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Volume II

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GROWTH OF GALLIUM ARSENIDE USING ION CLUSTER
BEAM TECHNOLOGY

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September 1988

Final Report for Period February 1984 - February 1987

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) This program was designed to study the feasibility of growing epitaxial GaAs thin films for subsequent application in electronic devices. Due to mechanical difficulties and design problems the technique of deposition via ionized clusters was not realized. Data collected is somewhat inconclusive. To answer the feasibility question further, work including modification of the hardware needs to be performed. To this point the techniques have been shown to be capable of growing single crystal GaAs, but the required electrical characteristics of the film are not present.					
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EPI-TECH CORPORATION

FINAL REPORT

VOLUME II

TITLE : Growth of Gallium Arsenide using Ion Cluster Beam Technology

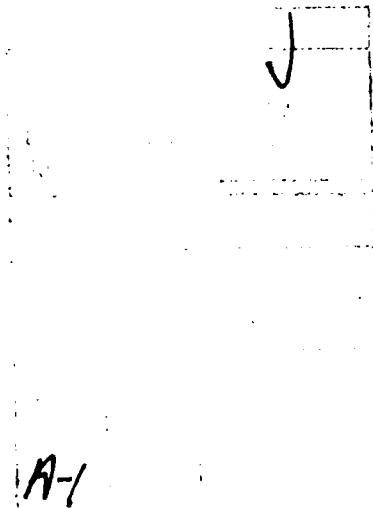
FOR : U.S. Air Force / AFWAL / XRPA AADR
Wright Patterson Air Force Base

CONTRACT NO : F33615-84-C-1562

CORPORATE OFFICIAL

AND PROJECT COORDINATOR : Dr. Robert L. Adams
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A-1

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VOLUME II

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APPENDIX A

A-1/A-2

NOZZLE LOG

Nozzle No.	Description*
01	Large orifice 0.40 inch diameter
02	DeLeval type nozzle with 0.050 inch diameter throat at the vena contracta
03	DeLeval type nozzle with 0.100 inch diameter throat at the vena contracta
03A	DeLeval type nozzle with 0.100 inch diameter throat at the vena contracta and 0.10 inch extension
03B	DeLeval type nozzle with 0.100 inch diameter throat at the vena contracta and 0.50 inch extension
04	DeLeval type nozzle with 0.250 inch diameter throat at the vena contracta
05A	DeLeval type nozzle with 0.150 inch diameter throat at the vena contracta
05B	DeLeval type nozzle with 0.150 inch diameter throat at the vena contracta and 0.50 inch extension

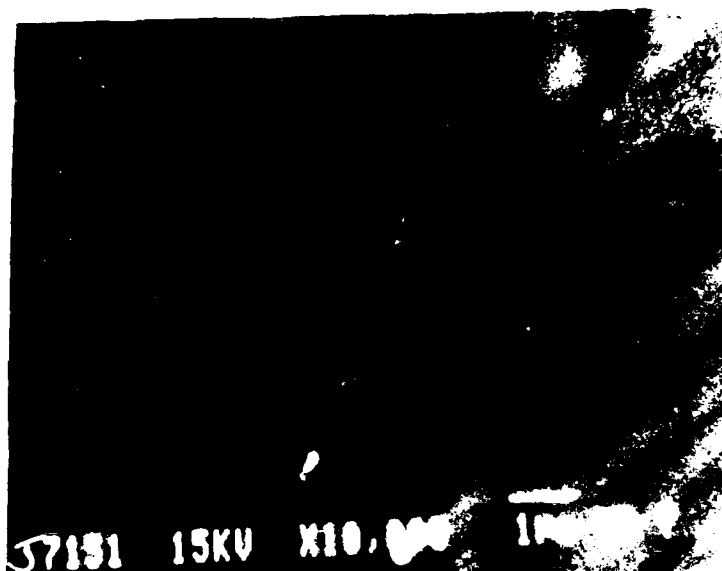
*Nozzles with extensions have had the vena contracta moved the indicated distance from the top of the crucible. This was done to allow cooler nozzle temperatures and improve cluster formation.

APPENDIX B

B-1/B-2

RUN NO. 002

SAMPLE #002



Film
Surface



Cleave
Cross
Section

Film
Thickness
Approximate 2.4 μm

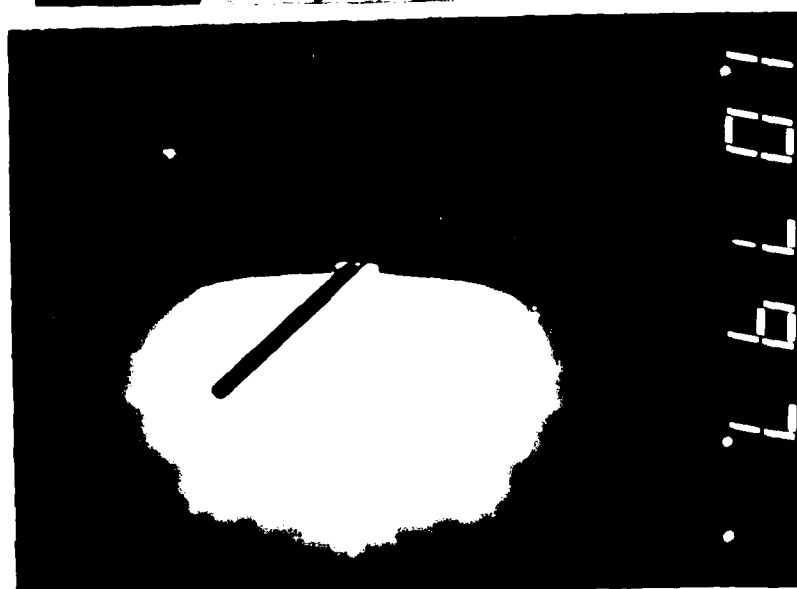
SAMPLE #002



ECP
(GaAs substrate)



ECP
(ICB film)



RHEEP
(ICB film)

SAMPLE #002



Substrate

Interface

GaAs Film

x40,000

TEM Micrograph of Cross-Section



x36,000

TEM Micrographs in Direction Normal to Surface

x36,000



SAMPLE #002



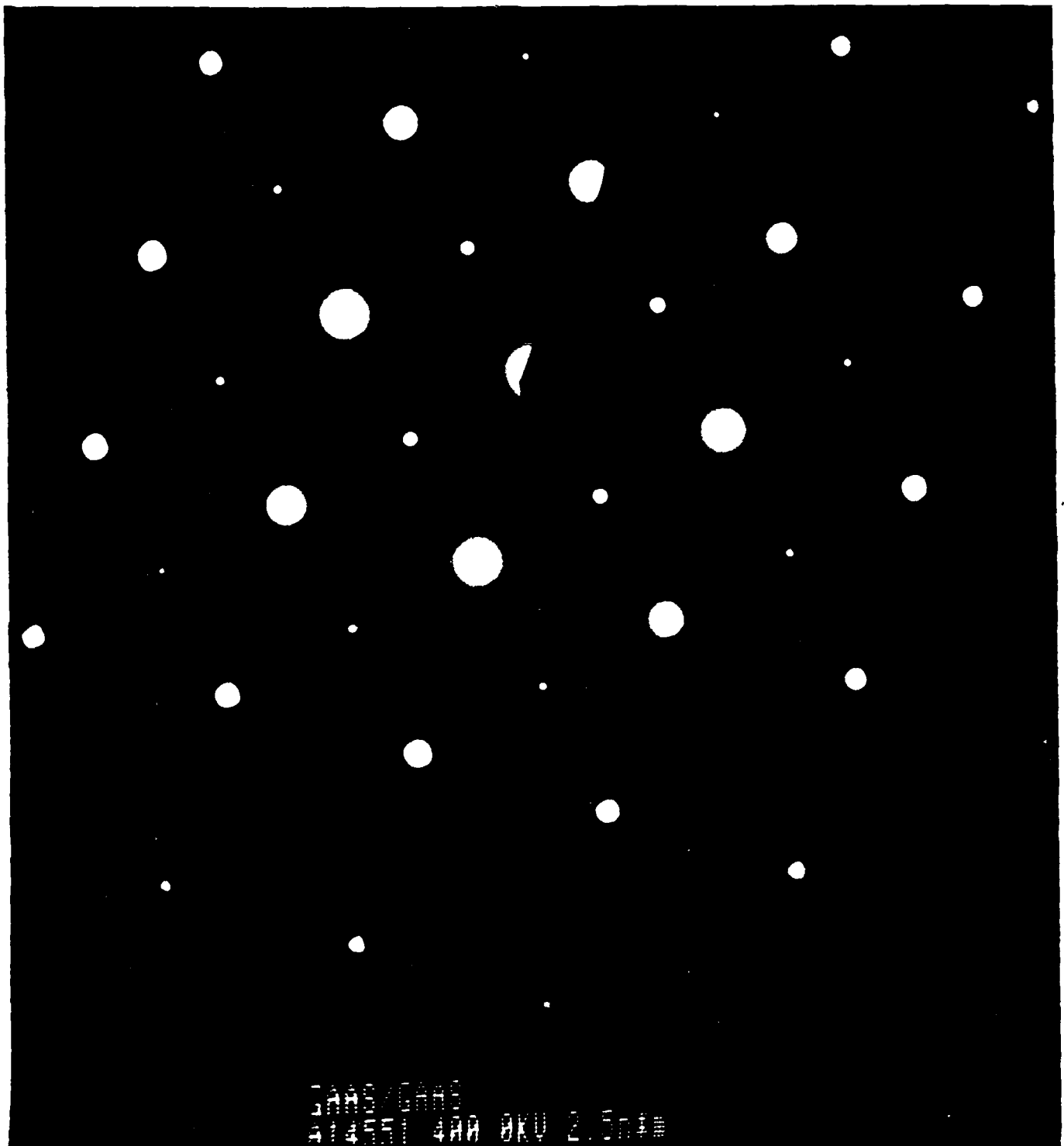
High Resolution TEM Micrograph of As/GaAs Interface

SAMPLE #002



High Resolution TEM Micrograph of As/GaAs Interface

SAMPLE #002

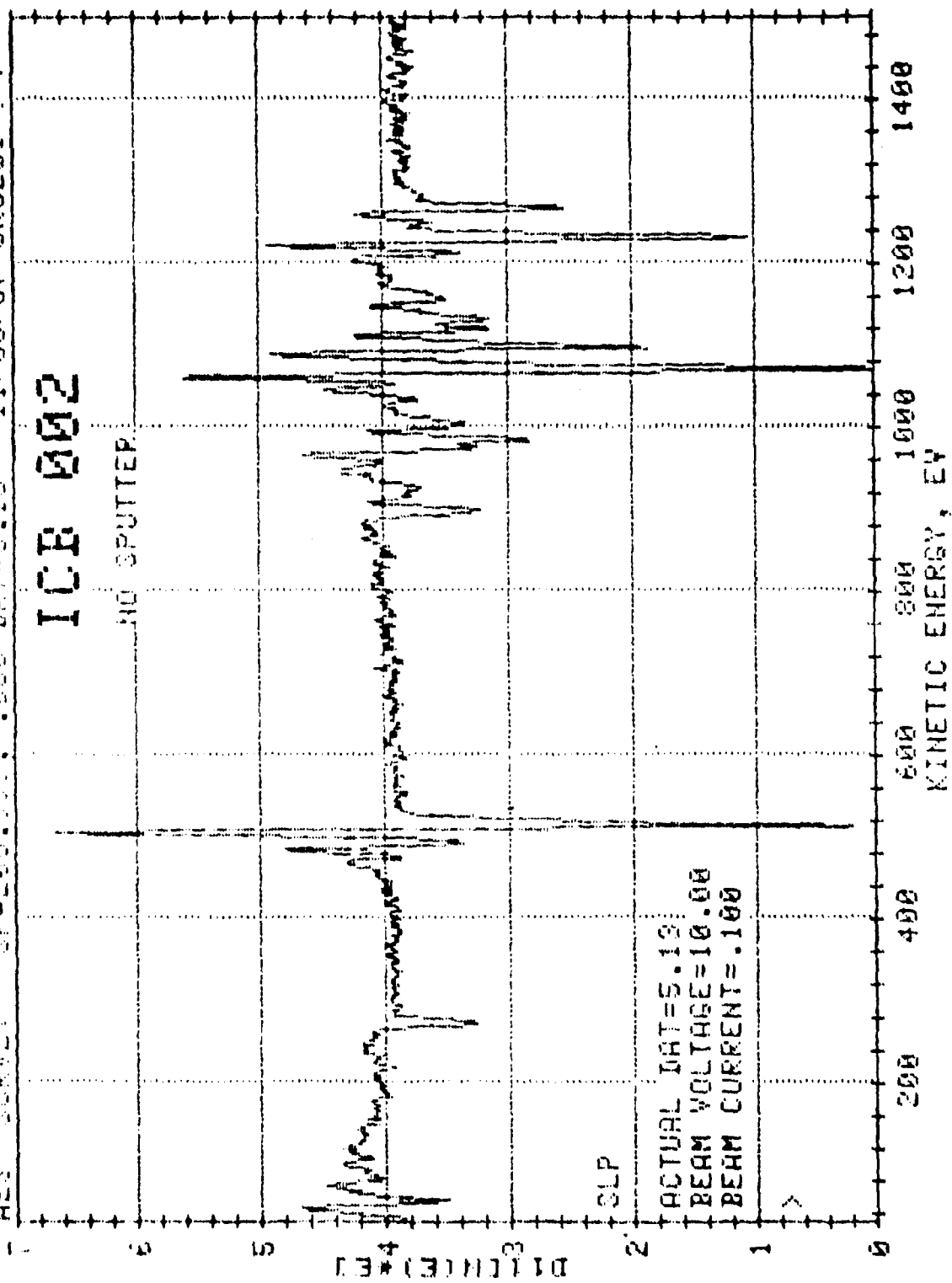


RHEED Pattern on (110) Cleaved Face

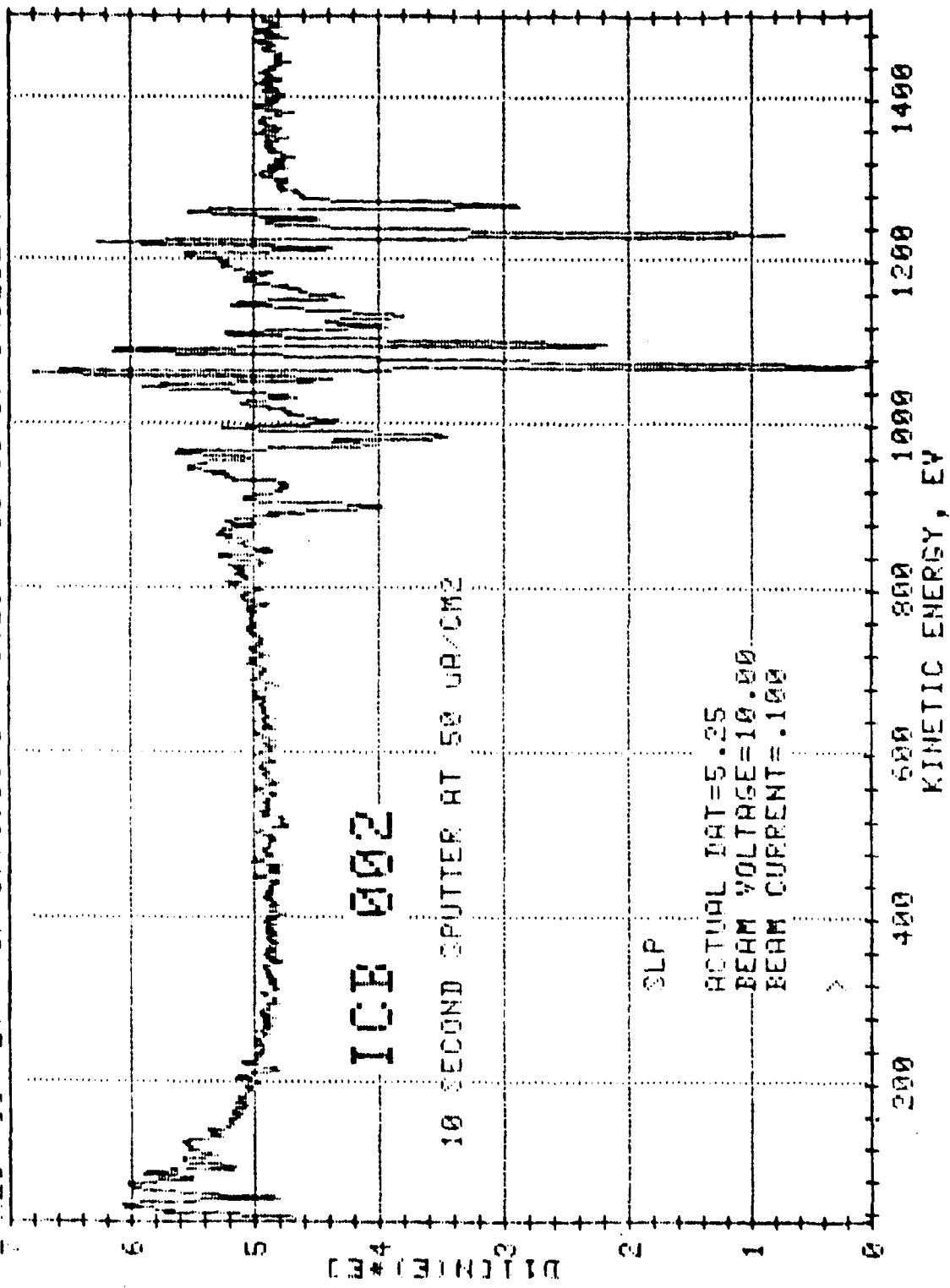
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ICR 002

NO SPUTTER

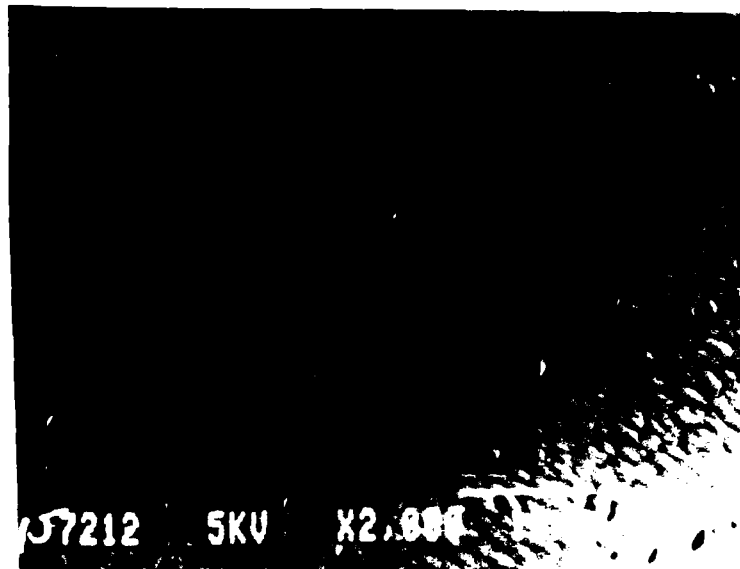


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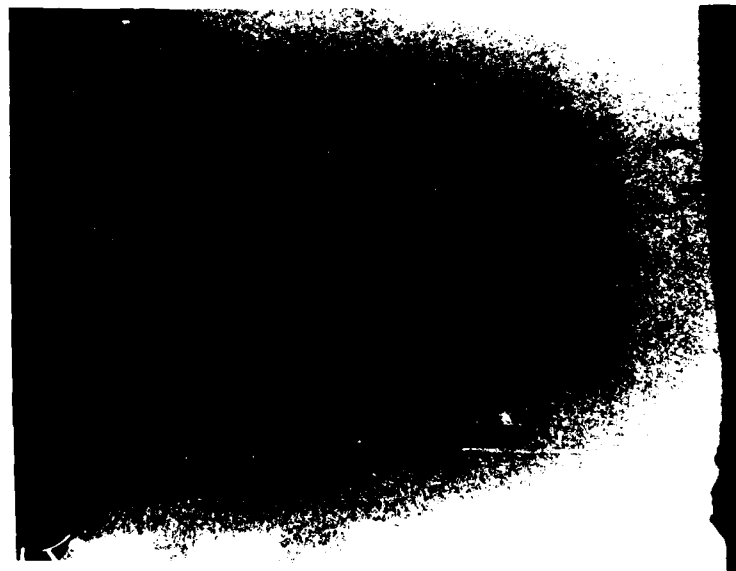


RUN NO. 003

SAMPLE #003



Film
Surface



Cleave
Cross
Section

Film
Thickness
Approximate? ?

