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Communications Research Centre

National Space Telecommunications Laboratory

FAILURE ANALYSIS GROUP

DEVICE AND MATERIALS ANALYSIS FOR CANADIAN INDUSTRY

DEPARTMENT OF COMMUNICATIONS
MINISTÈRE DES COMMUNICATIONS

CRC SERIAL DOCUMENT 03 – NSTL – 15 – 0

CANADA

COMMUNICATIONS RESEARCH CENTRE

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Published September 1970
OTTAWA

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Background

During 1969, a group of physicists were engaged by the Communications Research Centre to set up a materials analysis and device diagnostics facility, with particular emphasis on the physics of device failure. The group has now been in operation for more than a year, working at first in two general areas:

1. Research and development on problems related to device physics and materials analysis.
2. Analysis of the failure mechanisms in devices intended for use in the Canadian space satellite programmes.

And more recently in a third area:

3. Device and materials analysis for Canadian industry. This is done on a cost recoverable basis.

Consulting and Analysis for Industry

The research experience of the scientists and technicians in the Failure Analysis group covers most aspects of solid state physics, and the device diagnostic work on satellite problems has produced a broad range of expertise in materials and device analysis, as well as experience in interpreting analysis results. This expertise is being made available to interested industrial laboratories on a cost recoverable basis.

The materials analysis and device diagnostics is centered around scanning electron beam techniques. At present most of the work is being done on a Cambridge Instrument Scanning Electron Microscope (SEM) using a variety of detection modes.

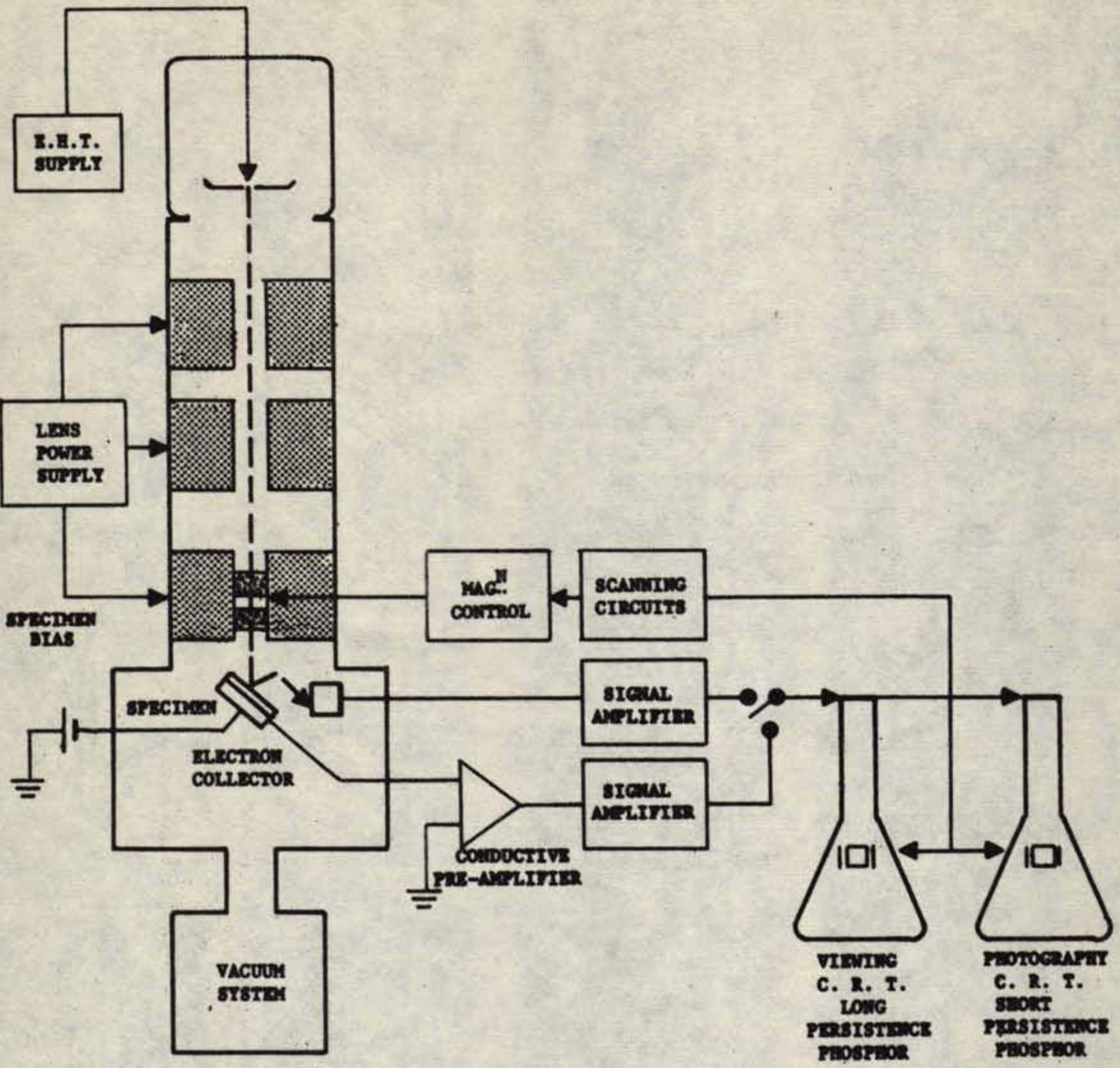
A second SEM and an electron beam microprobe will be in operation in late 1970, and a third SEM around the first of the year. The group also has additional equipment to supplement the electron beam instruments or to provide analysis not obtainable from them.

Analysis and test instruments which are in operation, or are being acquired, are listed below:

1. Cambridge Instruments Scanning Electron Microscope (SEM).
2. Materials Analysis Corp., SEM and electron microprobe (in operation late 1970).
3. Research prototype SEM, CRC design (in operation early 1971).
4. Barnes RM2A Infrared microscope.
5. Faxitron Model 804 Radiographic Inspection Unit.
6. Birtcher IC tester Model 800.
7. Bond pull-strength tester.
8. Temperature test chamber.
9. Device test area for standard V-I, C-V, and pulse measurements.
10. Tektronix curve tracers and oscilloscopes.
11. Optical microscopes, clean benches, electronic recording and test instruments.

