm rules in 256K bit DRAMs; thereby exceeding the limits of conventional light microscope techniques.

Hence, the use of SEMs, which have a small beam diameter of 15nm or less, have become a necessity in the I.C. industry. They are in wide use in R & D, process evaluation and quality control.

The S-6000 has been designed primarily for use in inline wafer processing. Design considerations have addressed the following points:

1. High accuracy/High sample throughput
2. Non-destructive to the in-process wafer
3. Direct high resolution/High speed imaging of uncoated samples
4. Full area coverage of 6" wafers
5. Easy operation and maintenance, high reliability
6. Minimum particle generation in the system
7. Installation in clean room/Fab areas (compact size, anti-vibration)
8. Reproducibility/Stability

CONSTRUCTION & FEATURES OF CD-MEASUREMENT SEM

Fig. 1 is a general view of the S-6000 CD measurement SEM with a field emission electron source. Fig. 2 shows the system construction.

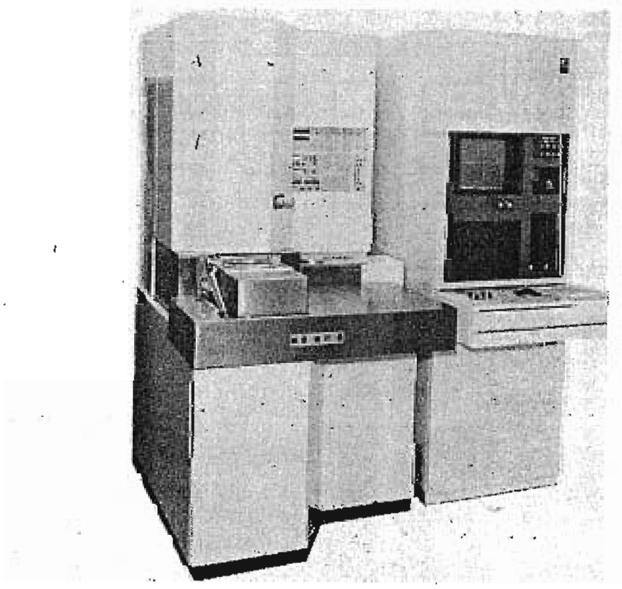


Figure 1. Hitachi S-6000
CD-Measurement SEM

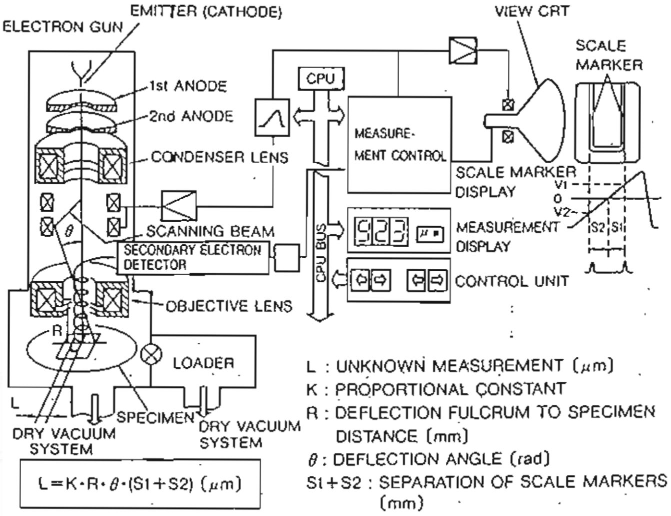


Figure 2. System construction of
CD-measurement SEM

High resolution image at a low kV operation

Most VLSI circuits are made of such insulating materials as SiO_2, Si_3N_4, and photo resist. These materials, when examined by electron beam, exhibit charging artifacts which prohibit proper imaging and measurements. In order to resolve this problem, a low accelerating voltages (at about 1KV) is employed. It improves the secondary electron emission from the specimen, thereby reducing charging. In the past, imaging resolution has been poor at low accelecrating voltage. This characteristic is common to thermionic electron sources such as tungsten hairpin and LaB_6 filaments. These sources generate large energy spread (1 to 2eV) of emitted electrons.