SAMPLE #003



ECP
(GaAs Substrate)



ECP
(ICD + FID)

SAMPLE #003



x60,000

TEM Micrograph of Cross-Section



x36,000



x36,000

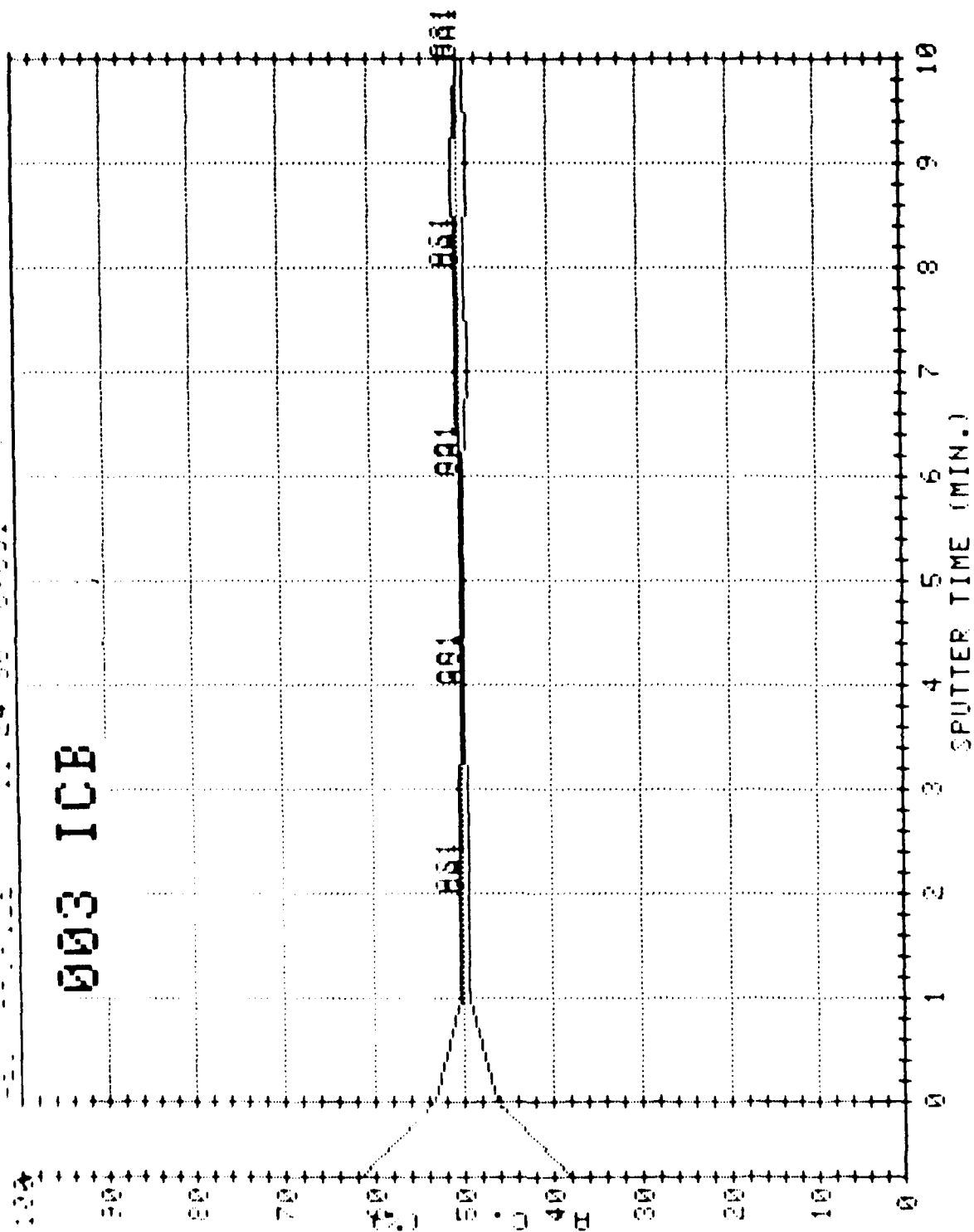
TEM Micrographs in Direction Normal to Surface

SAMPLE #003



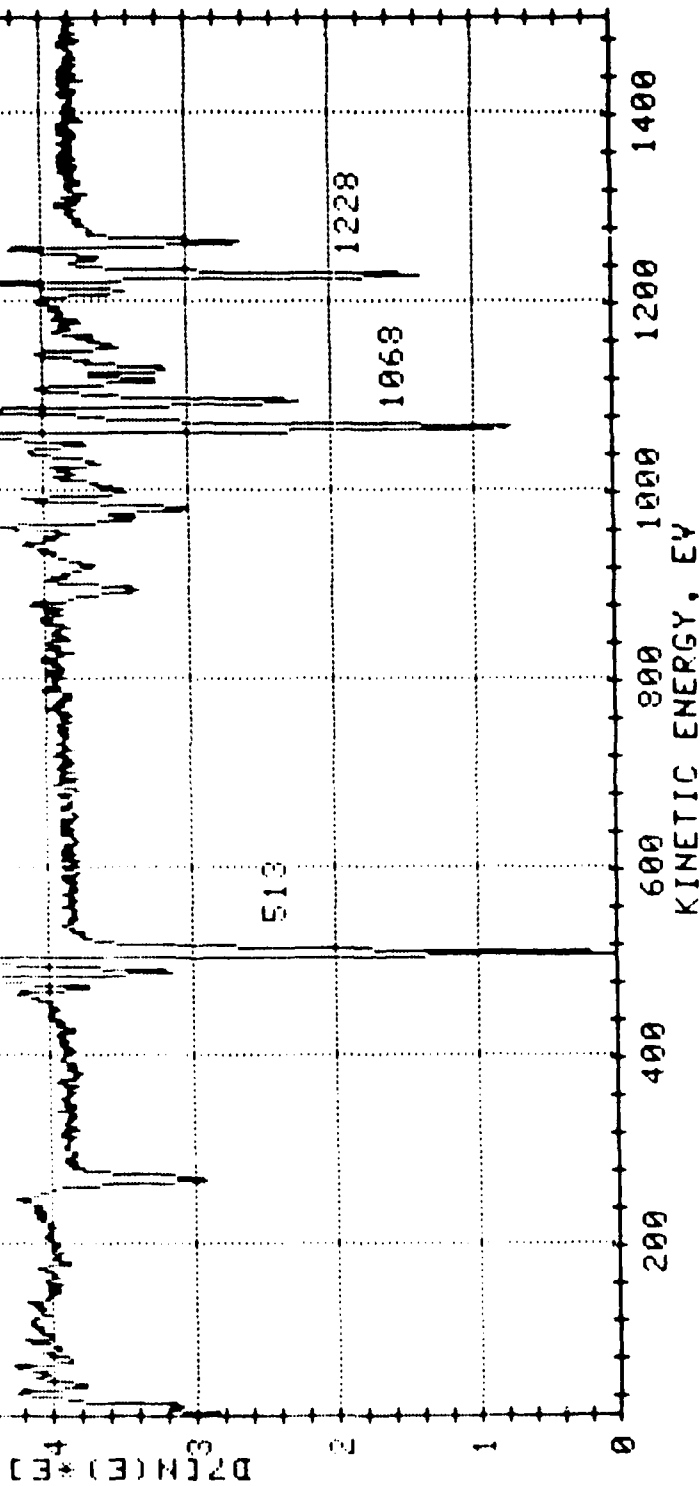
High Resolution TEM Micrograph of GaAs/GaAs Interface

003 ICB

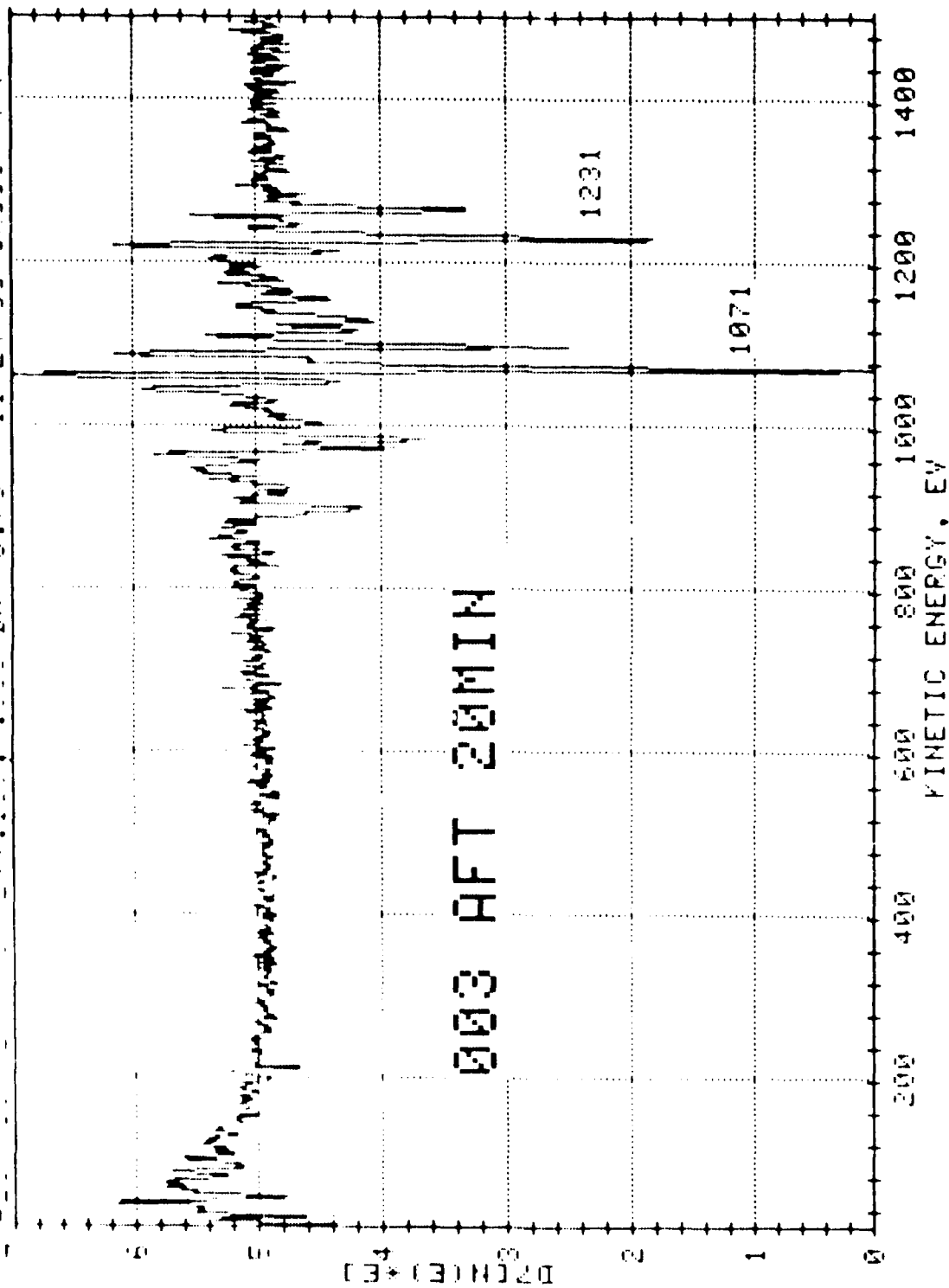


REF: 11/24/86 11/24/86 Y/F

003 ICB SURFACE BEF SPUTTER



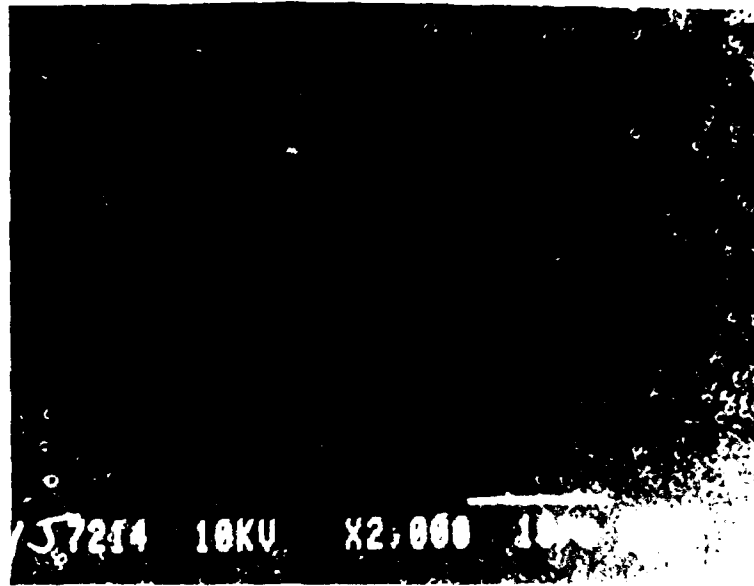
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RUN NO. 004