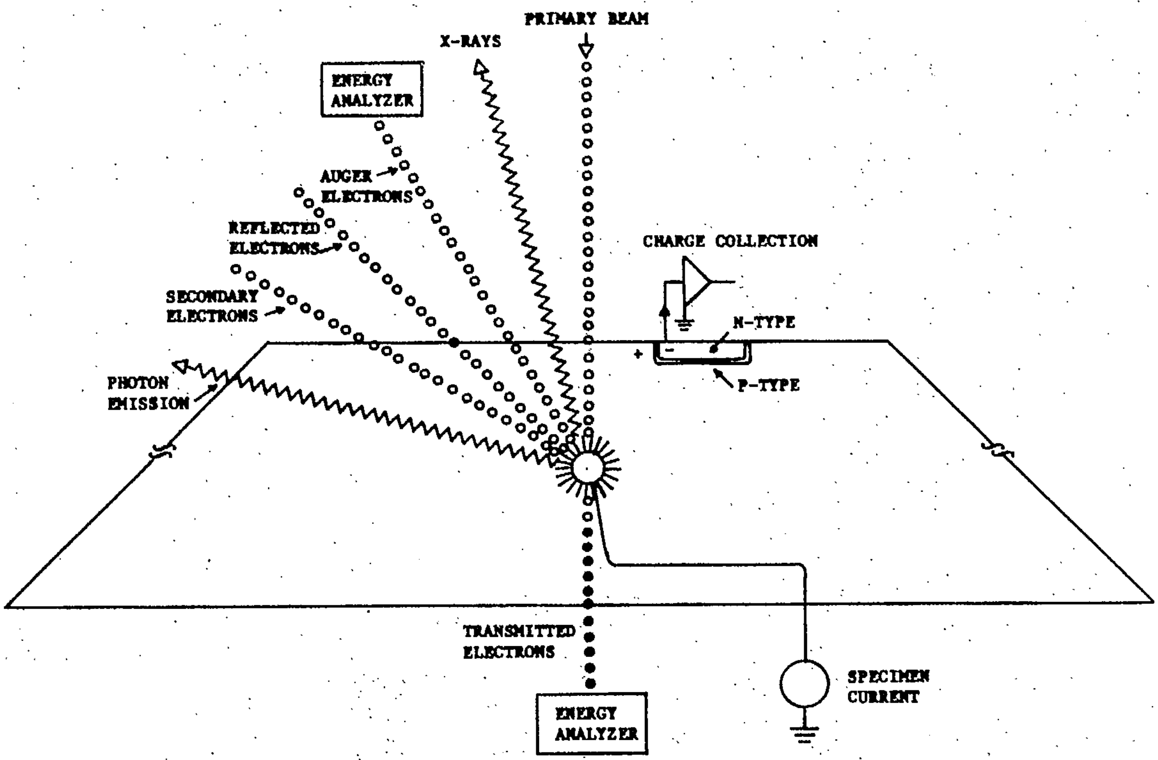
With this equipment, most of the test procedures of MIL-STD-883 can be performed, the exceptions being tests concerned with vibration, shock and humidity.

Photographs and specifications of the major instruments are shown on the following pages, along with a brief description of operating principles, and some typical analysis results.