The filed emission electron source utilizes a small energy spread of about 0.2eV, which results in small chromatic aberrations and high imaging resolution. Fig. 3 illustrates the relation of the attainable imaging resolution and accelerating voltage.

The filed emission electron source has a source brightness of about 100 to 1,000 times[1] that of thermionic source. Another advantage of the filed emission source is a long operating lifetime, which reduces maintenance time considerably. The high source brightness is instrumental in achieving high resolution image at a rapid TV-scan rate therefore permitting a flicker-free image on the CRT screen. This facilitates high sample throughput with convenient imaging and measurements. The filed emission electron source is an ideal electron source for a process evaluation SEM which requires prolonged continuous operation.

Specimen protection by minimum dose system

Under an electron beam irradiation in a SEM, semiconductor devices can be damaged during the examination.[2] This damage increases, at higher accelerating voltages and at higher dose rates. We have developed a minimum dose system (MDS) as shown in Fig. 4. It permits both imaging and measurement with a minimum electron dose rate (beam current x irradiation time (sec)).
Only during field selection (after the stage movement) and image memory the electron beam requires to be on the specimen a short permits of time. To achieve this, the electron beam is automatically blanked off during measurement and stage movement.

The measurement is done by using a frame memory image. This is an image processing system which permits quality images (S/N improvement) with a small electron beam dose.

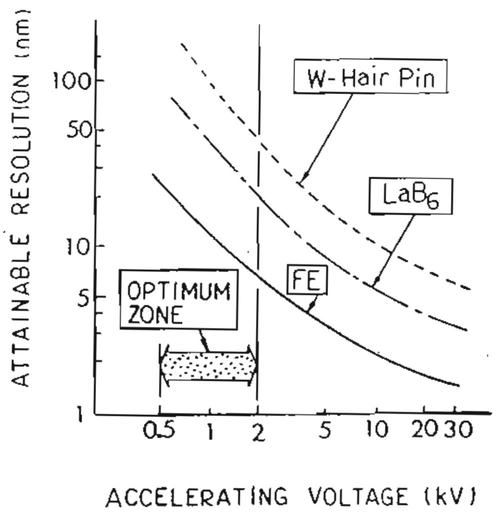


Figure 3. Attainable resolution at various operaling voltages

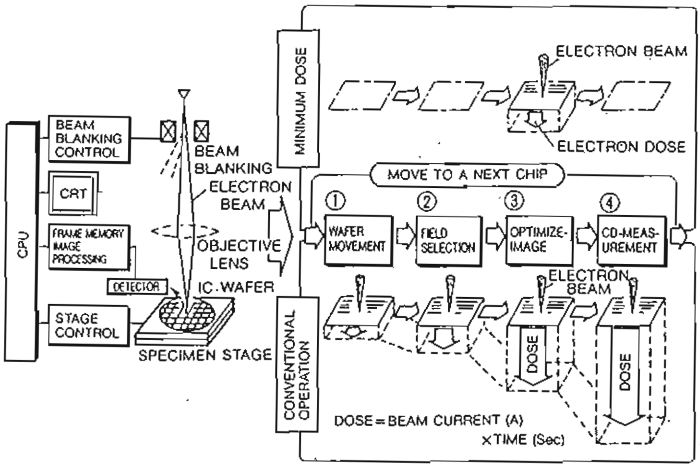


Figure 4. Minimum dose system (MDS)

Protection against particle generation and dry vacuum system

Foreign particle size considered "troublesome" in the process line is becoming smaller and smaller as VLSI fabrication technology advances. It is generally recognized that foreign particles of 1/5 to 1/10 of the wafer design rules have to be eliminated. Due to this consideration, we have employed roller mechanisms for wafer transport, wafer stage etc. in the S-6000. The vacuum system is composed of ion pumps for the electron gun and the associated electron optical system, and turbo-molecular pumps for the specimen chamber and the loader. Air leak/vent for the wafer exchange chamber is a two stage programmed leak design thus minimizing air turbulence and particle generation in the system. Particle generation tests produced results of 2pcs/5 inch wafer/0.5um diameter or greater particle.