B-20

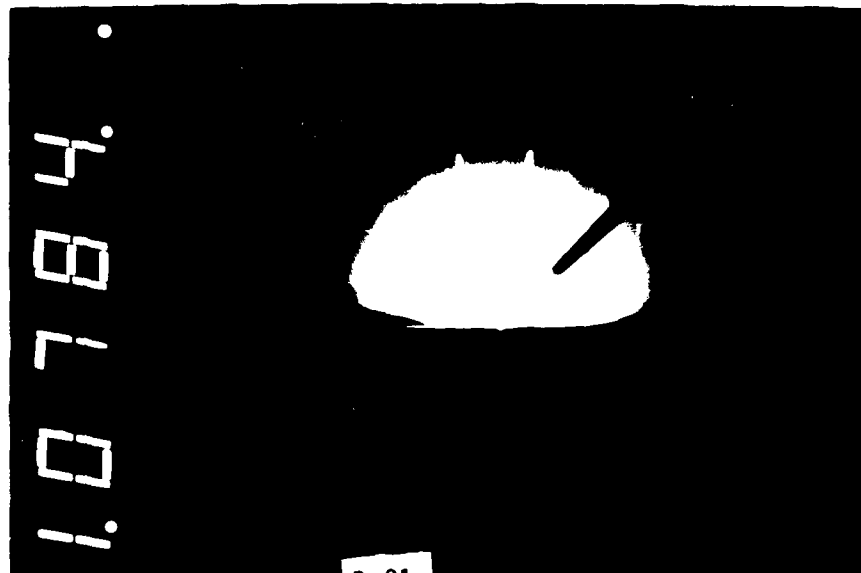
SAMPLE #004



SEM
Micrograph
of Film
Surface

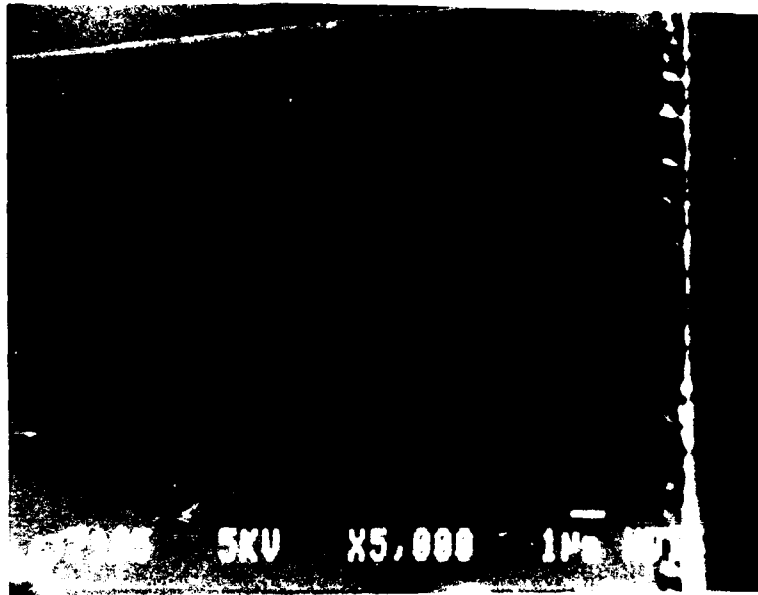


Electron
Channeling
Pattern from
Film Surface



RHEED
Pattern

SAMPLE #004



Cleave
Cross
Section

Film
Thickness
Approximately
0.9 μm

SAMPLE #004



x36,000

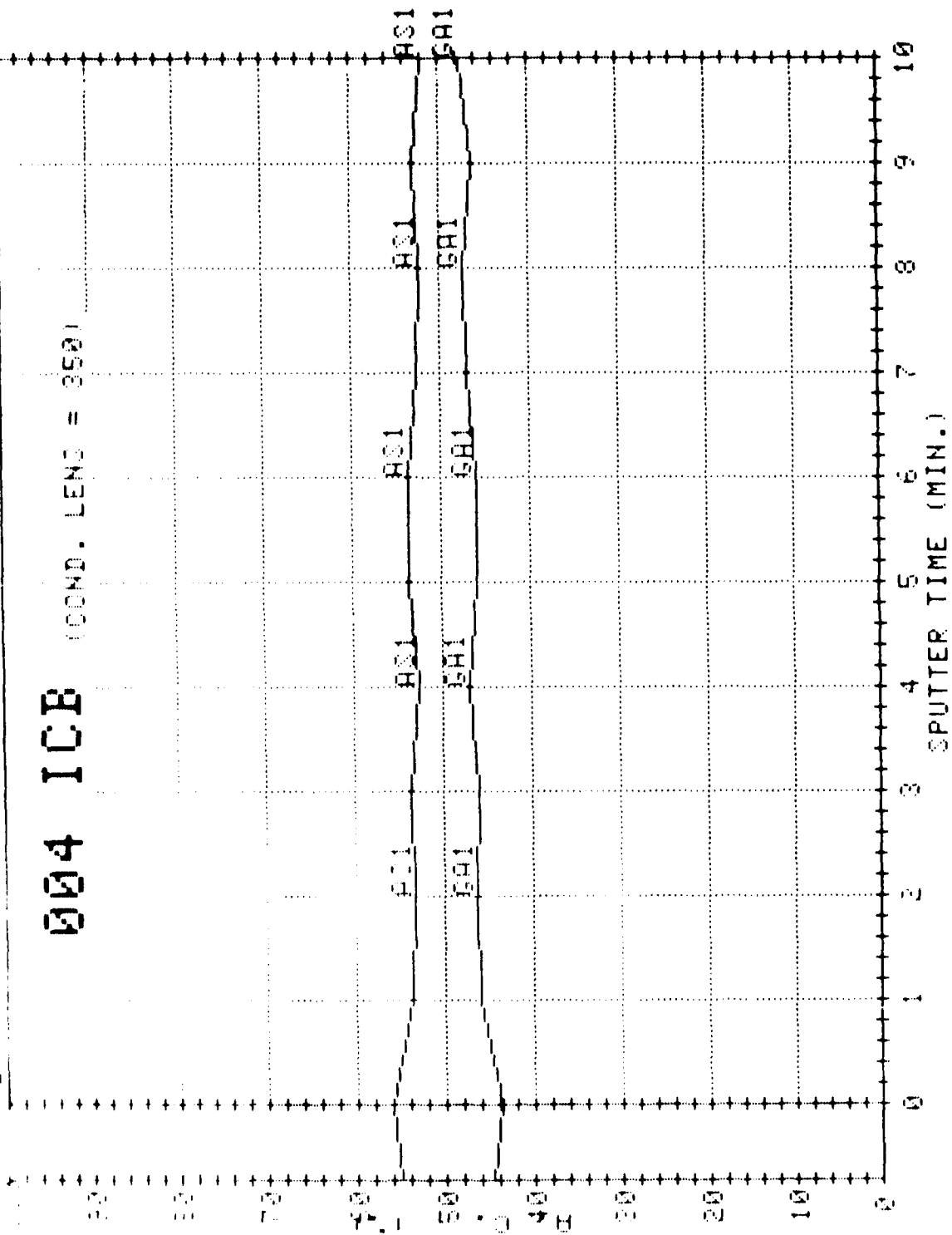
TEM Micrograph of Cross-Section



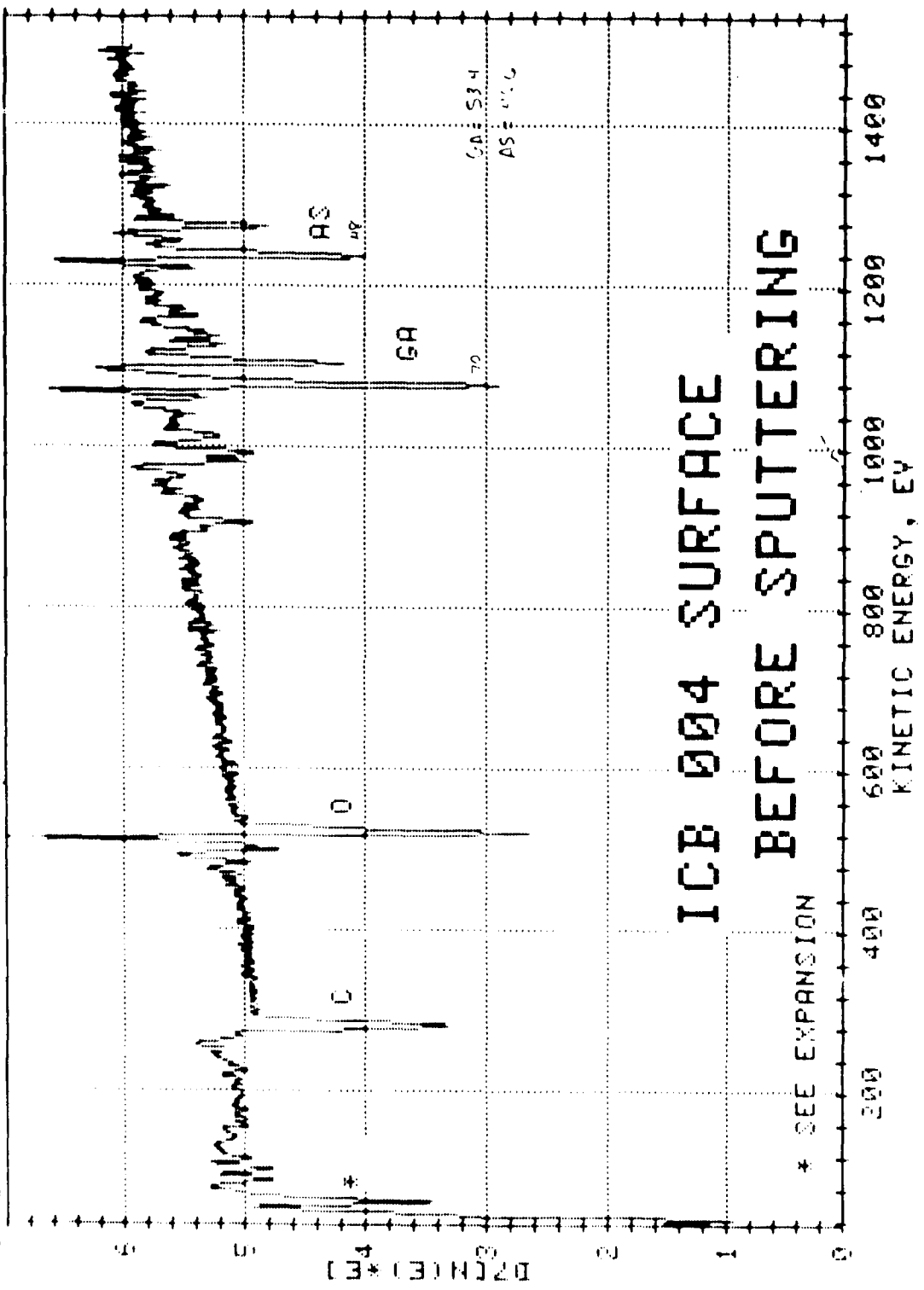
x80,000

TEM Micrograph in Direction Normal to Surface

0004 ICB (COND. LENS = 350)

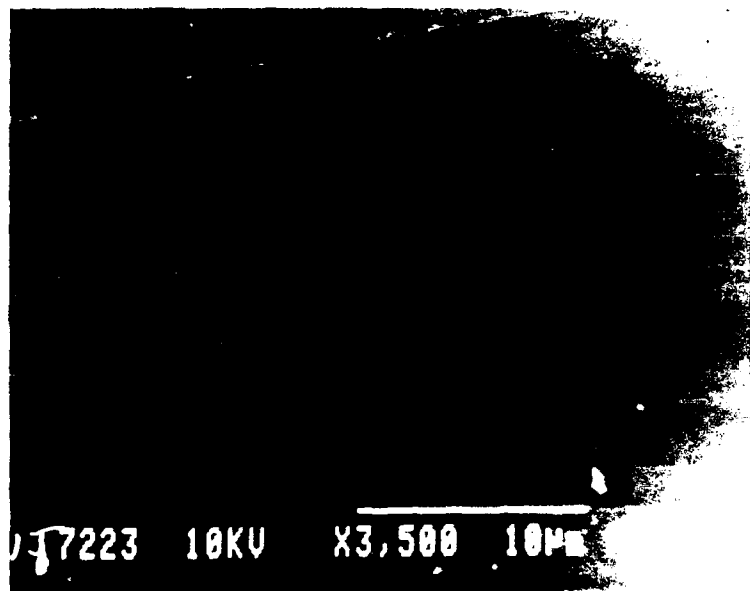


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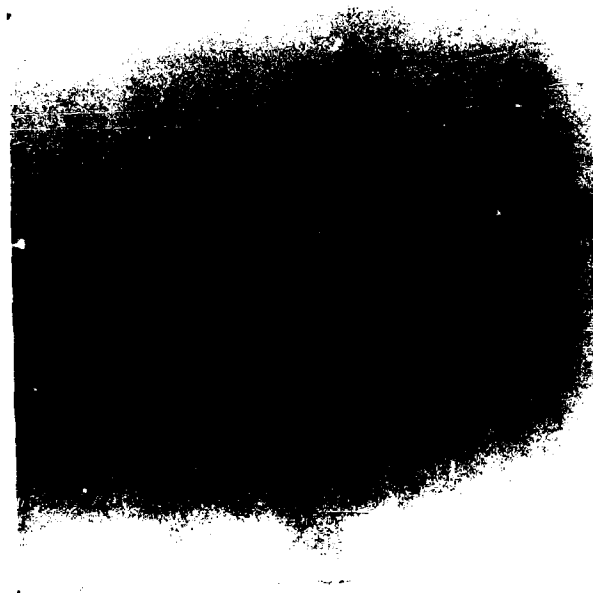


RUN NO. 005

SAMPLE #005



Film
Surface

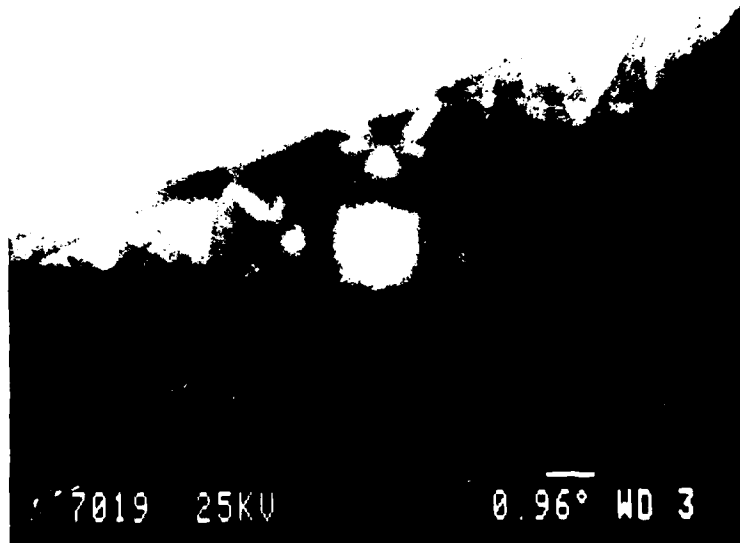


Cleave
Cross
Section

Film
Thickness
Approximately
0.6 µm

017

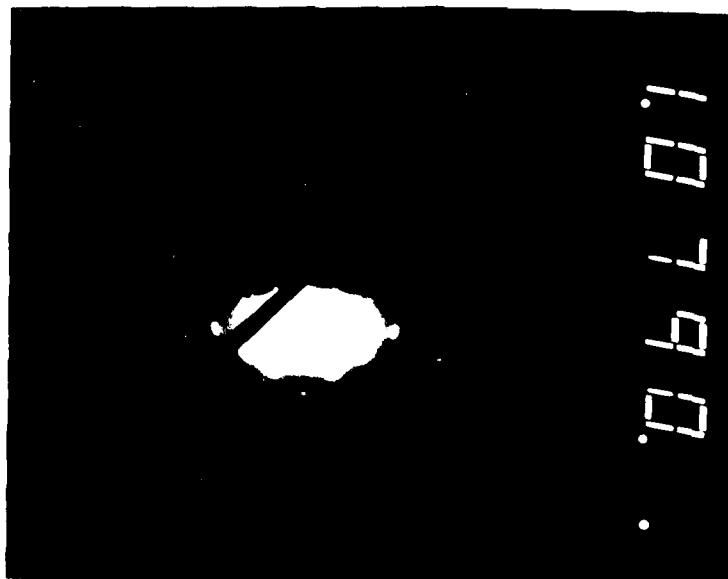
SAMPLE #005



ECP
(GaAs
Film
Substrate)

7019 25KV

0.96° WD 3

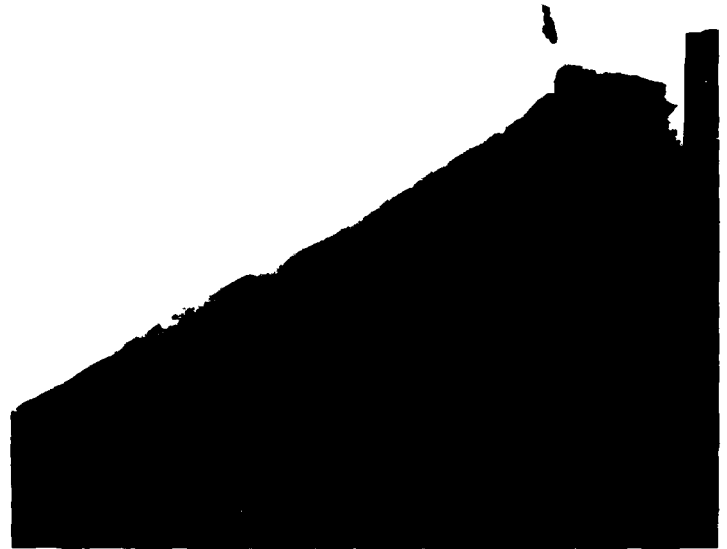


RHEED
(ICB Film)