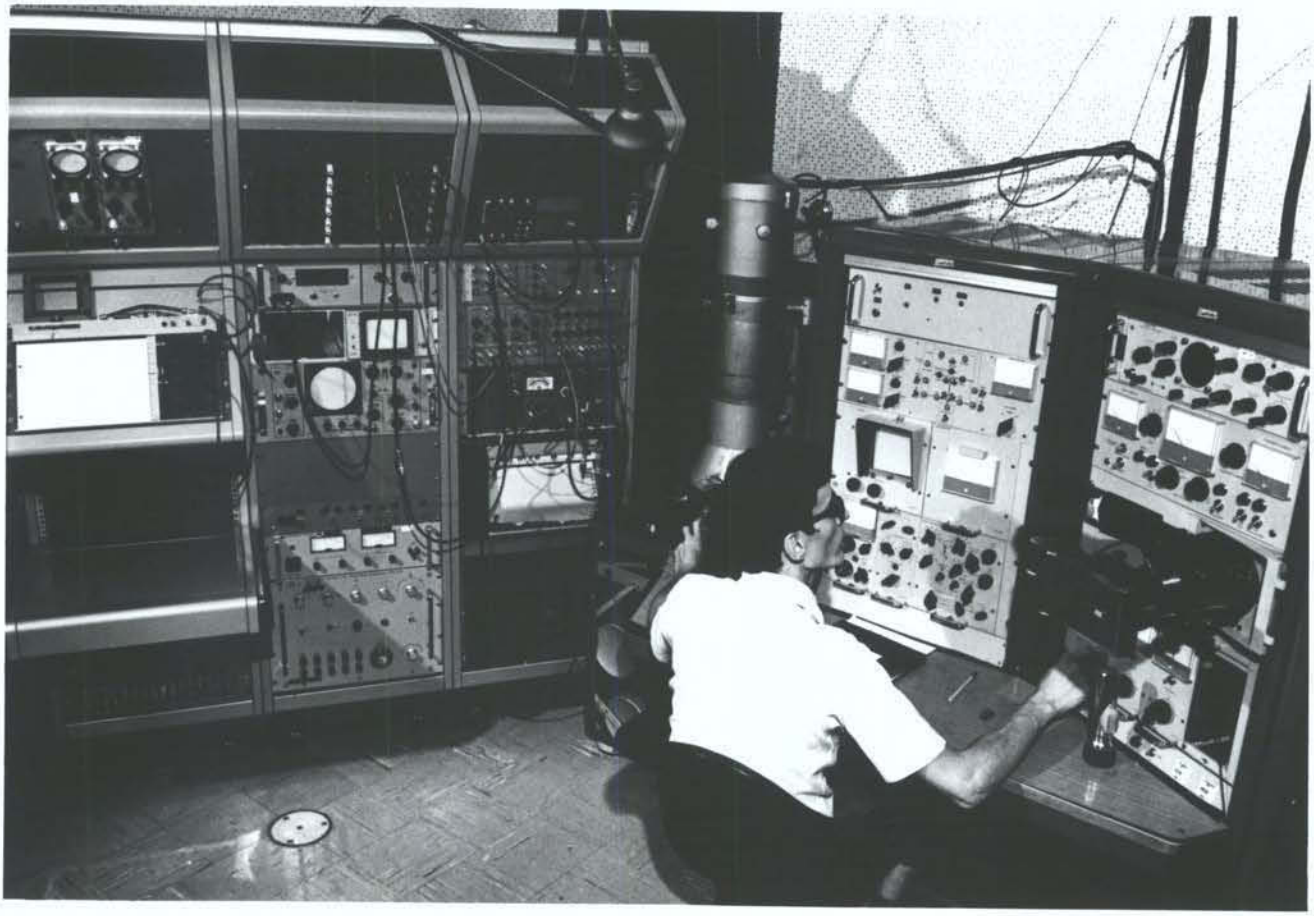
SCANNING ELECTRON MICROSCOPE

Electrons from a point source are accelerated by the EHT supply through three focussing lenses, and are incident on the specimen. Typical electron spot diameters are 200Å. The electron spot is scanned in a raster over the specimen, initiating a variety of physical processes which can be used as detection and display modes, (see next page). The signal from the specimen, secondary electron current for example, is amplified and used to intensity modulate the viewing CRT to produce a micrograph of the specimen. Magnifications from 20X to greater than 100,000X are possible. Because of the small divergence angle of the electron beam (about 10 milliradians) the SEM has a very large depth of focus. This is illustrated in the device micrographs on the following pages.



INTERACTION OF AN ELECTRON BEAM WITH A SOLID, SHOWING POSSIBLE S.E.M. DETECTION MODES.

Electrons incident on a solid can interact in the ways shown above, and these interactions can be used as detection modes to produce a SEM micrograph. The modes give different pictures and complementary information. The CRC instruments can operate in the following modes: secondary electrons, primary electrons, conductive, and cathodoluminescent. X-ray detection mode (micro-probe analysis) is nearing completion and an Auger detector is under construction.



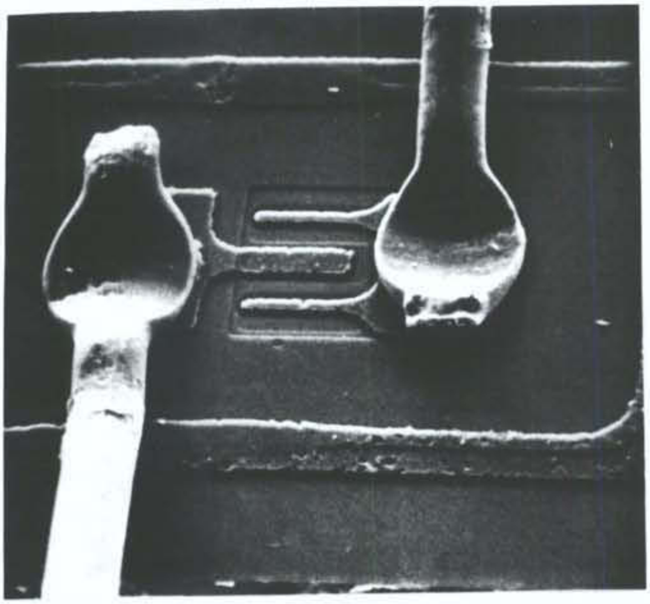
CAMBRIDGE INSTRUMENT CO., STEREOSCAN SEM

Basic Specifications:

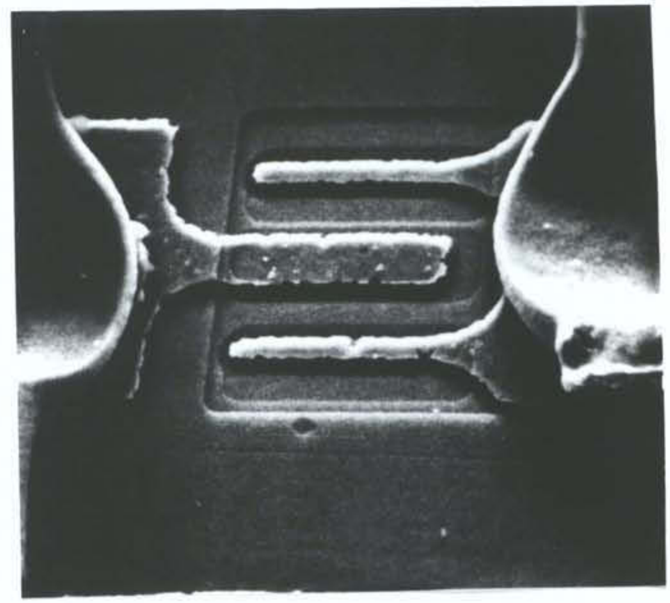
Magnification	-	20X to 100,000X
Accelerating Voltage	-	2 - 20 kV
Electron Spot Size	-	200Å or better
Vacuum	-	oil pumped, 10^{-5} torr

Detection Modes:

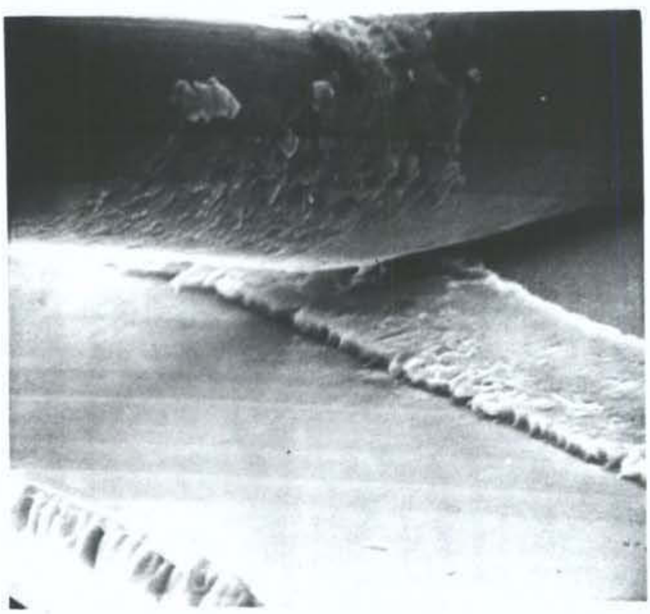
(a) emissive, secondary electrons
(b) emissive, reflected primary electron
(c) conductive, using junction charge collection current
(d) cathodoluminescent, using electron induced light output