MEASUREMENT AND EXAMPLES

Fig. 5 is the CD measurement procedure. This series of operation from input of measurement conditions to measurement, measured data processing and data print-out are all computer controlled and processed. Various settings of operating conditions are via CRT display and operator interaction. Fig. 6 is an example of measurement condition. The CRT displays wafer chip arrangement and specified chips for measurement. Stage movements and measurements are sequentially performed.

For the CD measurement of a wafer, there are two operating modes:

1. Cursor controlled type - in which operator aligns cursor to the object on CRT screen at a high magnification. The separation of the two cursors are computed terms of beam deflection, which yields the measurement.
2. Line profile type - in which line profile of a secondary electron signal is precessed and measurement is derived from a waveform. Fig. 7 is an example of automated measurement by line profile mode.

It shows a clear/sharp TV-scan image at a few ten thousand times and measurement is accurately and rapidly available from a frame memory image. From the shape or outlook of the pattern, it is possible to inspect the wafer.

Fig. 8 is an example of the measurement data printout. The printout data shows measurement conditions (date, wafer no., lot no., etc.), measurement (individual measurement, maximum, minimum, average, 3σ, etc.) under a measurement of 5 chips/wafer and 1 point/chip, we have achieved a throughput of 5 to 8 wafers/hour with a reproducibility of ±0.02um or better.

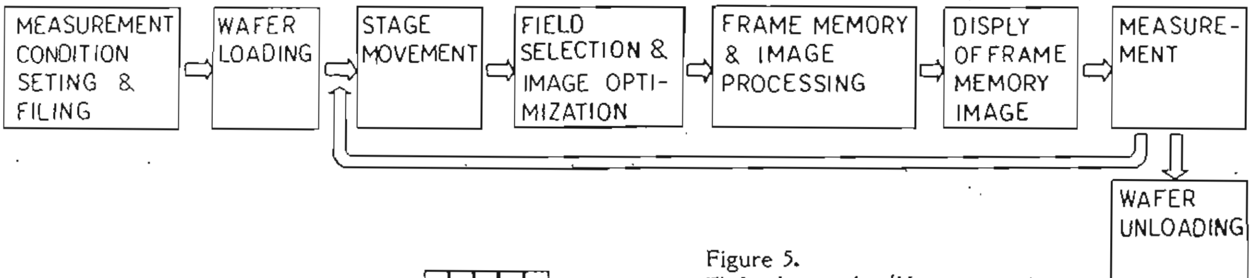
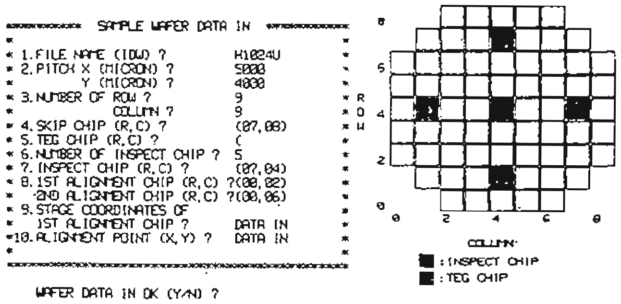


Figure 5.
Wafer inspection/Measurement procedure



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************  SAMPLE WAFER DATA IN  ************
*                                              *
* 1.FILE NAME (IDW) ?            H1024U        *
* 2.PITCH X (MICRON) ?           5000          *
*         Y (MICRON) ?           4000          *
* 3.NUMBER OF ROW ?              9             *
*             COLUMN ?           9             *
* 4.SKIP CHIP (R,C) ?            (07,08)       *
* 5.TEG CHIP (R,C) ?             (             *
* 6.NUMBER OF INSPECT CHIP ?     5             *
* 7.INSPECT CHIP (R,C) ?         (07,04)       *
* 8.1ST ALIGNMENT CHIP (R,C) ?(00,02)          *
*   2ND ALIGNMENT CHIP (R,C) ?(00,06)          *
* 9.STAGE COORDINATES OF                       *
*   1ST ALIGNMENT CHIP ?         DATA IN       *
*10.ALIGNMENT POINT (X,Y) ?      DATA IN       *
*                                              *
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   WAFER DATA IN OK (Y/N) ?
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Figure 6. Input of measurement condition