SAMPLE #005



x13,000

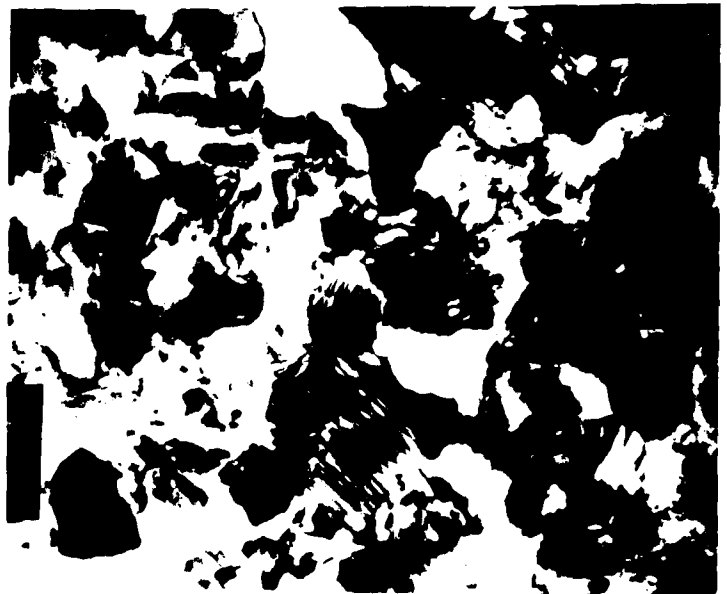


x130,000

TEM Micrographs of Cross-Section



x80,000



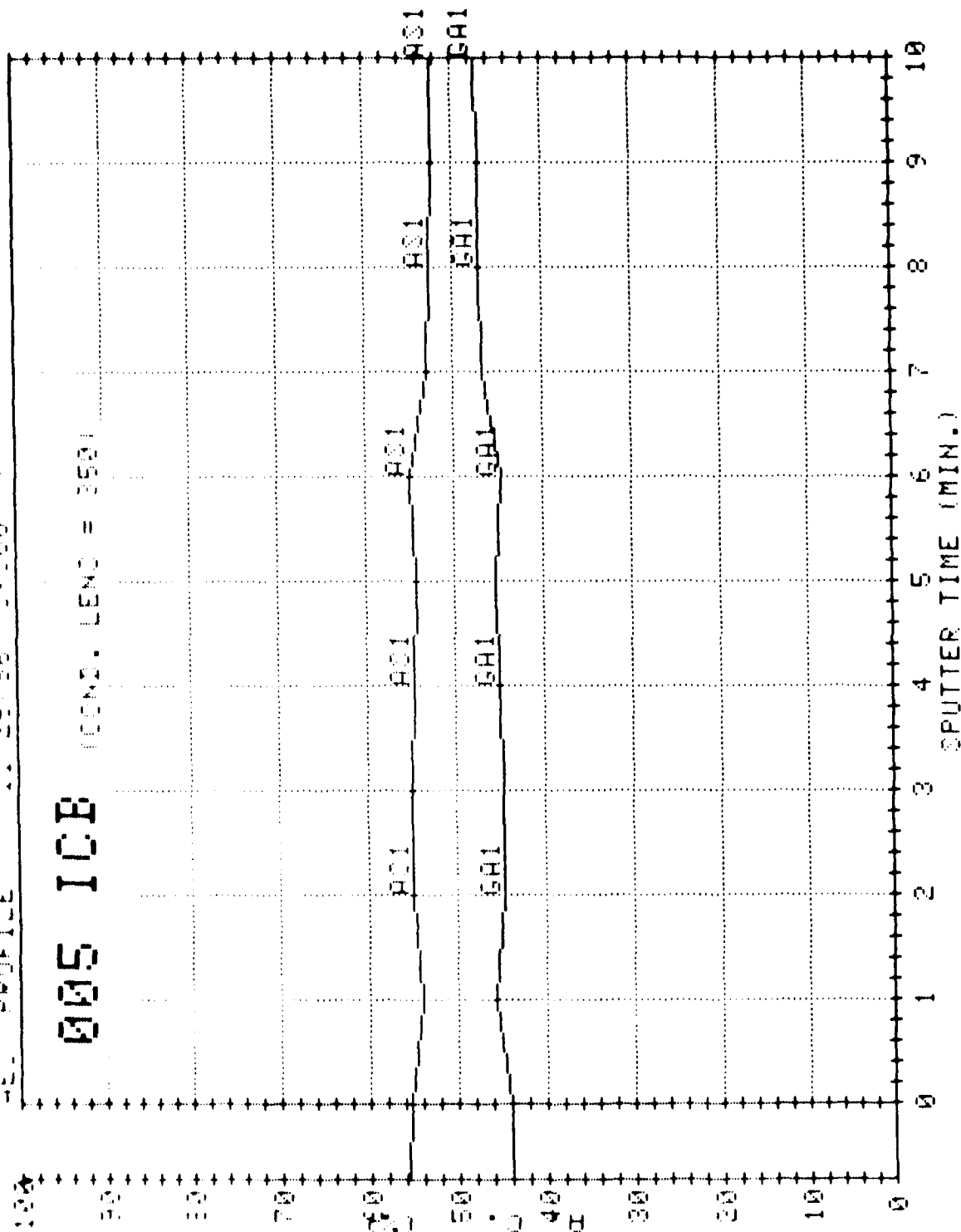
x130,000

TEM Micrographs in Direction Normal to Surface

SET PROFILE 11 25 98 18098 F

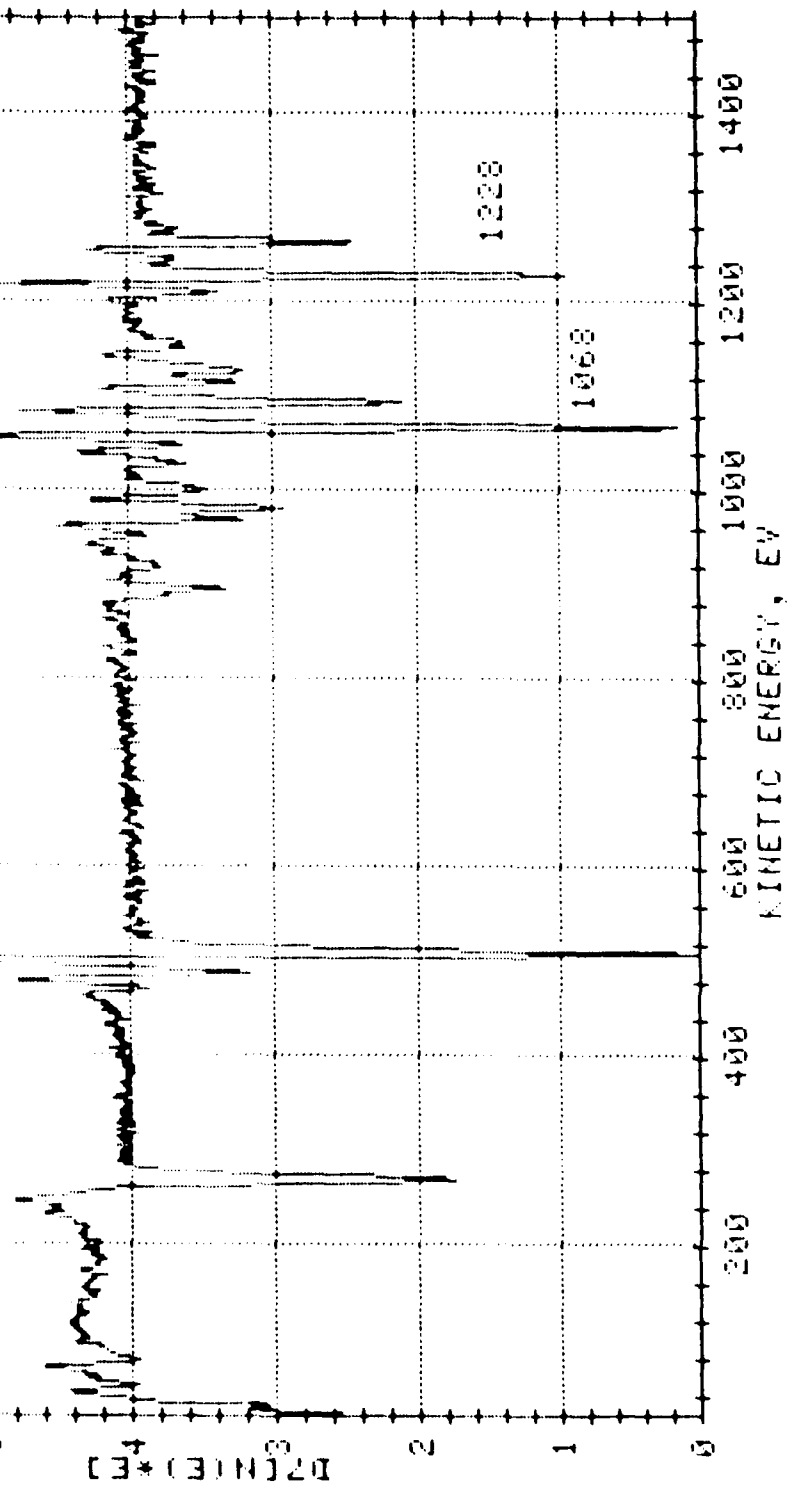
005 ICB

(COND. LENC = 350)



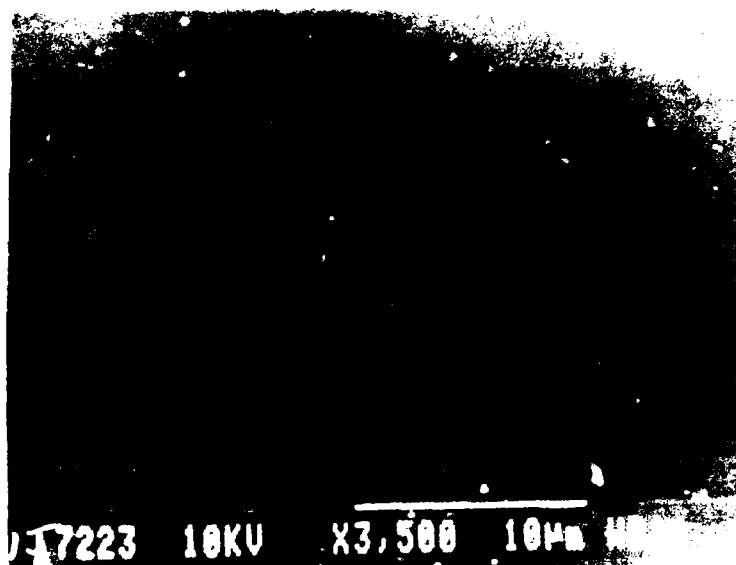
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005 ICB
REF SPUT.



RUN NO. 006

SAMPLE #006

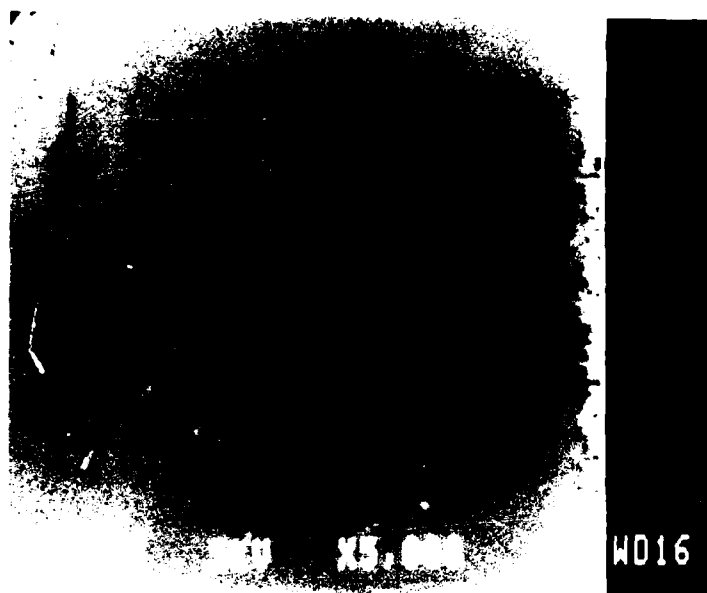


SEM
Micrograph
of Film
Surface



Electron
channeling
pattern taken
near wafer
edge. The
sharp pattern
emanates from
the exposed
substrate
surface. The
ICB film
(top) does
not yield a
channeling
pattern.

SAMPLE #006



Cleave
Cross
Section

Film
Thickness
Approximately
0.8 μm

SAMPLE #006



x17,000



x80,000

TEM Micrographs of Cross-Section



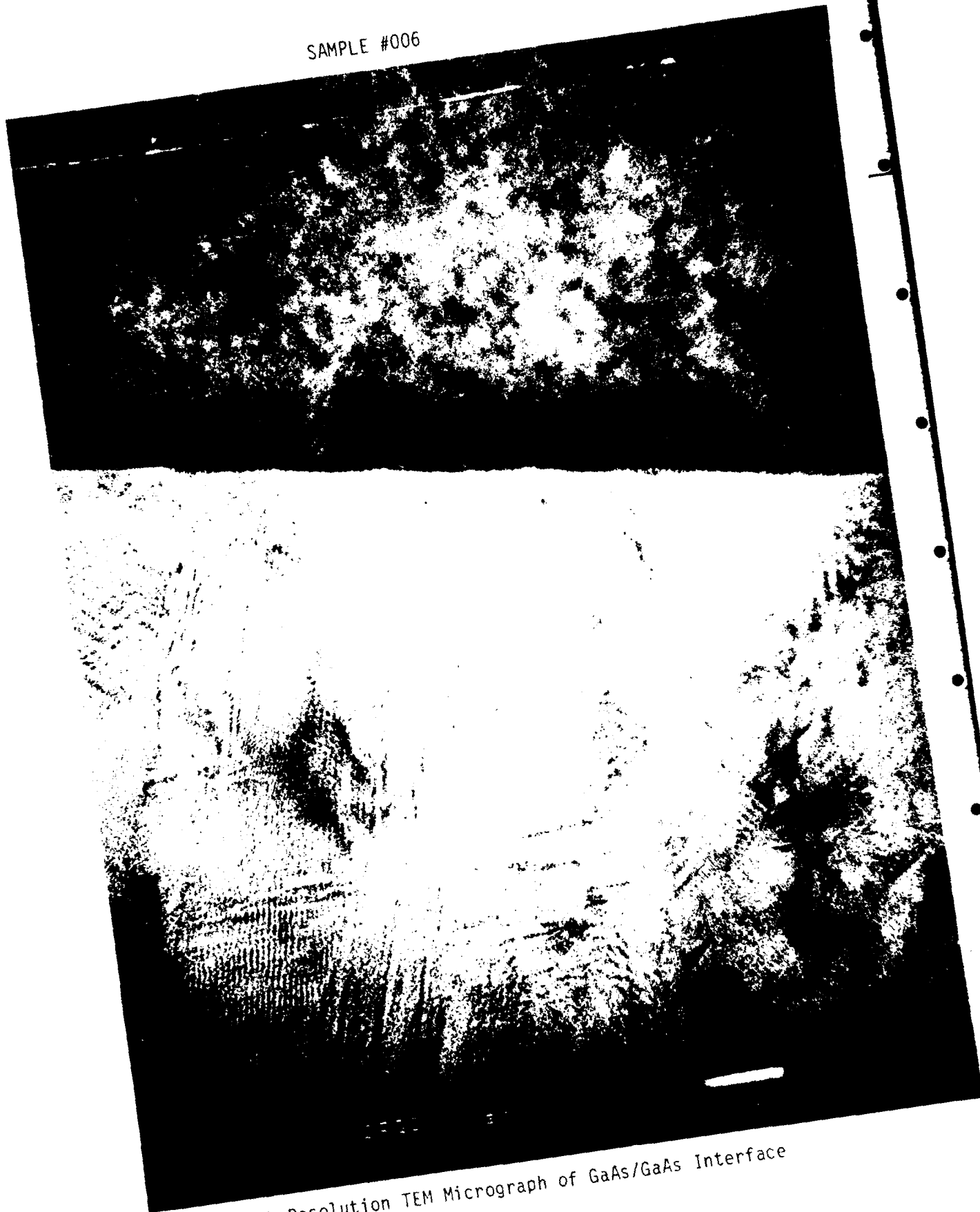
x80,000



x170,000

TEM Micrographs in Direction Normal to Surface

SAMPLE #006



High Resolution TEM Micrograph of GaAs/GaAs Interface

SAMPLE #006

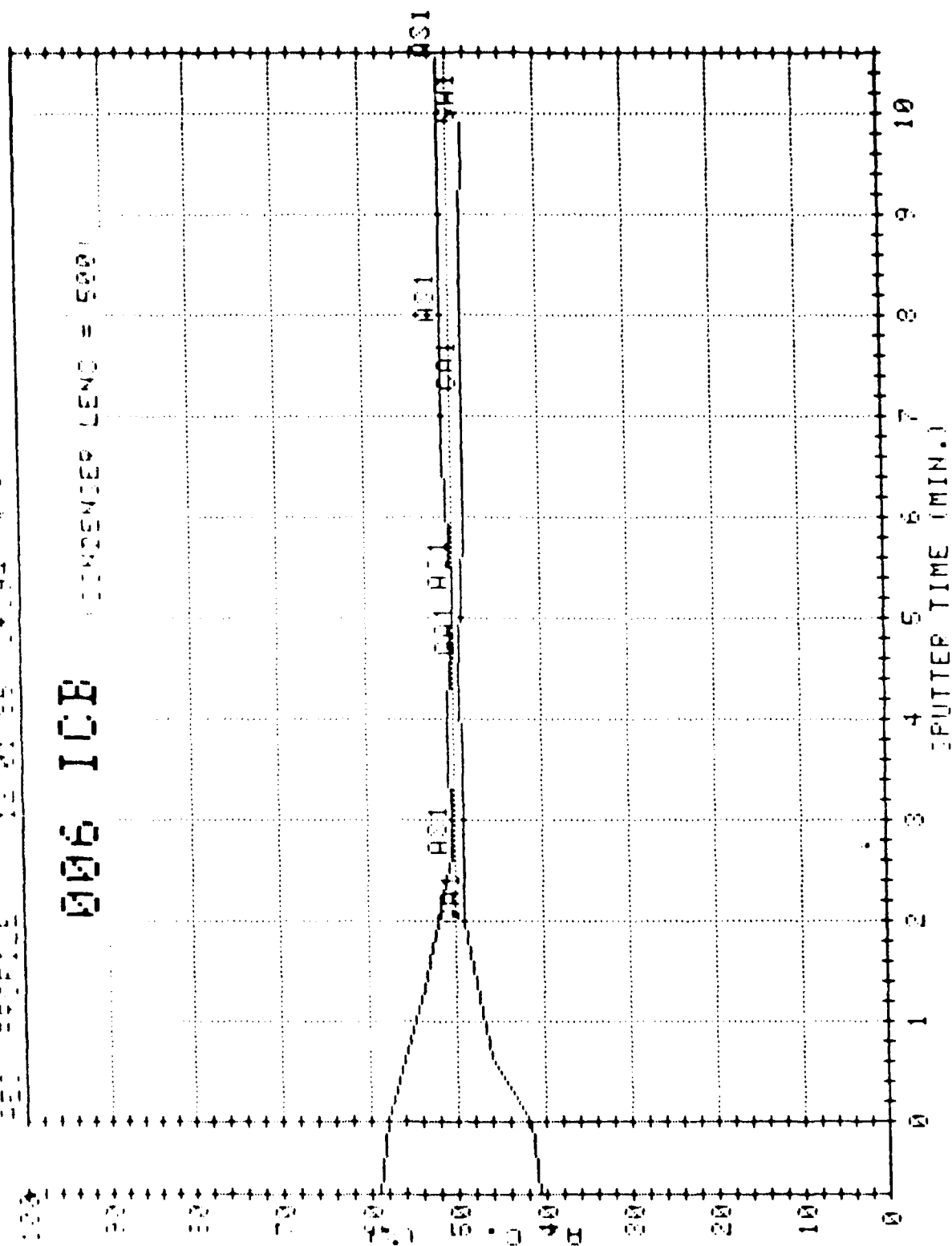


High Resolution TEM Micrograph of GaAs/GaAs Interface

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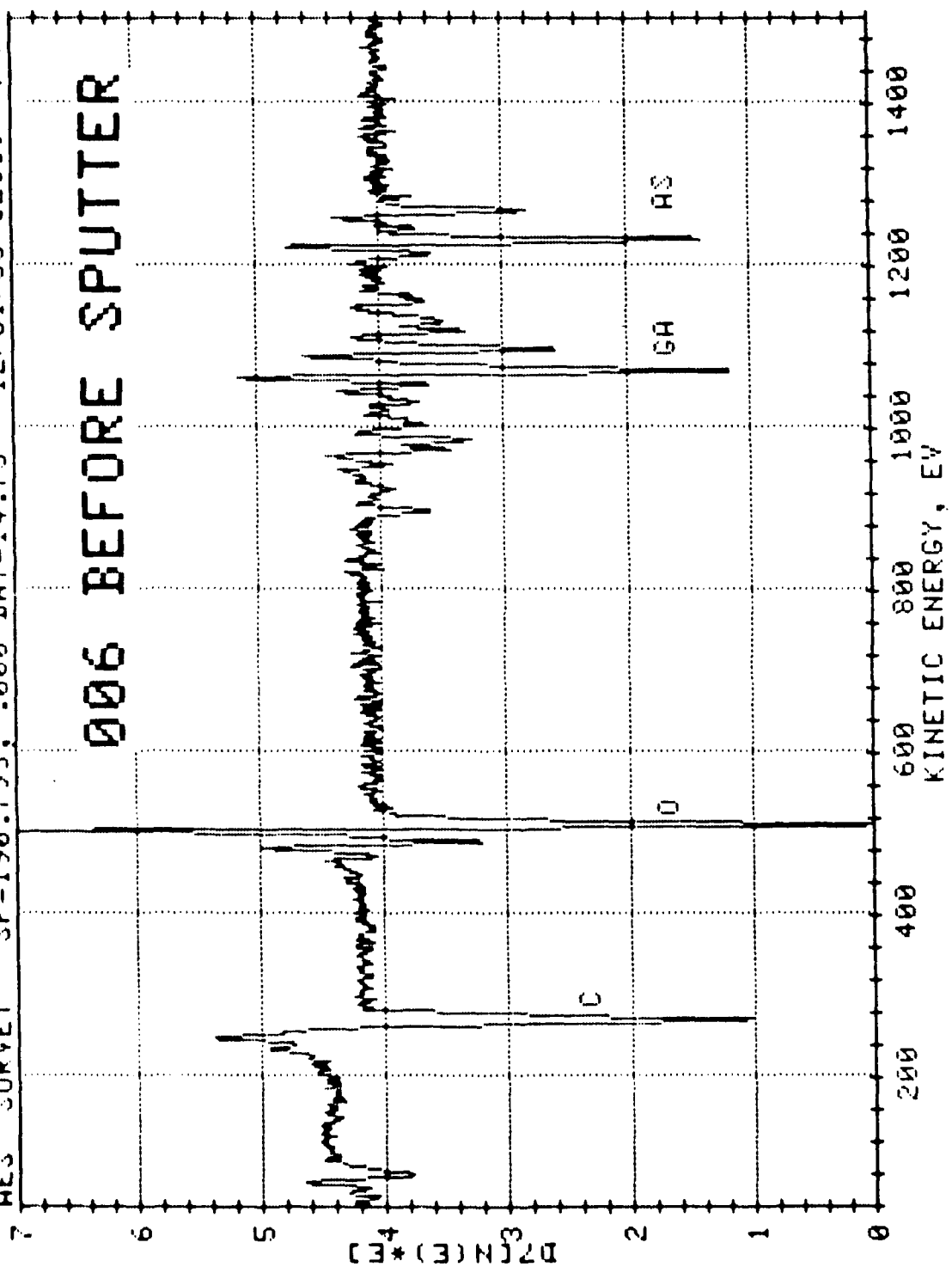
0006 ICB