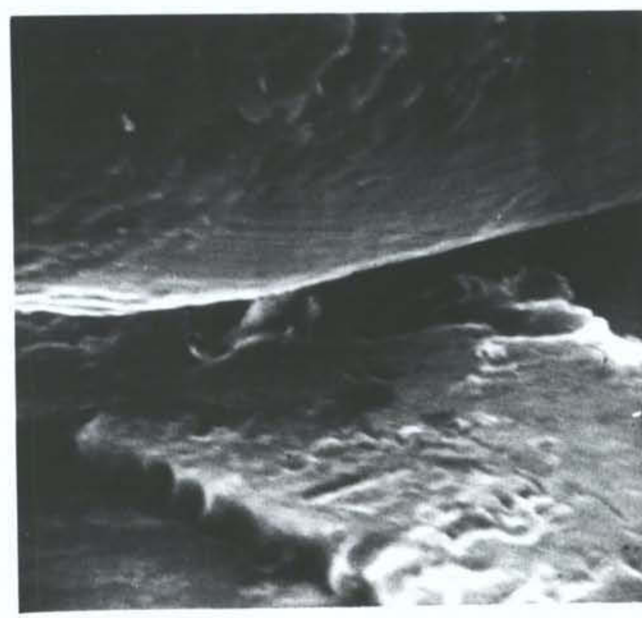
(A) X500 20µ



(B) X1000 10µ



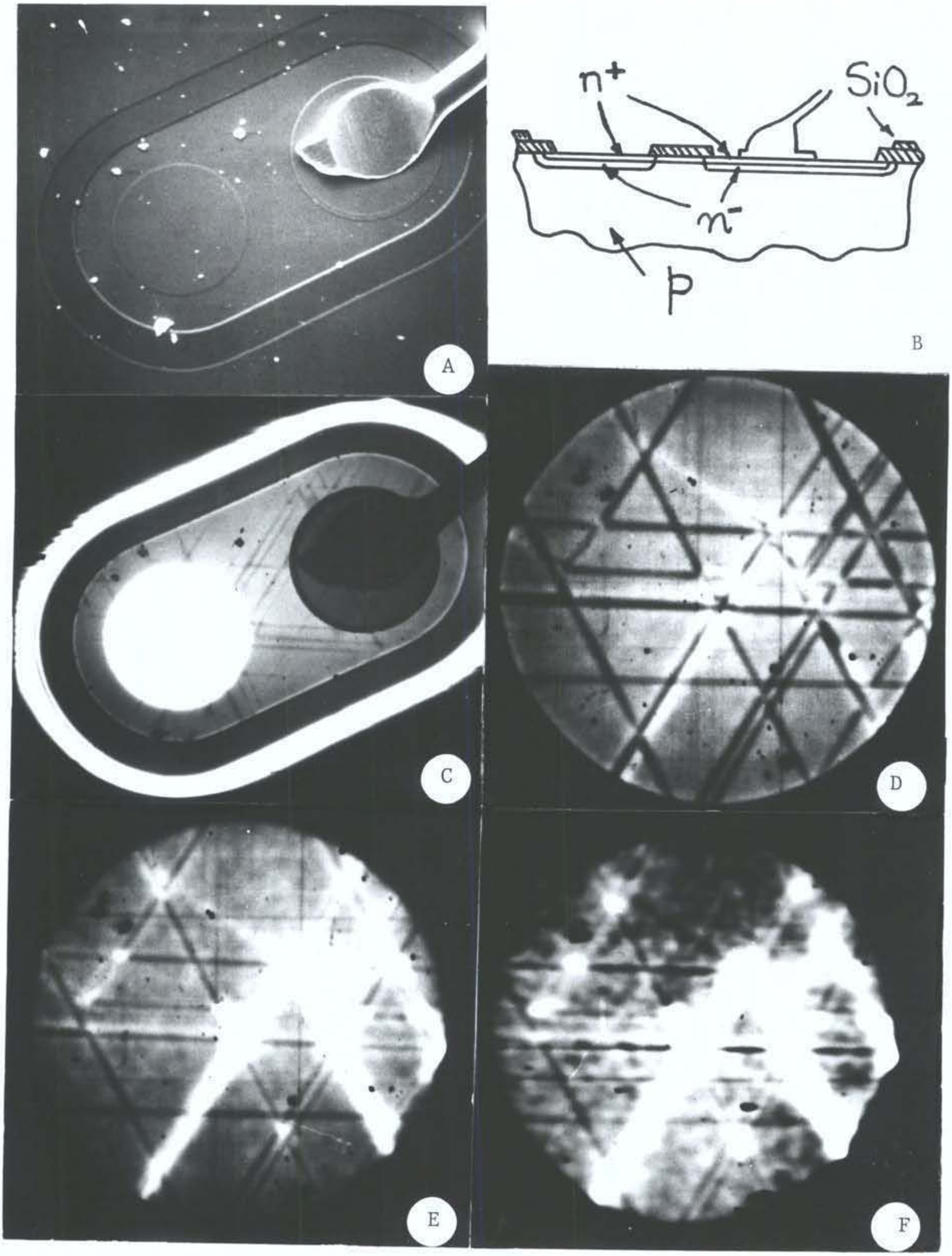
(C) X2000 5µ



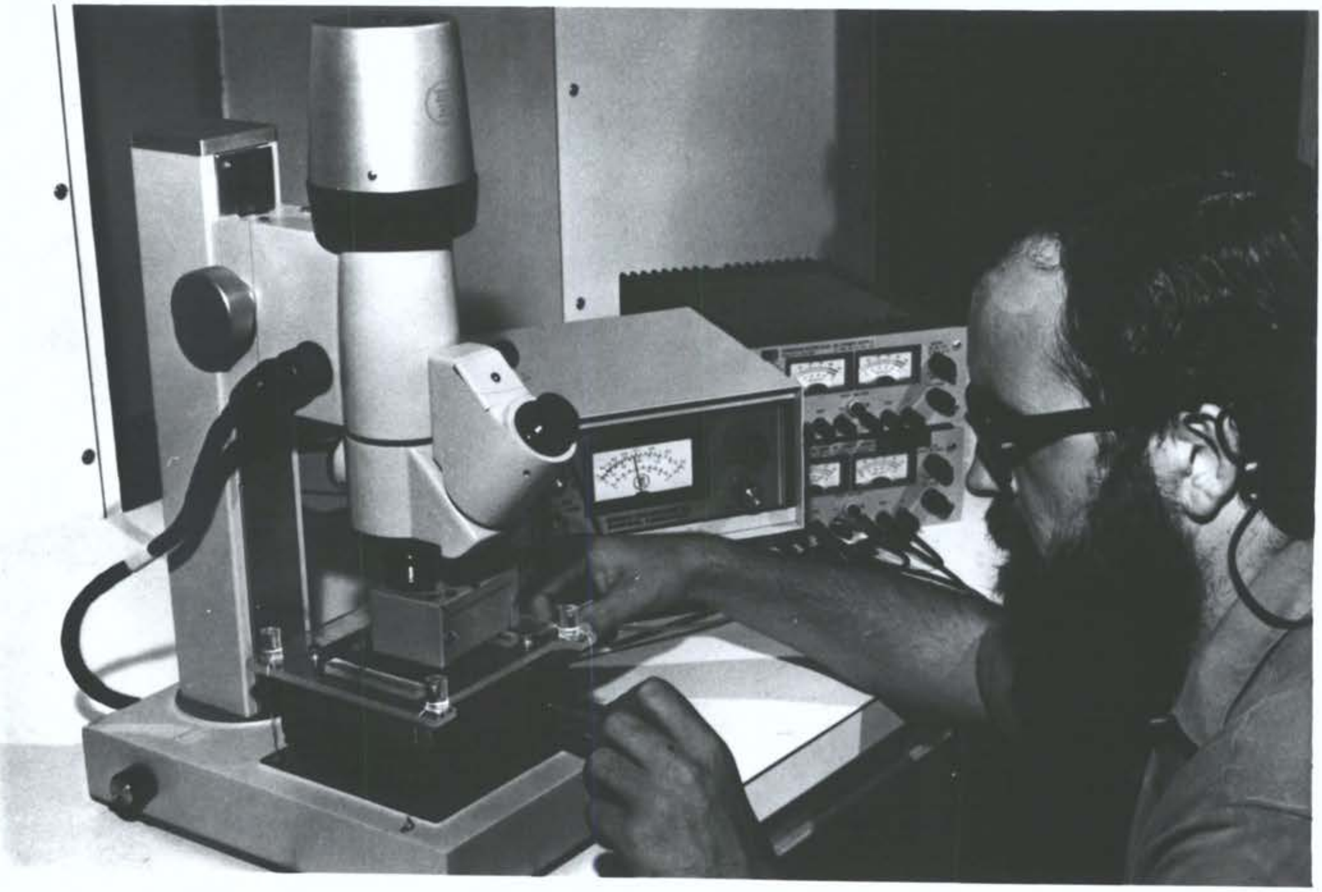
(D) X5000 2µ

FAILURE ANALYSIS OF SL 101-65 TRANSISTOR

This transistor developed an emitter to collector short during trials and was submitted for analysis. Examination (A) & (B) showed no evidence of electrical failure at the bonding points. Note, however, that the metallization has numerous indentations. Further examination at a steeper angle (C) & (D) showed that the emitter (left lead in (A)) may be touching the field relief electrons. Subsequent probing with micromanipulators confirmed this to be the cause of failure.



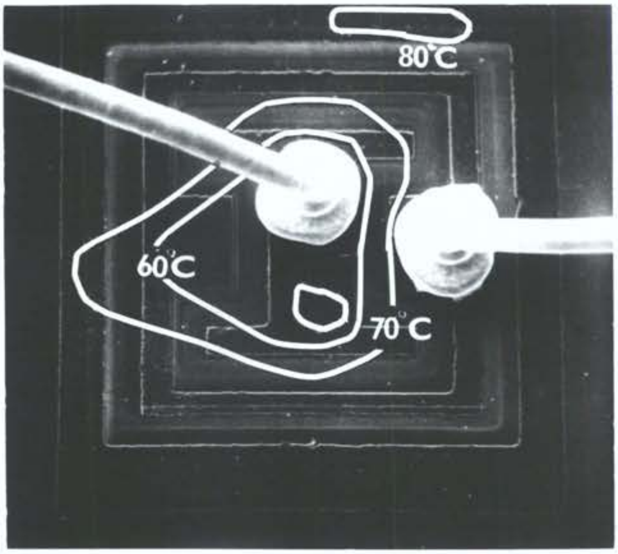
This series of micrographs shows details of the breakdown regions in a silicon guard-ring diode. (a) shows an emissive micrograph of the device and its surface detail, (b) is a sketch of the cross-section of the diode. In (c), p-n junction charge collection is used as the detection