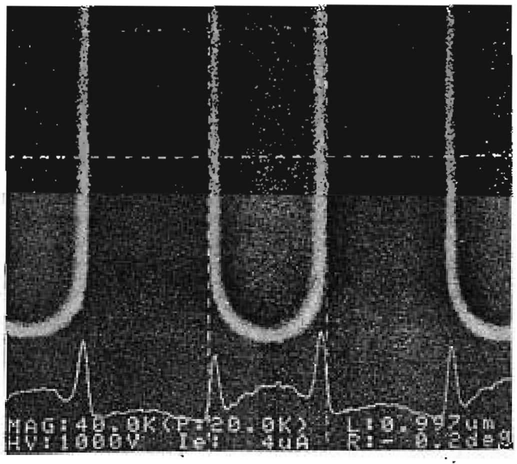
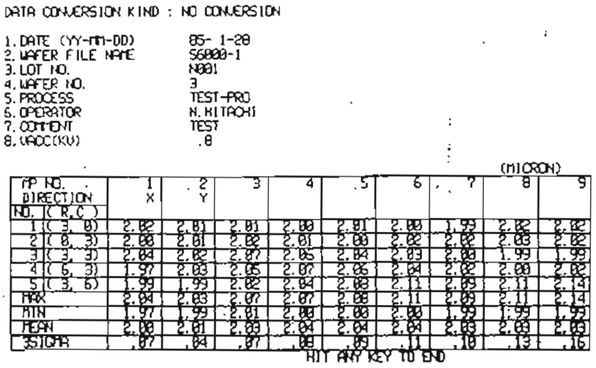


Figure 7. Example of CD-measurement
(Specimen: Resist on Si_3N_4)



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DATA CONVERSION KIND : NO CONVERSION

1.DATE (YY-MM-DD)         85- 1-28
2.WAFER FILE NAME         S6000-1
3.LOT NO.                 N001
4.WAFER NO.               3
5.PROCESS                 TEST-PRO
6.OPERATOR                N.HITACHI
7.COMMENT                 TEST
8.VACC(KV)                 .8
                                                                     (MICRON)
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MP NO. DIRECTION NO. (R,C)	1 X	2 Y	3	4	5	6	7	8	9
1 (3, 0)	2.02	2.01	2.01	2.00	2.01	2.00	1.99	2.02	2.02
2 (0, 3)	2.00	2.01	2.02	2.01	2.00	2.02	2.02	2.03	2.02
3 (3, 3)	2.04	2.02	2.07	2.05	2.04	2.03	2.00	1.99	1.99
4 (6, 3)	1.97	2.03	2.05	2.07	2.06	2.04	2.02	2.00	2.02
5 (3, 6)	1.99	1.99	2.02	2.04	2.08	2.11	2.09	2.11	2.14
MAX	2.04	2.03	2.07	2.07	2.08	2.11	2.09	2.11	2.14
MIN	1.97	1.99	2.01	2.00	2.00	2.00	1.99	1.99	1.99
MEAN	2.00	2.01	2.03	2.04	2.04	2.04	2.03	2.03	2.03
3SIGMA	.07	.04	.07	.08	.09	.11	.10	.13	.16

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                              HIT ANY KEY TO END
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Figure 8. Example of data printout

CONCLUSION

We have completed development of a dedicated line width measurement SEM with a field emission electron source which permits high resolution imaging of 15nm at 1KV at a rapid TV-scan rate. It allows a high accuracy CD measurement. It achieved a sample through of 5 to 8 wafers/hour under a measurement of 5 chips/wafer and 1 point/chip and a measurement reproducibility of ±0.02um or ±1% (0.1 to 200um).

ACKNOWLEDGEMENT

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REFERENCES

1. T. Komoda, S. Saito, Scanning Electron Microscopy/1972 (part 1), P. 129.
2. N. Hashimoto, H. Todokoro, S. Fukuhara, K. Senoo, Proceeding of the 13th Comference on Solid State Devices, Tokyo, 1981;Japanese Journal of Applied physics, VoL. 21 (1982), P. 199~203