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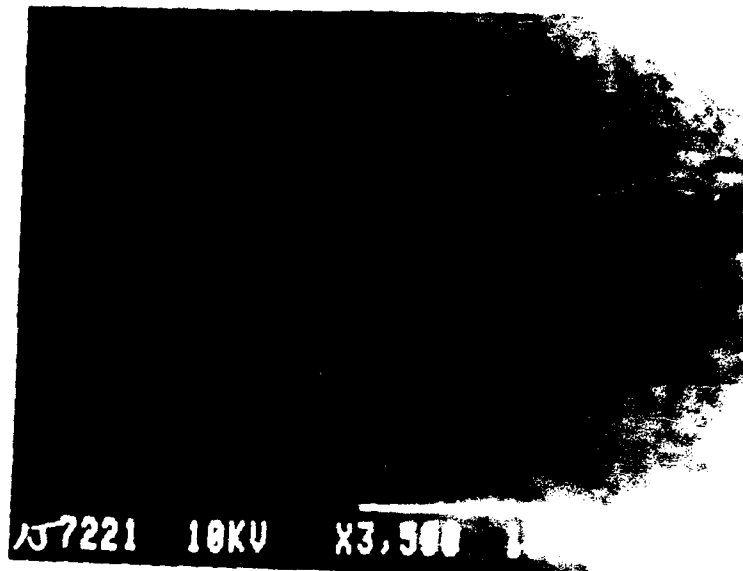
006 BEFORE SPUTTER



RUN NO. 007

B-40

SAMPLE #007

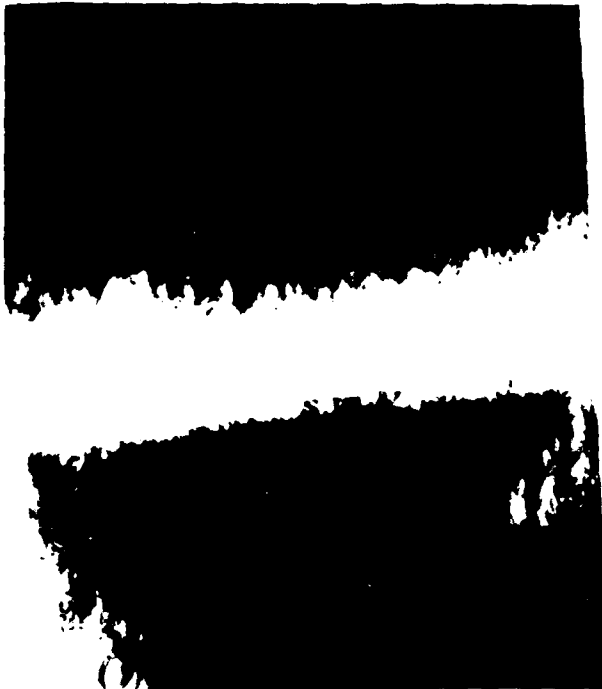


SEM
Micrograph
of Film
Surface



Electron
channeling
pattern taken
near wafer
edge. The
sharp pattern
emanates from
the exposed
substrate
surface. The
ICB film
(top) does
not yield a
channeling
pattern.

SAMPLE #007



x22,000



x36,000

TEM Micrographs of Cross-Section



x80,000



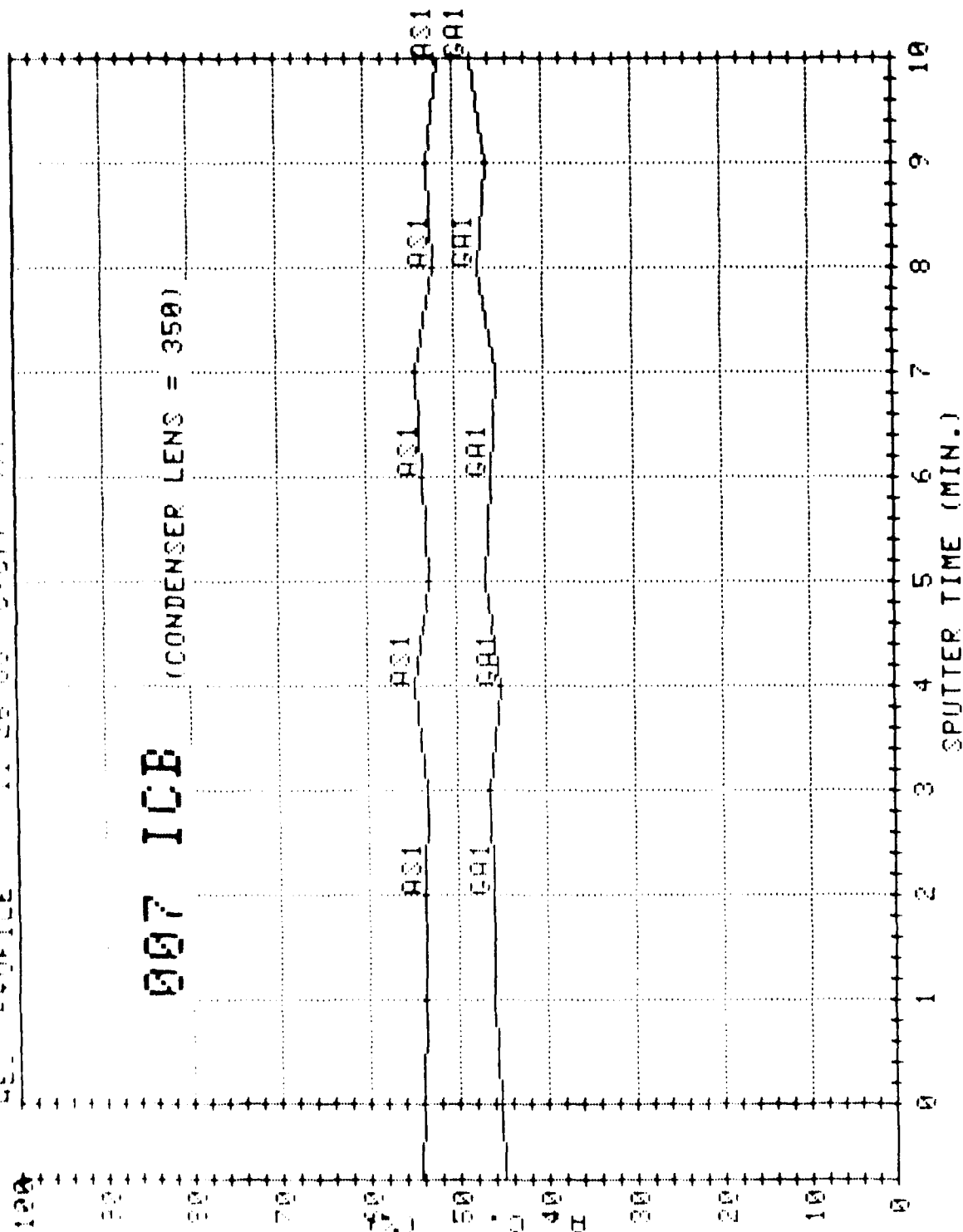
x170,000

TEM Micrographs in Direction Normal to Surface

007 PROFILE 11/26/86 09077 V/F

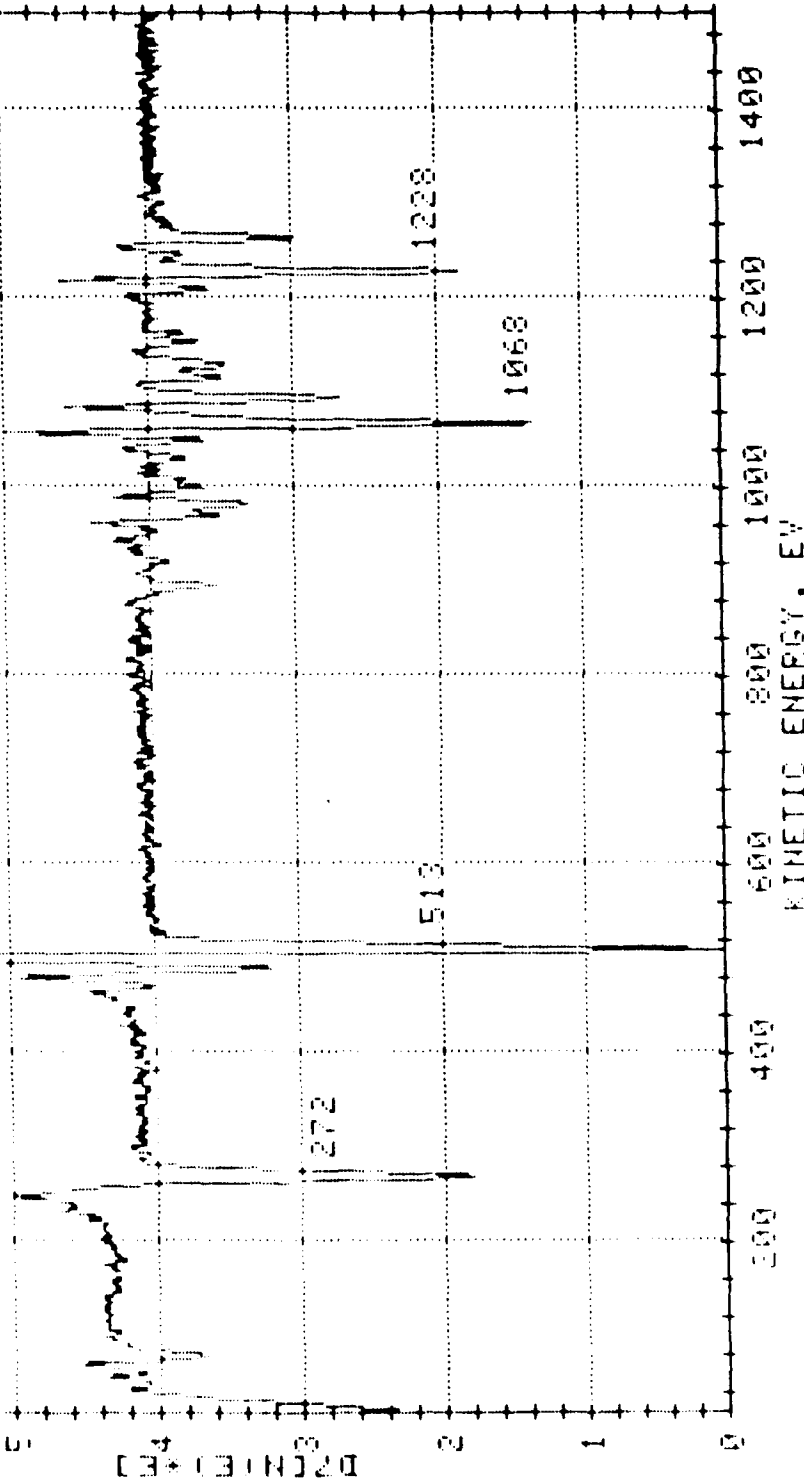
007 ICB

(CONDENSER LENS = 350)



007 ICB BEFORE SPUTTERING

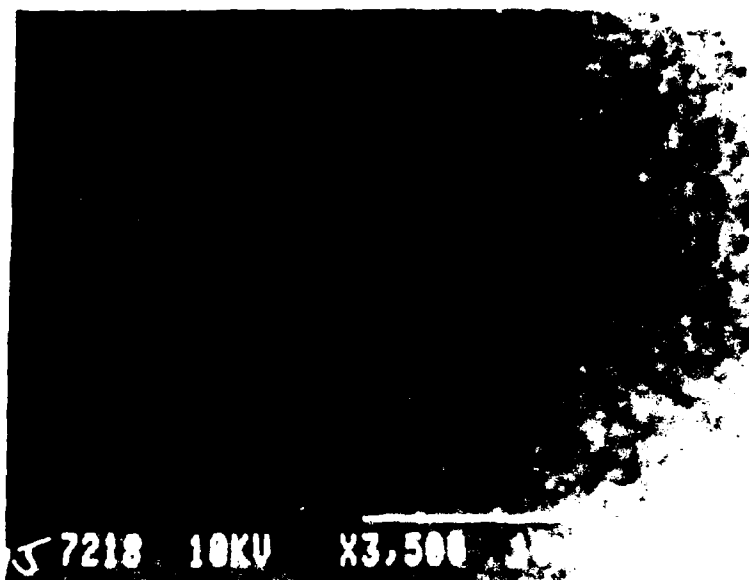
007 ICB
BEFORE SPUTTERING



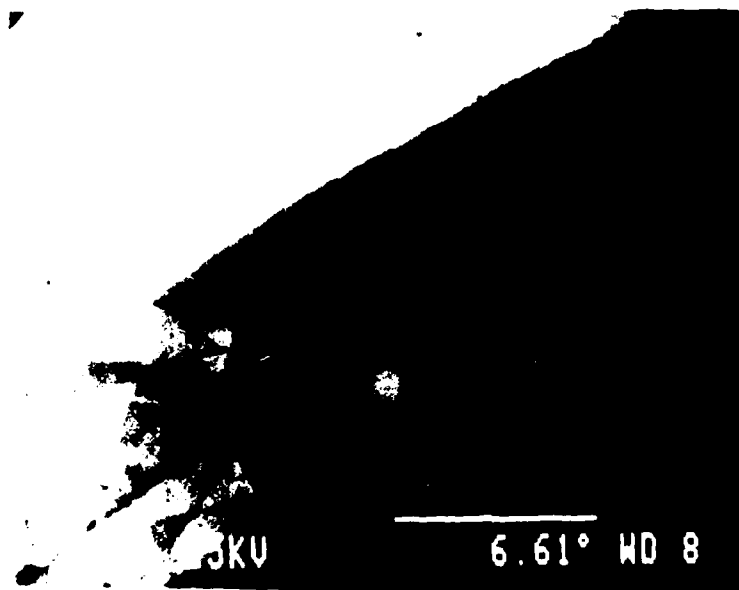
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B-45

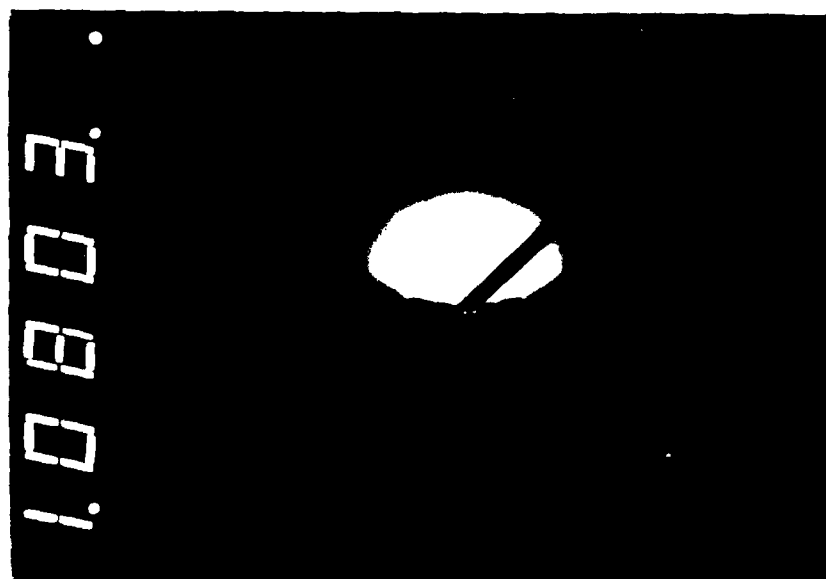
SAMPLE #008



SEM
Micrograph
of Film
Surface

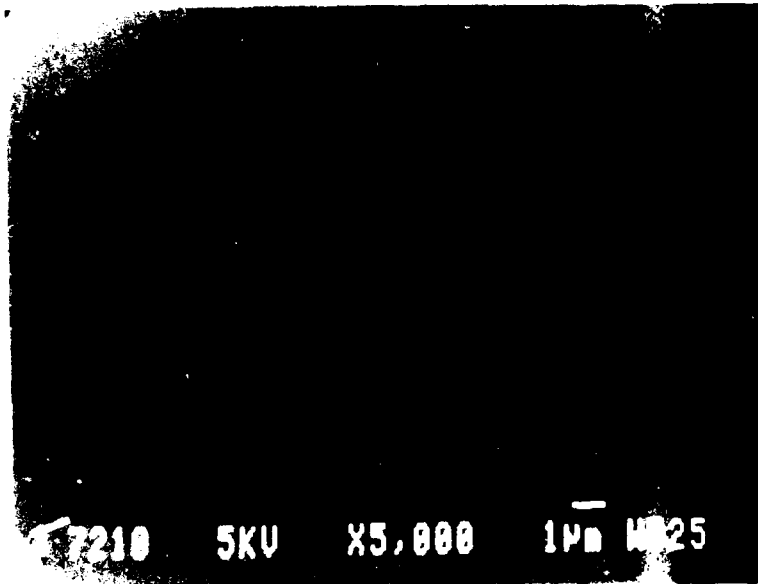


Electron
channeling
pattern taken
near wafer
edge. The
sharp pattern
emanates from
the exposed
substrate
surface. The
ICB film
(top) does
not yield a
channeling
pattern.