mode, revealing the junction depletion regions under zero bias. Note the outer bright ring which is the isolation diffusion and is not detected by (a), the emissive mode. In (d), the bright spot of (c) is shown in more detail at higher magnification and improved contrast. The dark lines are silicon crystal dislocations detected by the decrease of carrier lifetime in defect regions. In (e), increasing back bias has initiated carrier multiplication which is enhanced in the high field region at the crystal defects, (f) shows further increased bias and the onset of general junction breakdown.



BARNES INFRARED MICROSCOPE
MODEL RM - 2A

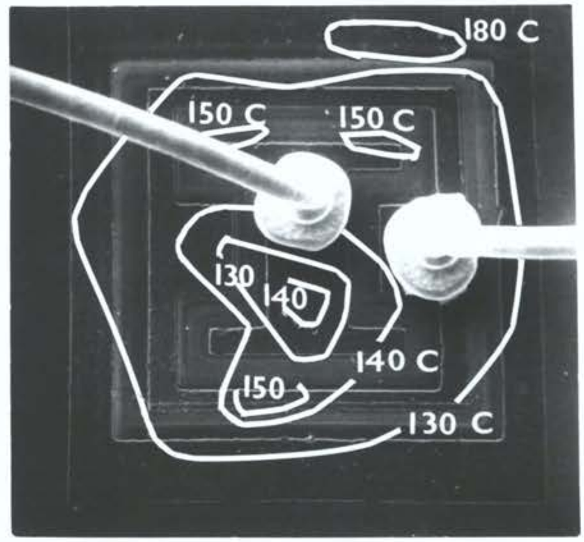
Specifications:

Spectral Range	-	1.8 to 5.5 microns
Optical Resolution	-	10 microns
Temperature Resolution	-	typically 0.1°C at 100°C



2N2905 Transistor operating at ½ watt collector dissipation. The isotherms show fairly uniform heating except for warm spot on outer metallization. The isotherms are plotted on a SEM emissive micrograph of the device.