RHEED Pattern

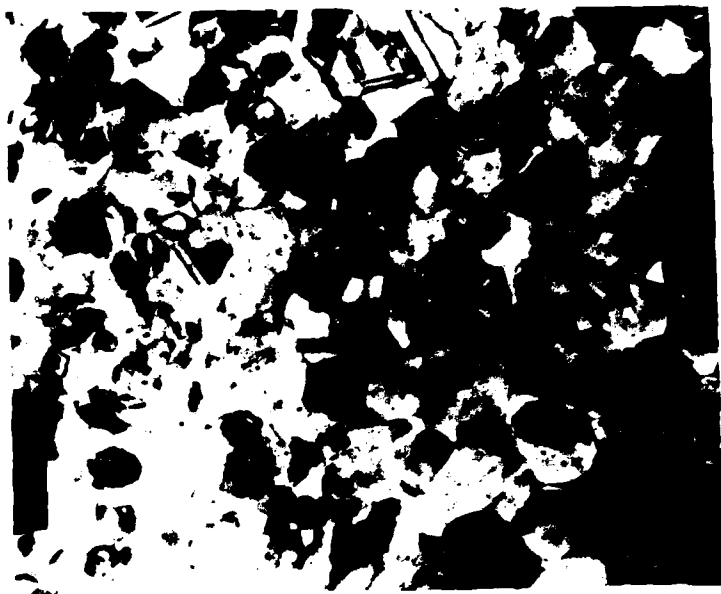
SAMPLE #008



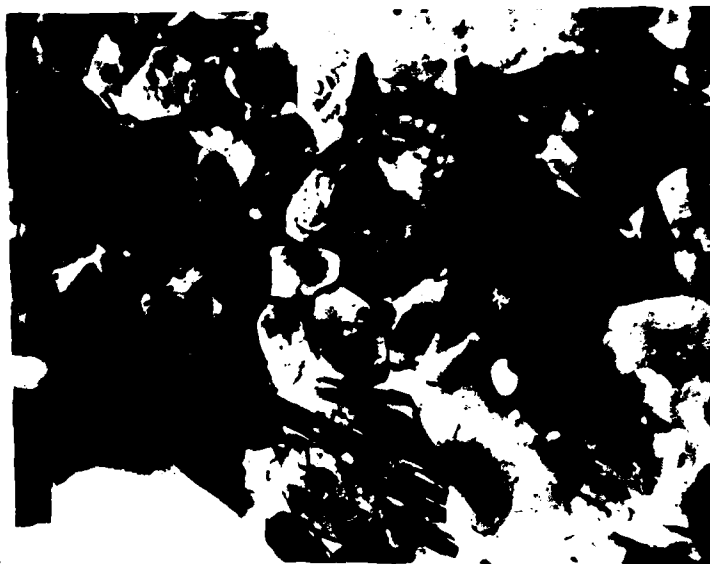
Cleave
Cross
Section

Film
Thickness
Approximately
1.0 μm

SAMPLE #008



x36,000



x36,000



x80,000

TEM Micrographs in Direction Normal to Surface

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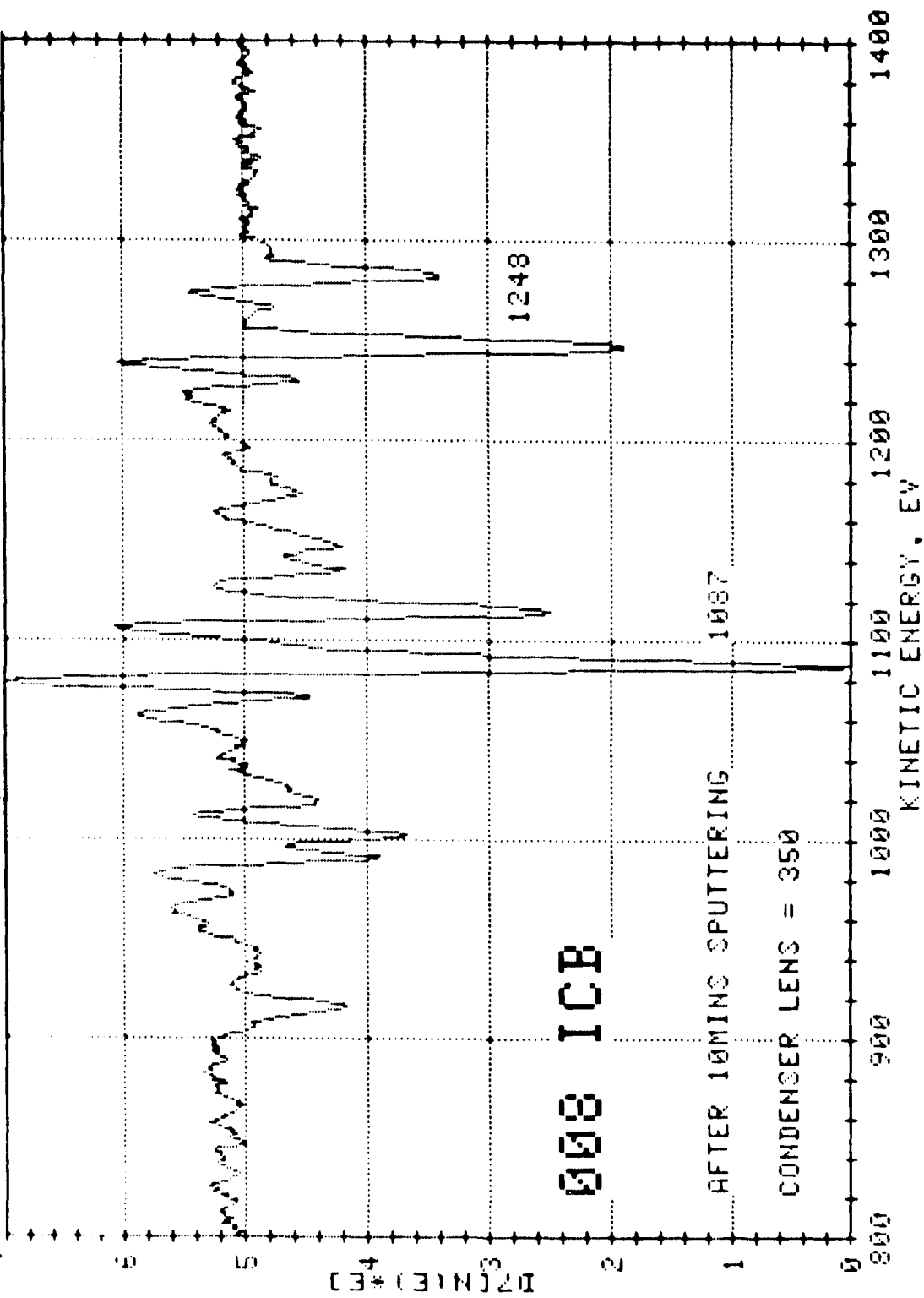
008 ICB

BEF SPUT.

DZINCE*EJ

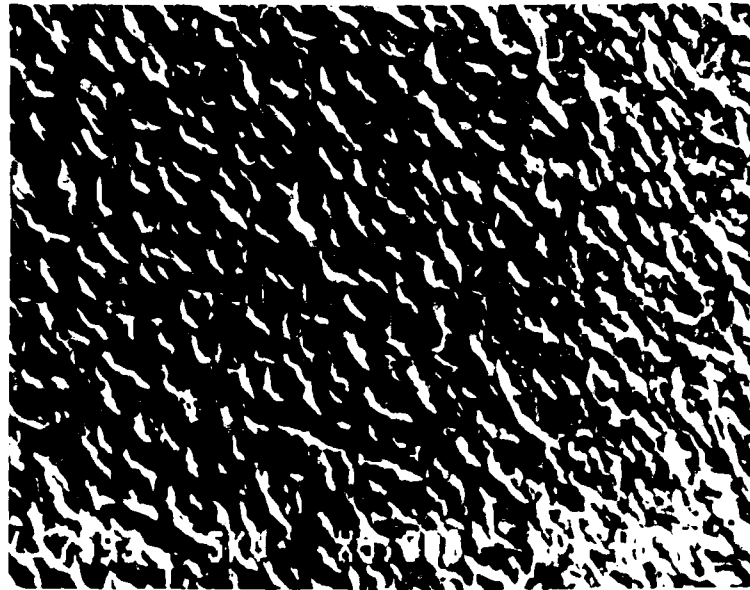
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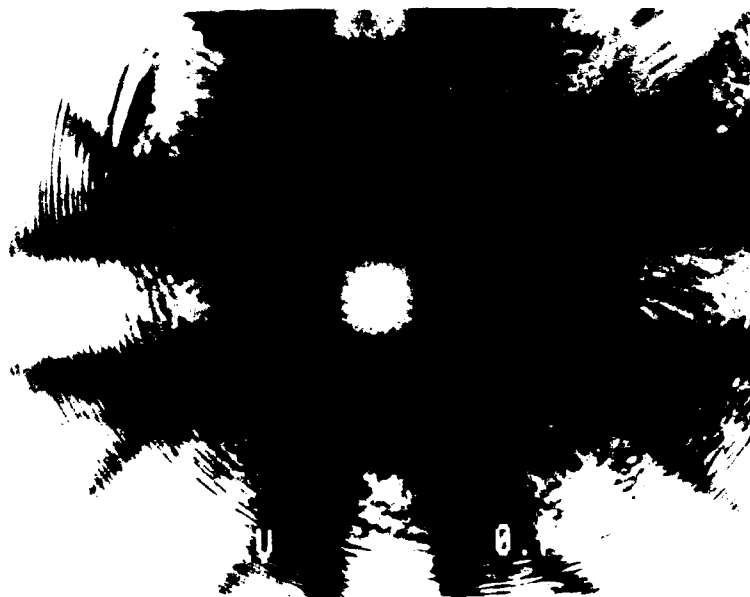


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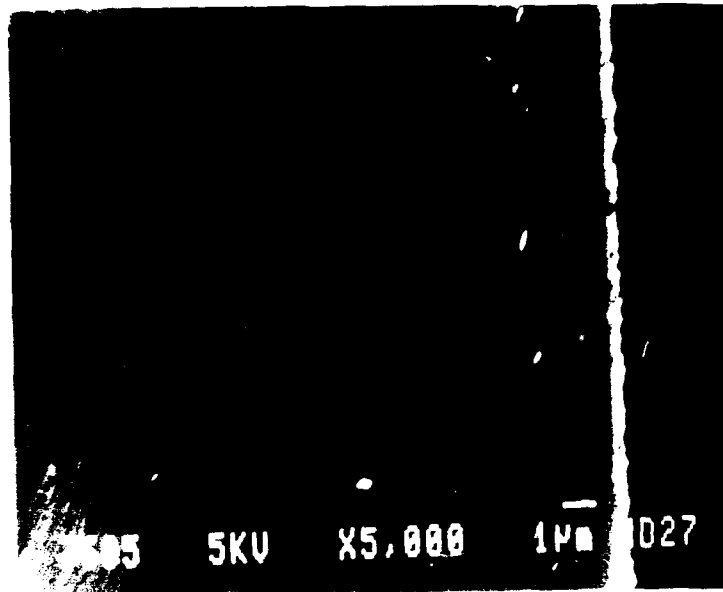


SEM Micrograph of Film Surface



Electron Channeling Pattern from Film Surface

SAMPLE #010



Cleave
Cross
Section

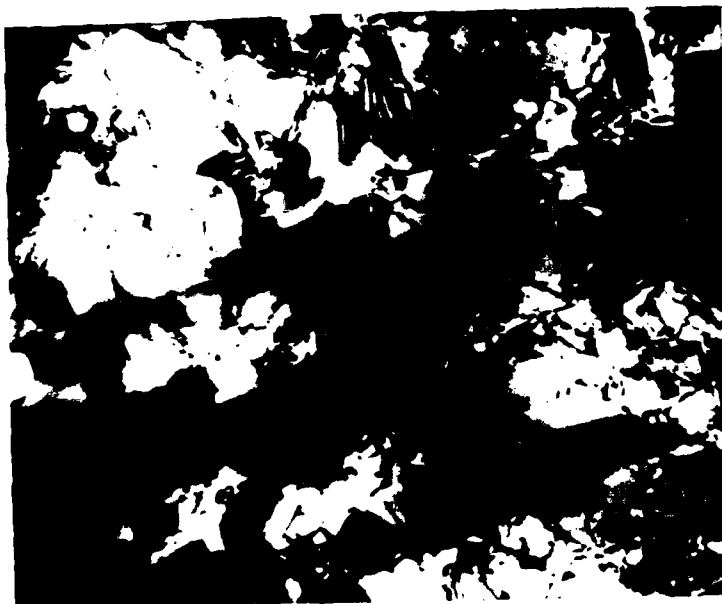
Film
Thickness
Approximately ?

SAMPLE #010



x30,000

TEM Micrograph of Cross-Section



x36,000

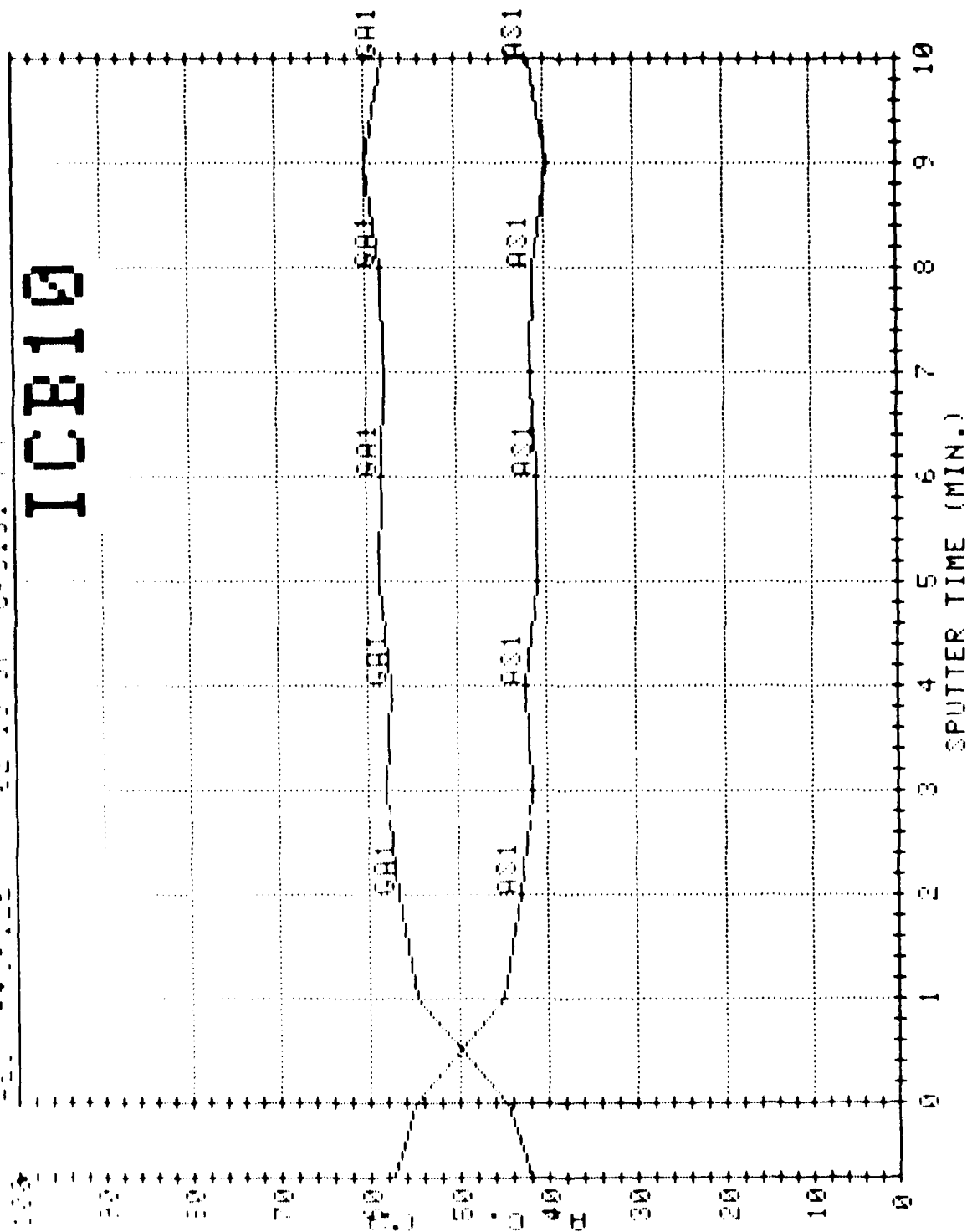


x80,000

TEM Micrographs in Direction Normal to Surface

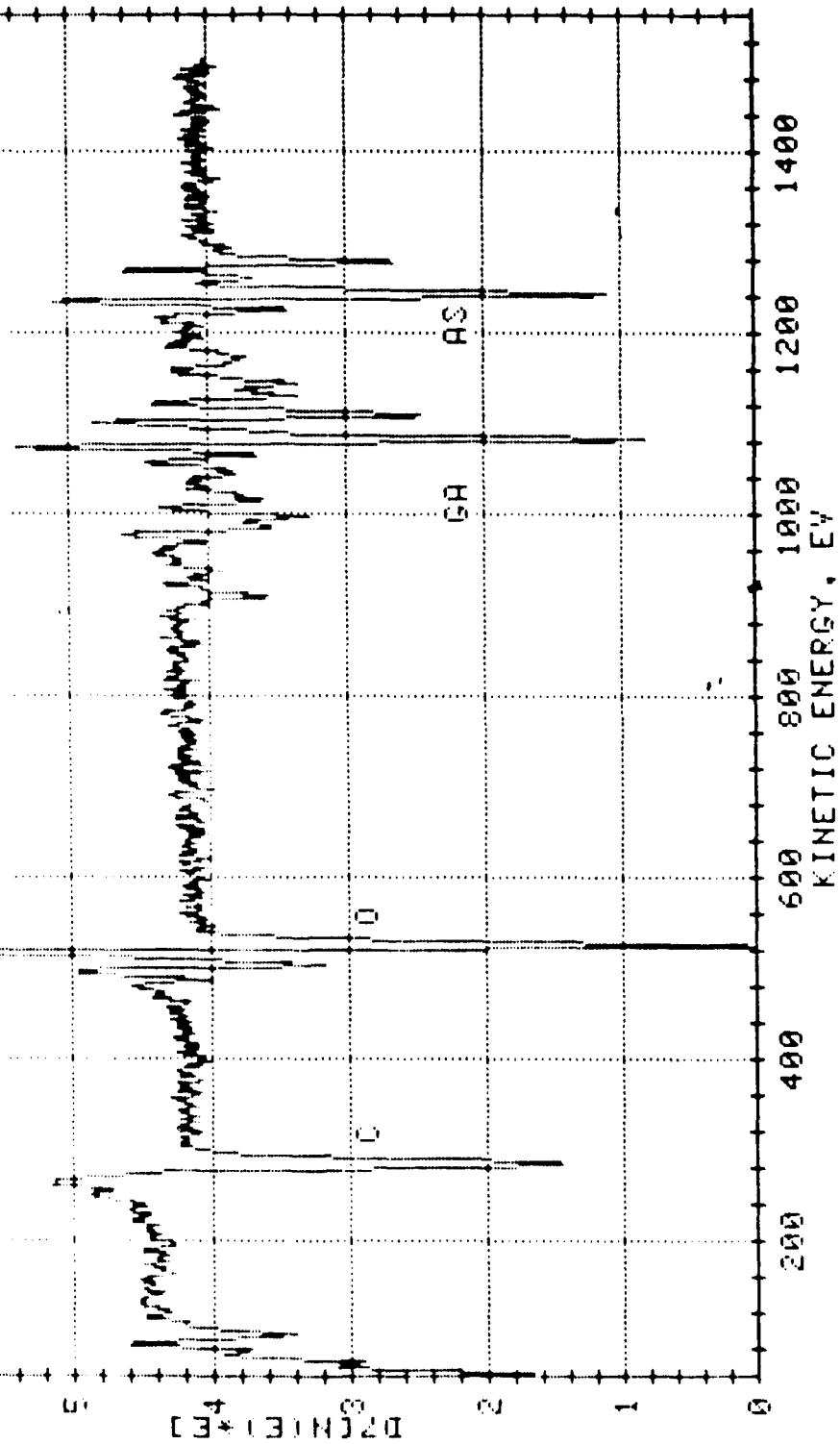
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ICB10



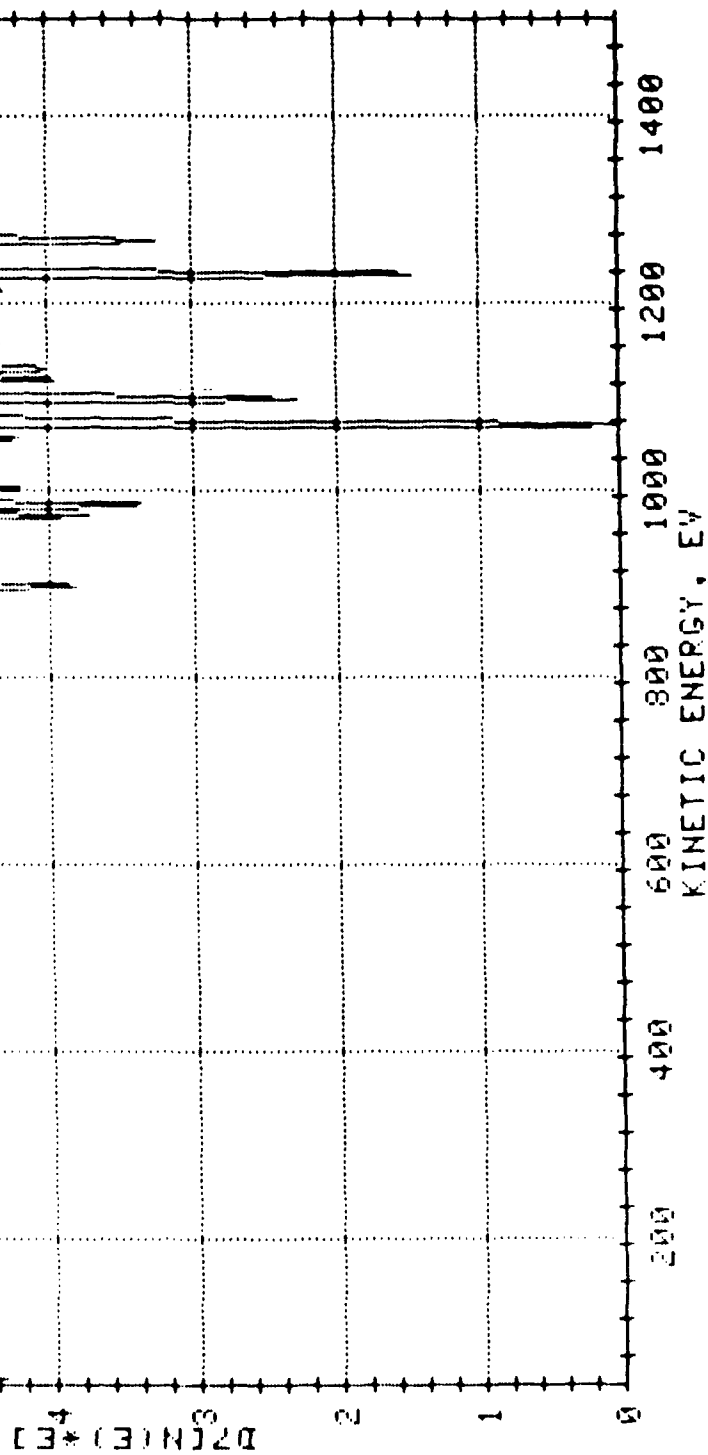
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ICE 010 SURFACE BEFORE SPUTTERING



DEC 11 1987 15:33:24.0, .000 DAY=10.25 02/18/87 CPC136 V/F

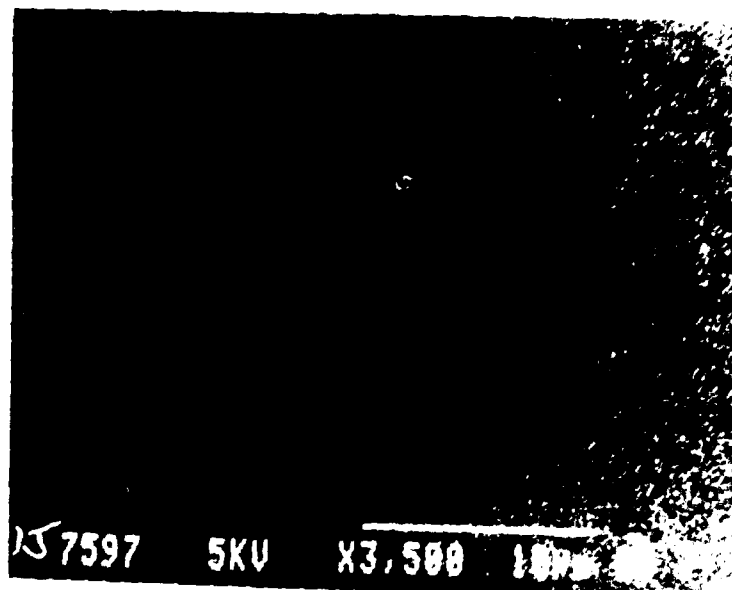
ICB #10 AFTER 20MIN SPU



RUN NO. 011

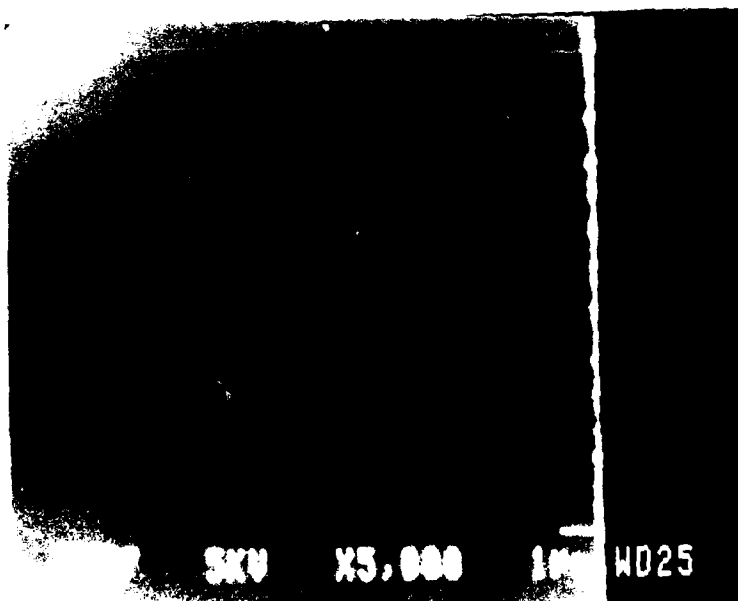
B-52

SAMPLE #011



Film
Surface

157597 5KV X3,500 100μm

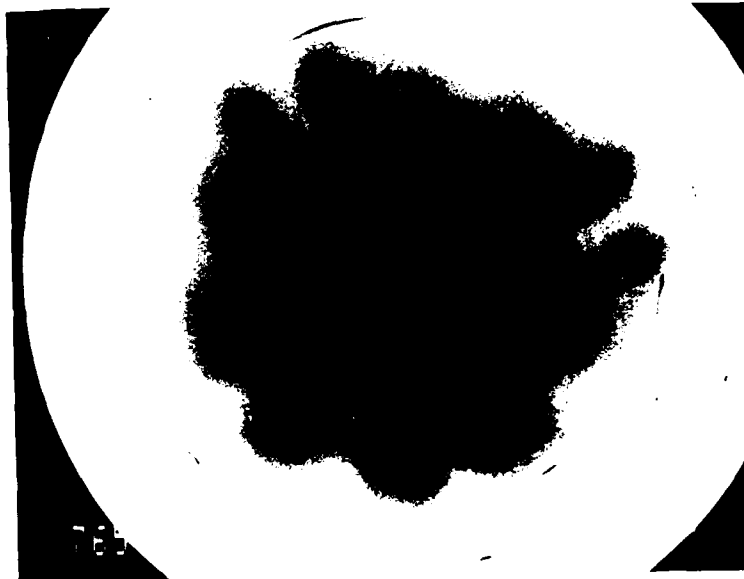


Cleave
Cross
Section

Film
Thickness
Approximately ?

5KV X5,000 100μm WD25

SAMPLE #011



ECP
(Film)

B-60

SAMPLE #011



x130,000

TEM Micrograph of Cross-Section



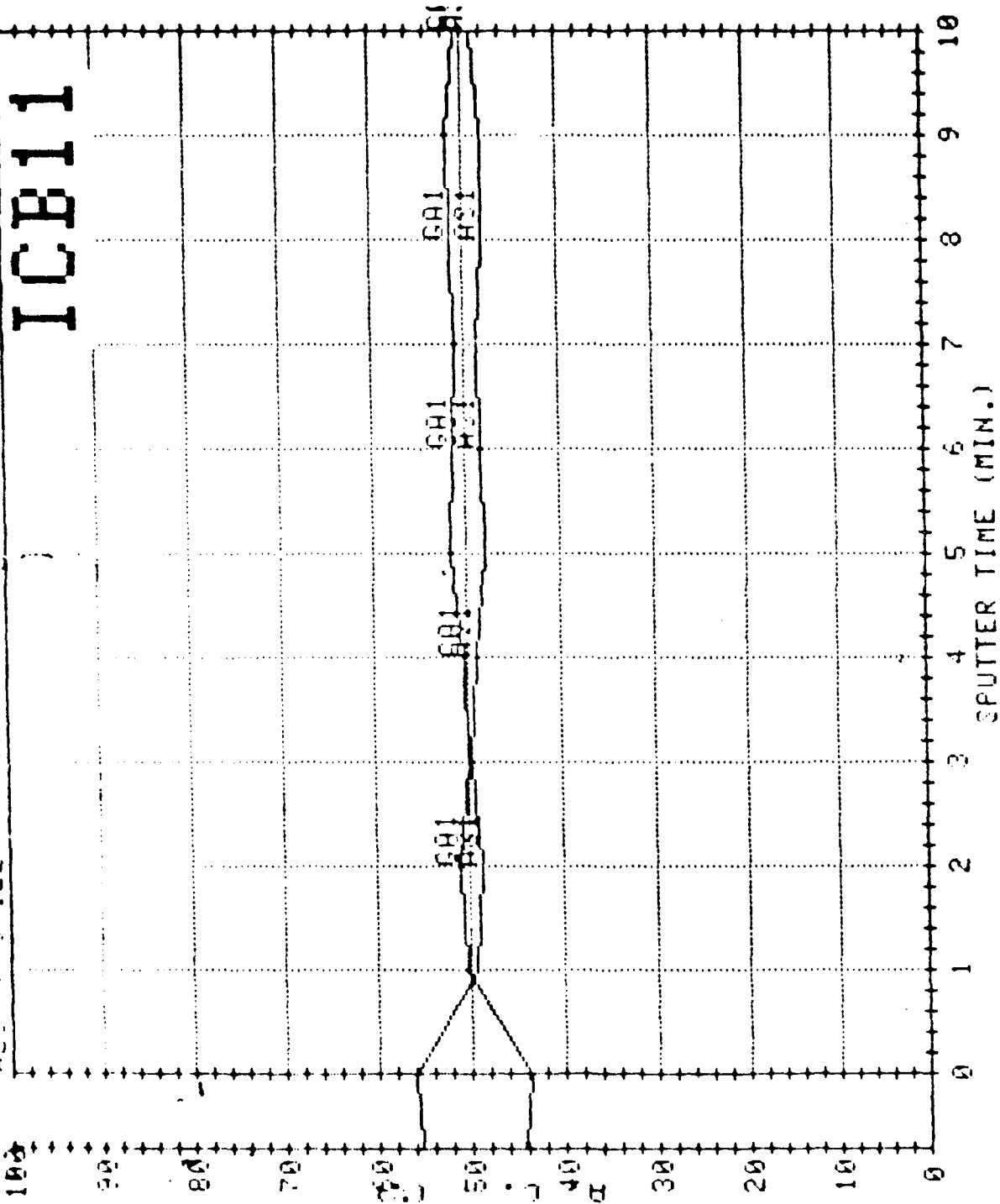
x36,000



x80,000

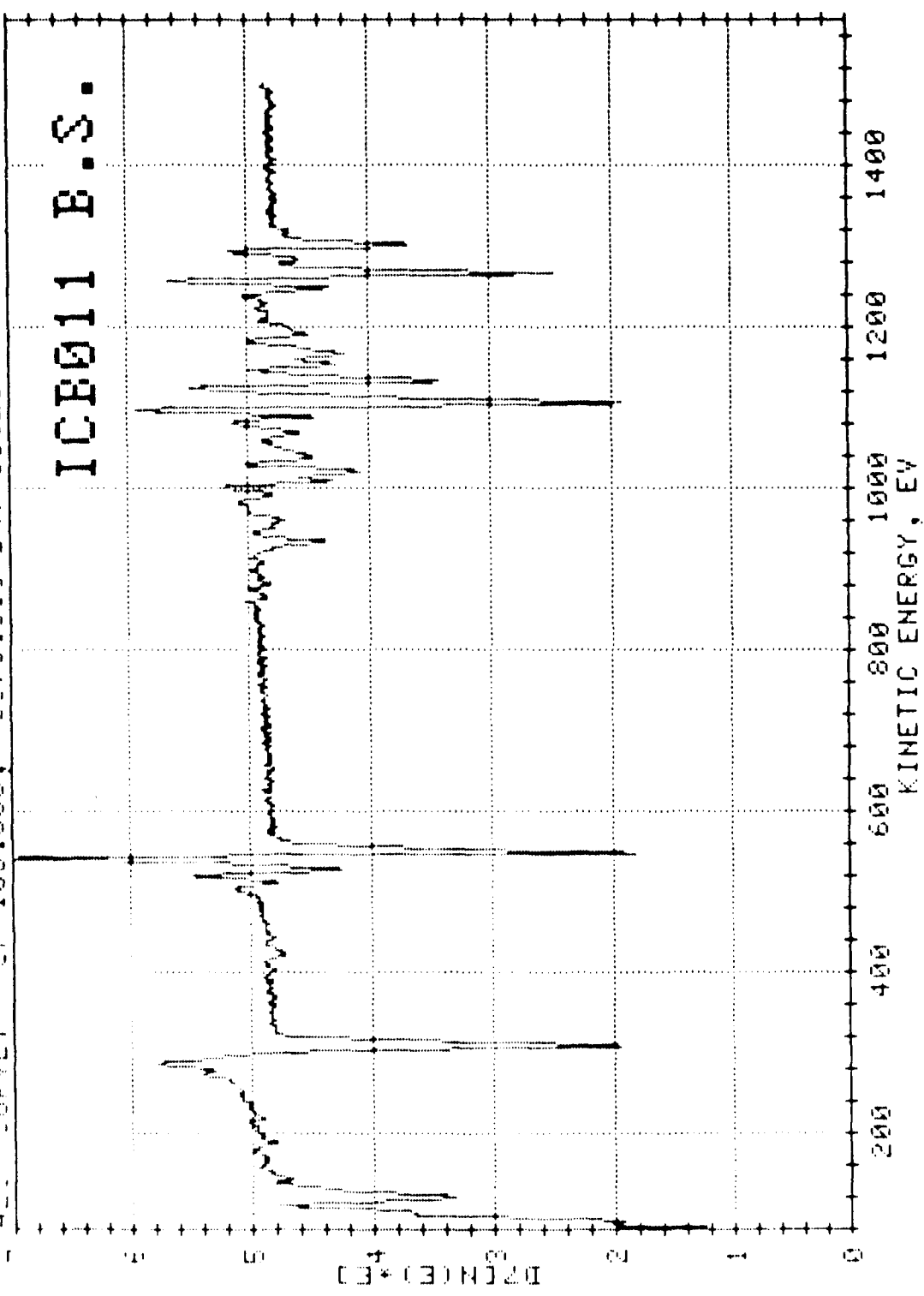
TEM Micrographs in Direction Normal to Surface

REF PROFILE 02 13 87 CRO130 WLF



SEC SURVEY CF=183.066, -3075.510 DAT=10.26 01/15/86 CRC108 V/F

ICB011 E.S.