Magnification 200X



2N2905 Transistor operating at 1 watt collector dissipation. Hot spots are developing in H shaped emitter area. Device failed at 2 watts by collector emitter short.

Magnification 200X

Transistor Isotherms at ½ watt and 1 watt operating levels, obtained by Infrared Microscope.

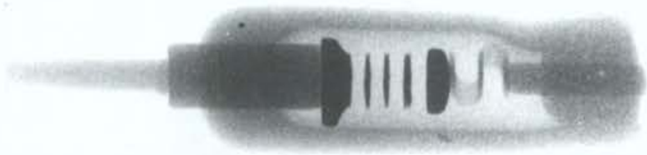
FAXITRON 804 RADIOGRAPHIC INSPECTION UNIT

Resolution - approximately 1 mil.

ACTUAL SIZE

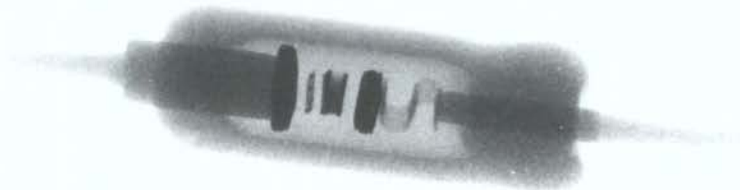
PHOTOGRAPHIC ENLARGEMENT

1.5 kV diode, note regular spacing of semiconductor chips in the diode body.



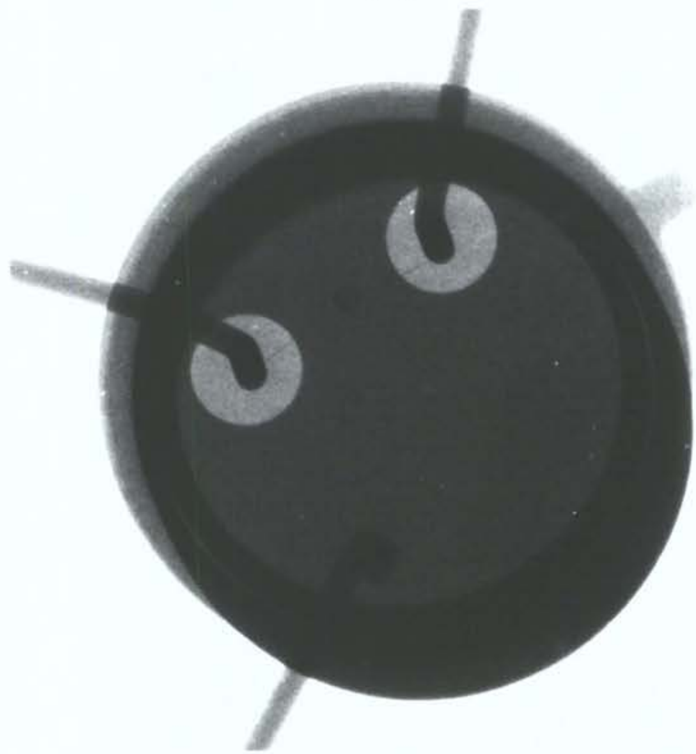
X12

Defective diode of type shown above. Device was operated beyond specifications, causing breakdown between the semiconductor wafers.



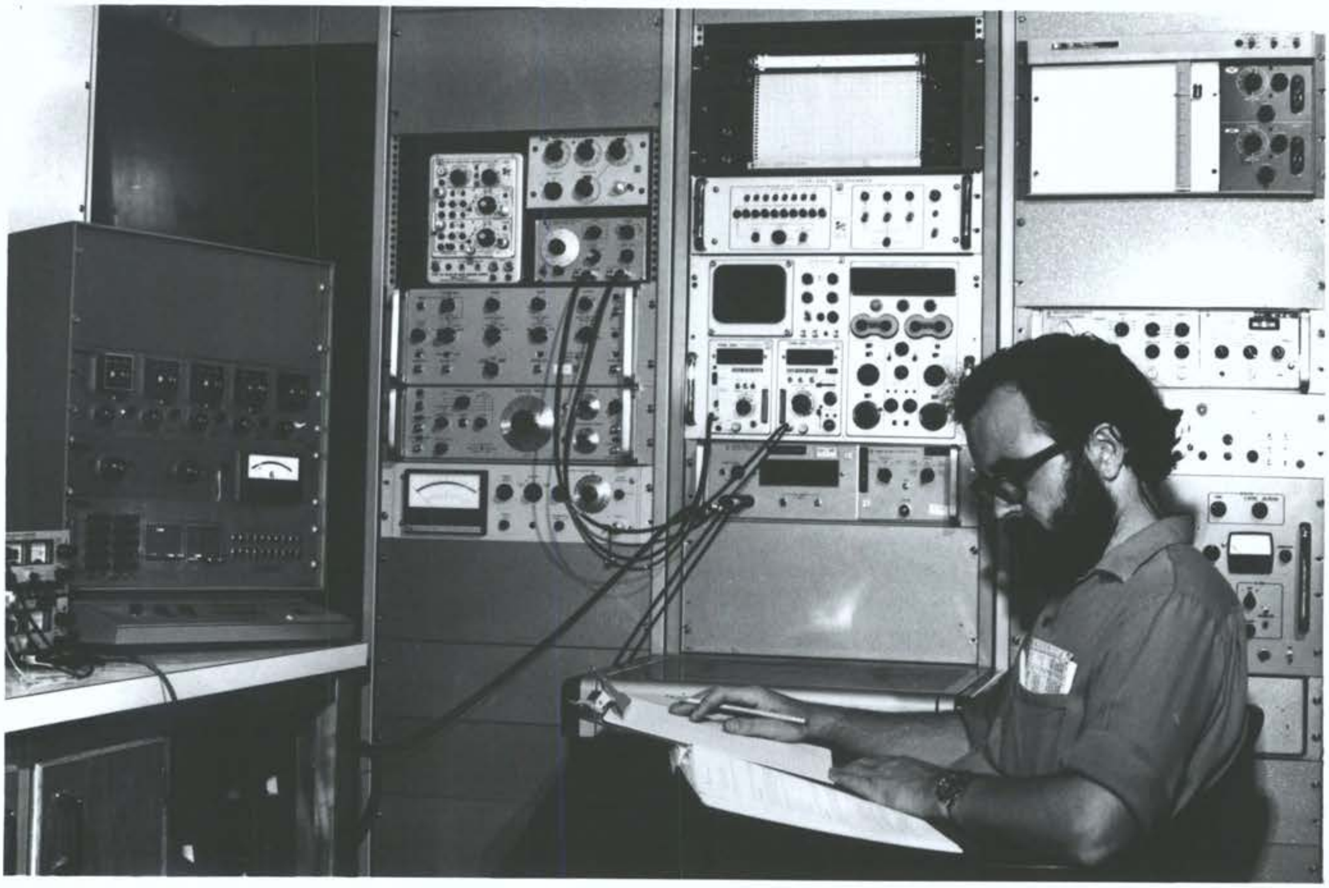
X12

2N1142 transistor.
Note that the position of the semiconductor chip can be identified, but no detail is obtained. Lead continuity to the chip is verified.



X10

X-ray Radiographs of Semiconductor Devices

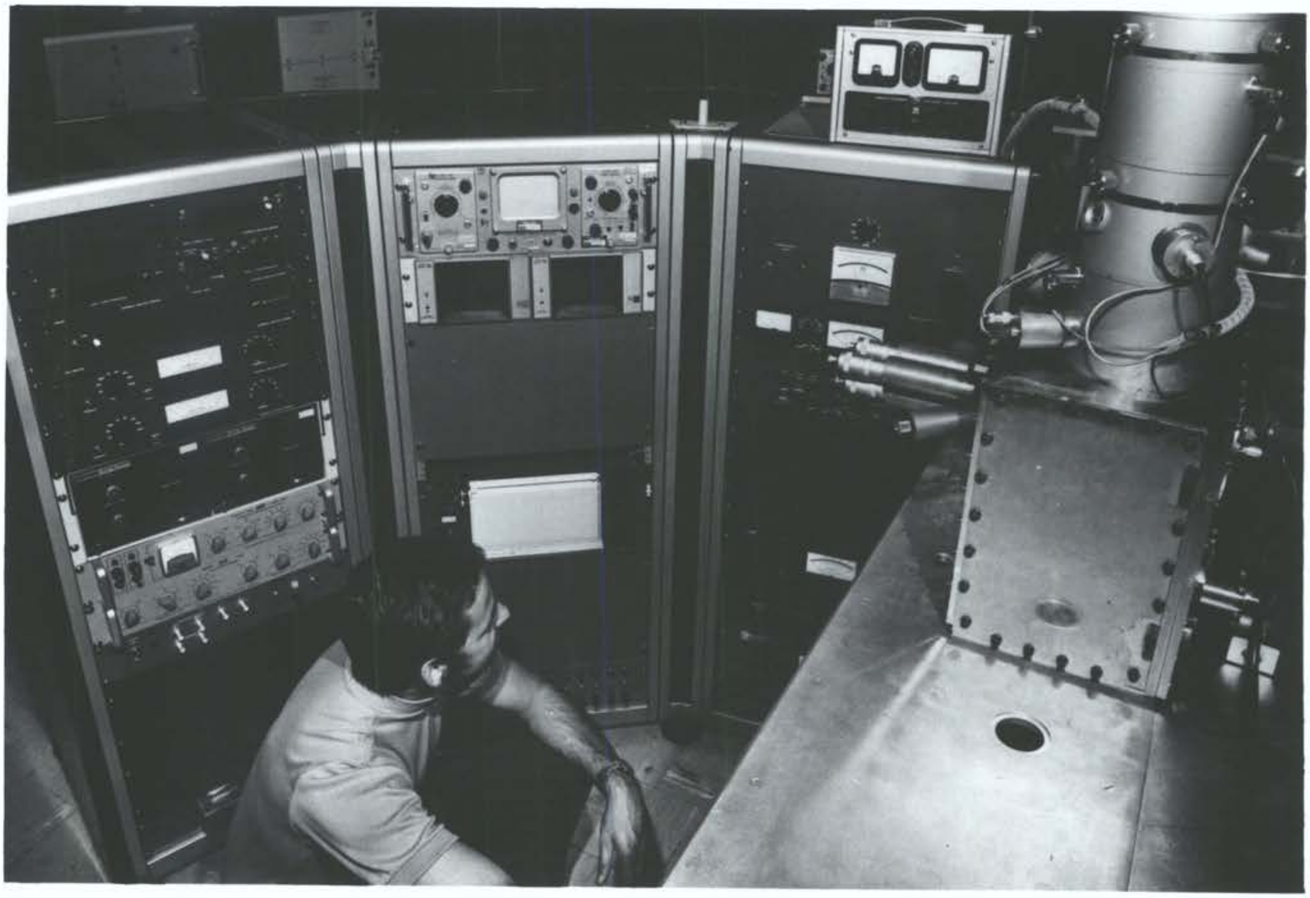


SEMICONDUCTOR DEVICE MEASUREMENTS

Equipment and Function

(a) Birtcher 800 I.C. tester - d.c. and a.c. tests up to 10 nSec rise and fall times.
(b) Tektronix 567 oscilloscope and 6R1A digital readout, with HP 214A 1 nSec pulse generator for fast pulse testing.
(c) Tektronix 575 Curve Tracer.
(d) Constant current sources, Keithley 261 and 225. Keithley Electrometer 610CR, log current amplifier 10^{-11} to 10^{-3} amps for V-I plotting on HP 7035B X-Y plotter.
(e) Rack mounted temperature chamber Statham SD 6 (not shown) for device tests from -20° to 270°C.
(f) Boonton 75C Capacitone Bridge for C-V measurements on MOS devices ($0.1H_Z$ to $1MH_Z$), and p-n junctions ($1kH_Z$ to $1MH_Z$).
(g) Mechanical probes for tests after decapping, 1 nSec response and 1 pAmp. leakage at 500V.

70-20551



MATERIALS ANALYSIS CORPORATION
MODIFIED SERIES 700 COLUMN

A. Used as a SEM

Specifications

Magnification	-	20X to 100,000X
Acceleration Voltage	-	2 - 30 kV
Resolution	-	250Å or better
Vacuum	-	ion pumped, 10^{-8} torr
Detection Modes	-	emissive, conductive, and cathodoluminescent

B Used as an electron microprobe

Specifications

Spectrometers	-	two channel dispersive; detects all elements heavier than Boron (Z=5)
Resolution	-	1 micron
Acceleration Voltage	-	2 - 30 kV
Vacuum	-	ion pumped, 10^{-8} torr

Analysis Procedure

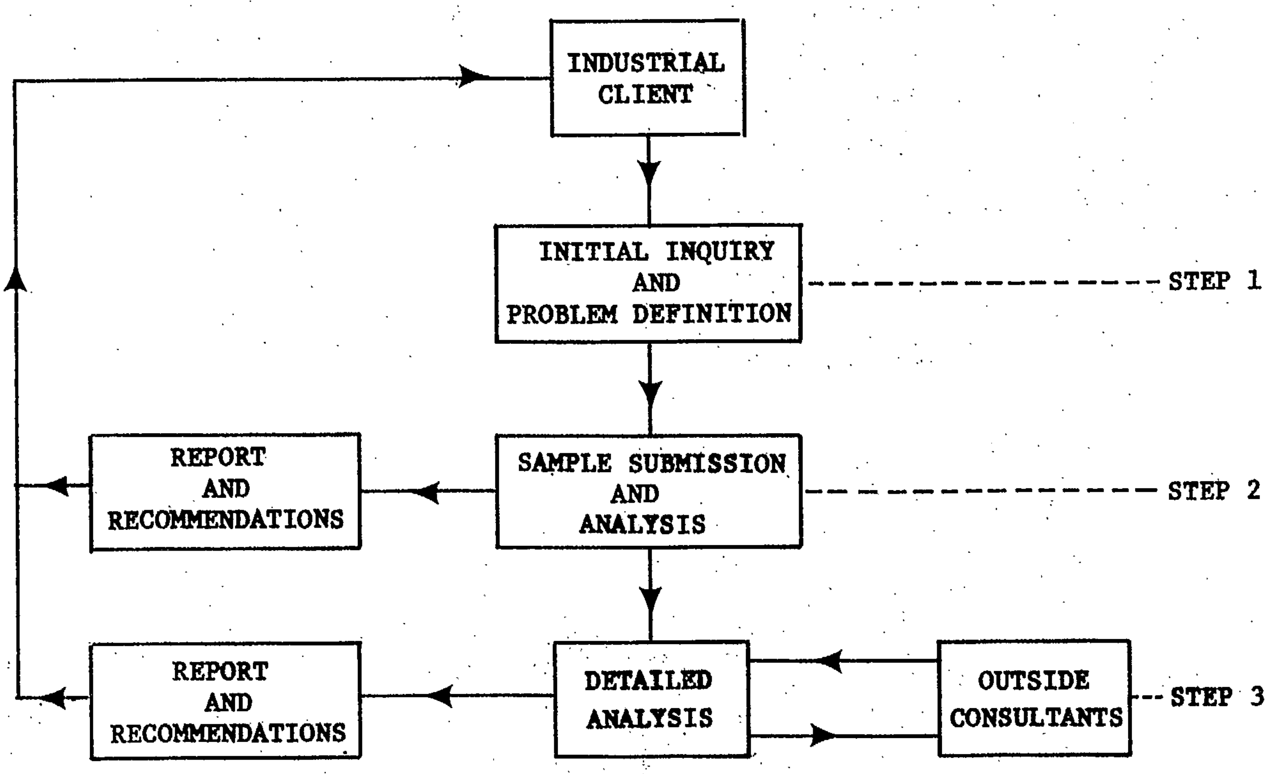
The steps in our analysis and reporting procedure are described below, and a flow chart for a typical analysis problem is shown on the next page.

1. The initial phase, problem definition, is worked out in discussions between the industrial and CRC scientists. This can be done via telephone, but it is preferable, especially on the first job, to have the industrial scientist visit CRC. Once the extent of the problem is defined, an estimate of the cost of the next step can be arrived at.
2. The sample is submitted along with a Request for Analysis form, (see last pages of this booklet). The analysis ends with a written report which includes a recommendation for further action where required. The majority of problems are complete at this point.
3. In some cases, the analysis may point to other areas where work is necessary to give a more complete solution to the problem. These more detailed analyses are not undertaken without further authorization from the client, and on completion, a written report and recommendations are submitted. Outside consultants may be used if necessary, with the client's knowledge. The rates charged for analysis time are listed below.

SEM	\$36.70/hour
Professional	\$18.30/hour
Technician	\$12.00/hour
Secretary	\$ 6.26/hour

The group has been doing industrial analysis work since April 1970. The problems have included ceramic particle sizing, identification of failure mechanism in devices, assessment of device quality, assessment of lithographic edge definition, identification of foreign inclusion and plating quality in Kovar leads, investigation of phase variations in coal.

We invite your inquiries, and hope that we can help with your production and research problems.



ANALYSIS FLOW CHART

REQUEST FOR ANALYSIS

DATE: ______________________

1. Name and address of company.

2. Name and position of company representative requesting analysis.

3. Brief description of problem.

4. Maximum expenditure. ______________________

Authorized by: ______________________

Please send the completed form and samples to:

Dr. C. D. Cox
Failure Analysis Group
C.R.C.
P.O. Box 490, Terminal A
Ottawa 2, Ontario

Note: All analysis results are confidential and are the property of the requesting agency. Whatever use is made of the analyses or recommendations submitted by CRC is the responsibility of the requesting agency.

REQUEST FOR ANALYSIS

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