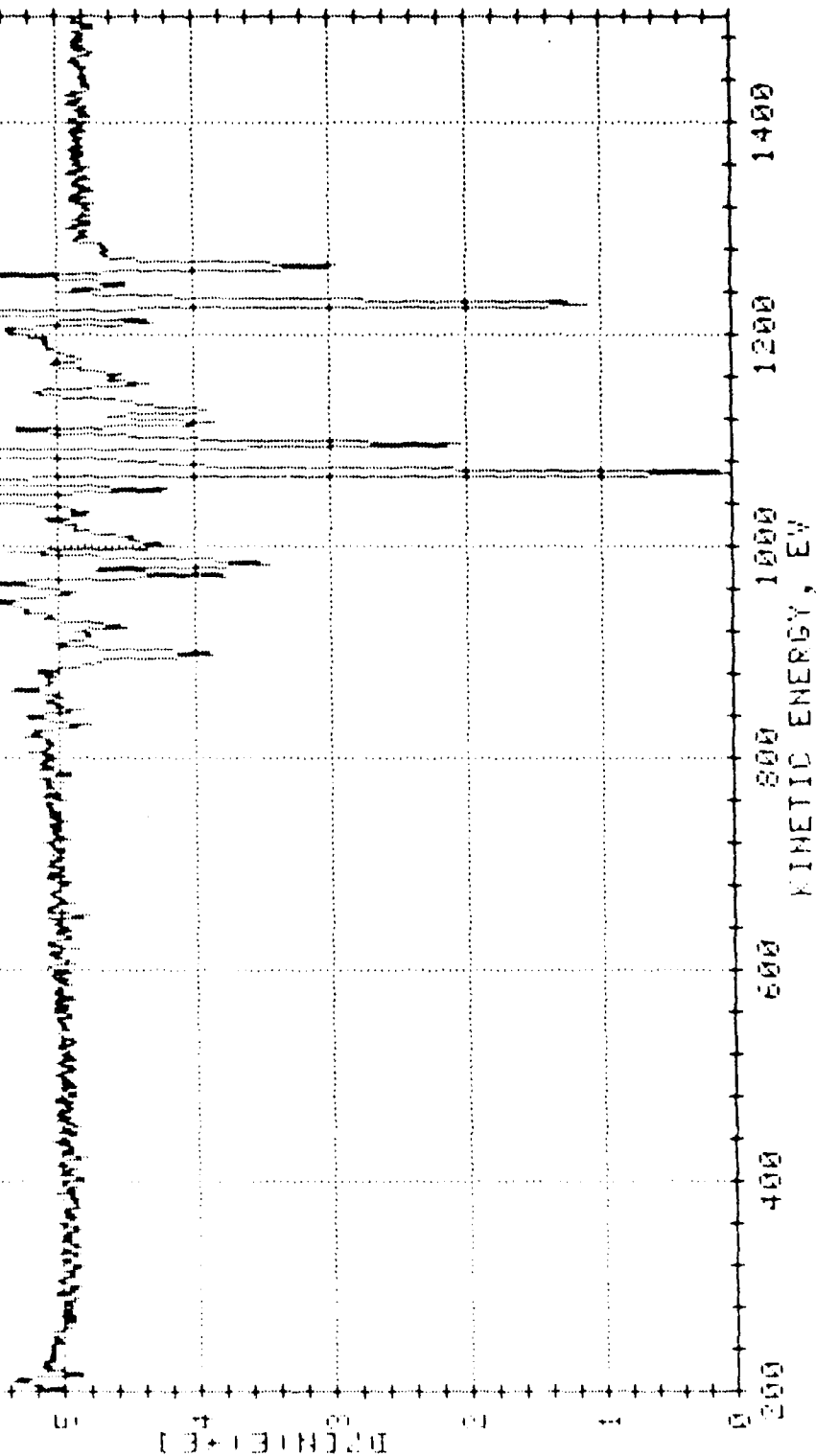


REF: 1.00EY OF=134.756, .000 DAT=10.26 01/16/66 CP0117 V/F

E111 ICB

AFTER 10MIN CPU TTERINS

COND. LEND=350

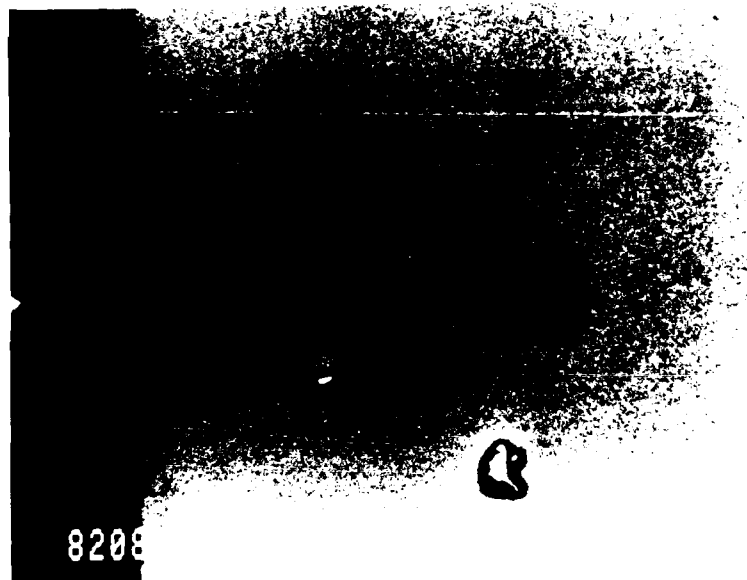


RUN NO. 012

SAMPLE #012



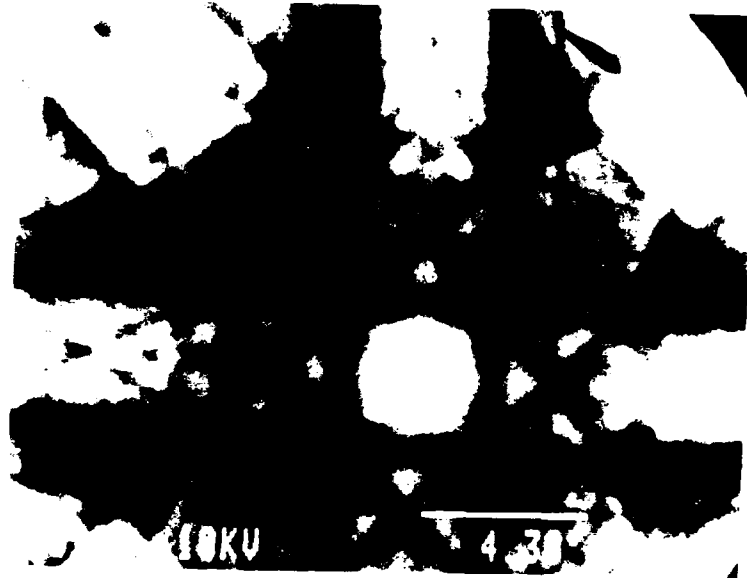
Film
Surface



Cleave
Cross
Section

Film
Thickness
Approximately ?

SAMPLE #012



ECP
(Film)

B-67

SAMPLE #012



x36,000

TEM Micrographs in Direction Normal to Surface



x36,000

SAMPLE #012



x13,000



x46,000

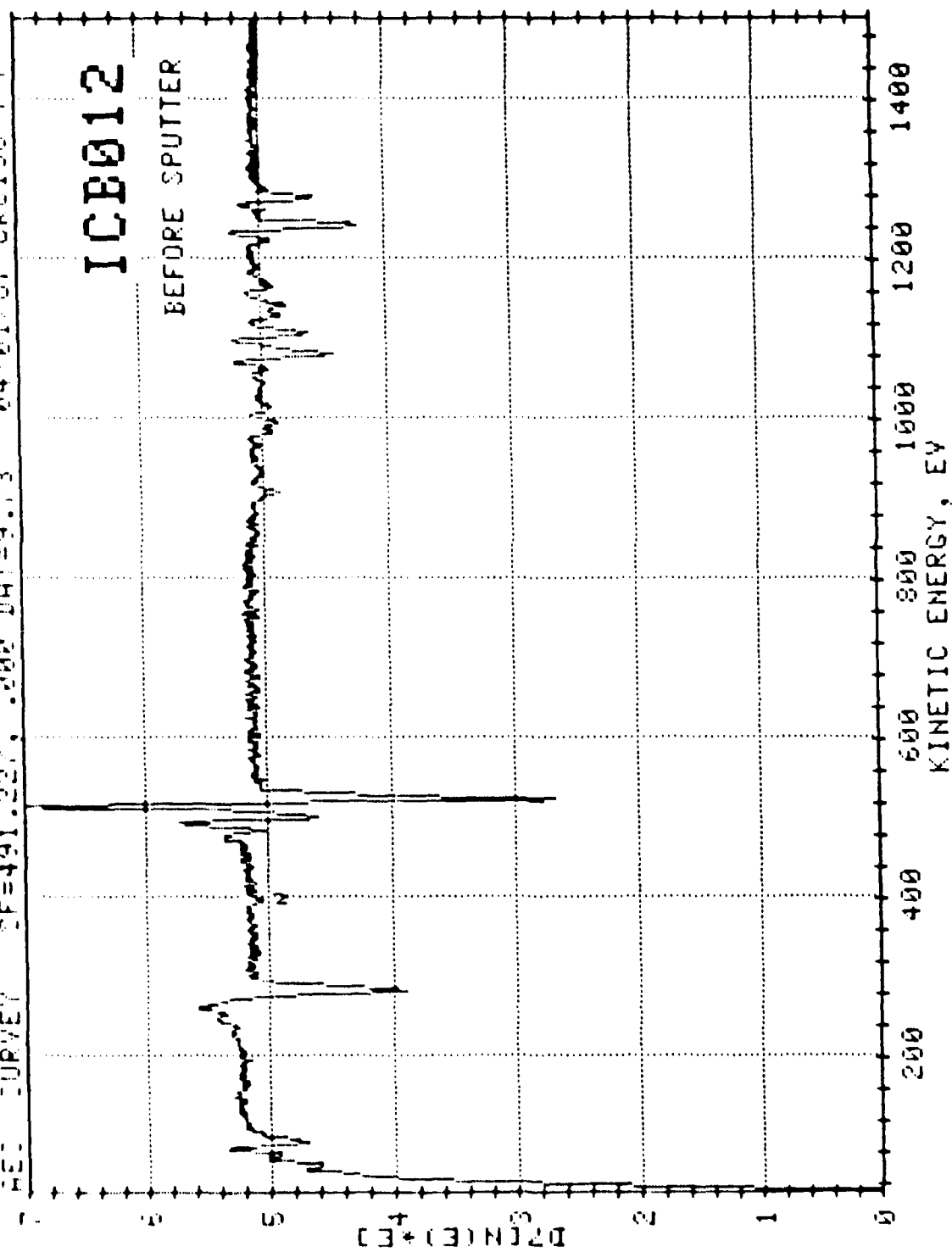


x60,000

REC SURVEY CF=491.227, .200 DAY=9.73 04-21/87 CRC138 V.F

ICB012

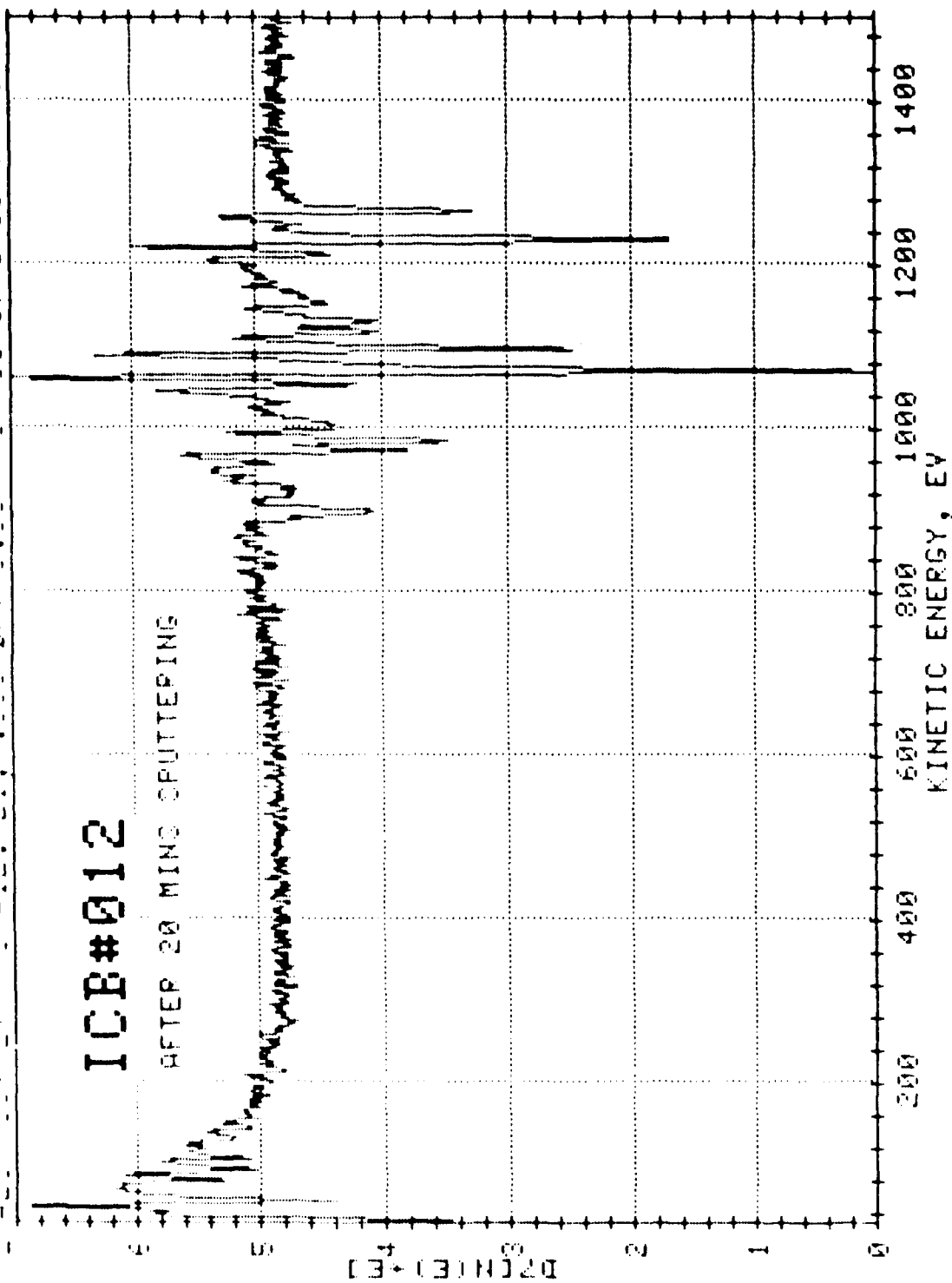
BEFORE SPUTTER



EE: 11.95V EF: 12.70V .000 DAY=8.53 24/01/87 CRC144 P-C

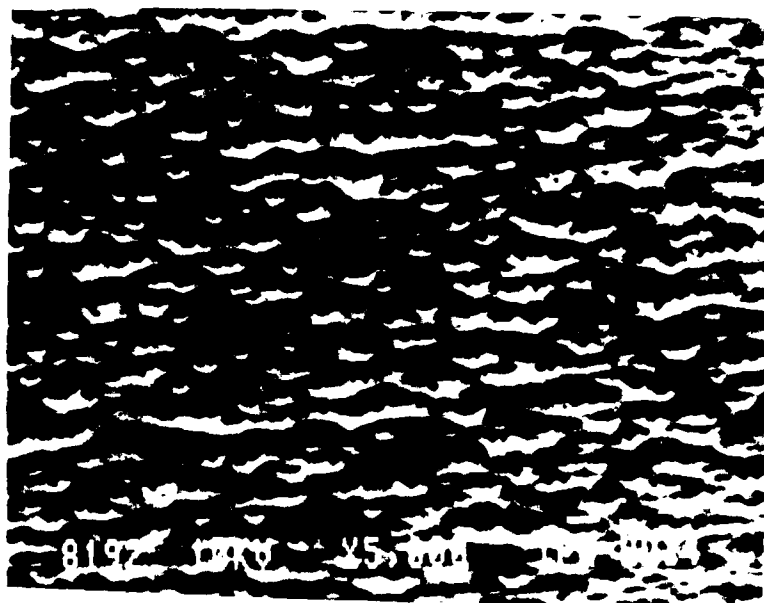
ICB#012

AFTER 20 MINO SPUTTERING

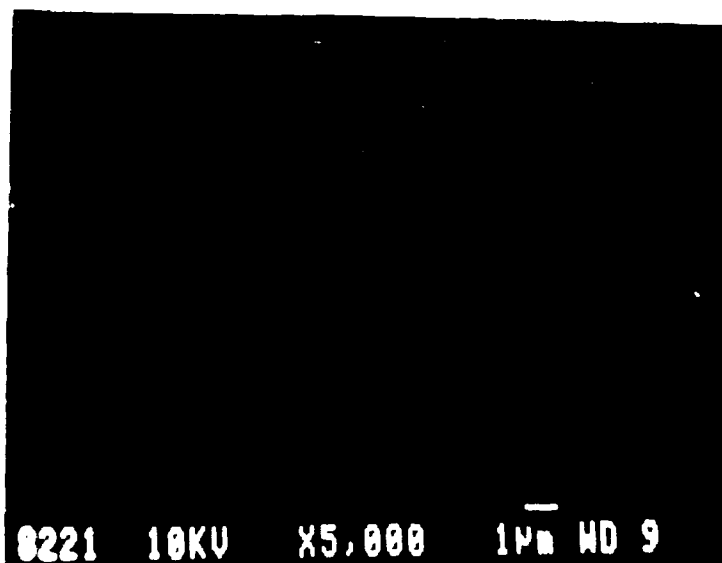


RUN NO. 013

SAMPLE #013



Film
Surface



Cleave
Cross
Section

Film
Thickness
Approximately ?

SAMPLE #013



ECP
(Film)

SAMPLE #013



x28,000

TEM Micrograph of Cross-Section



x36,000



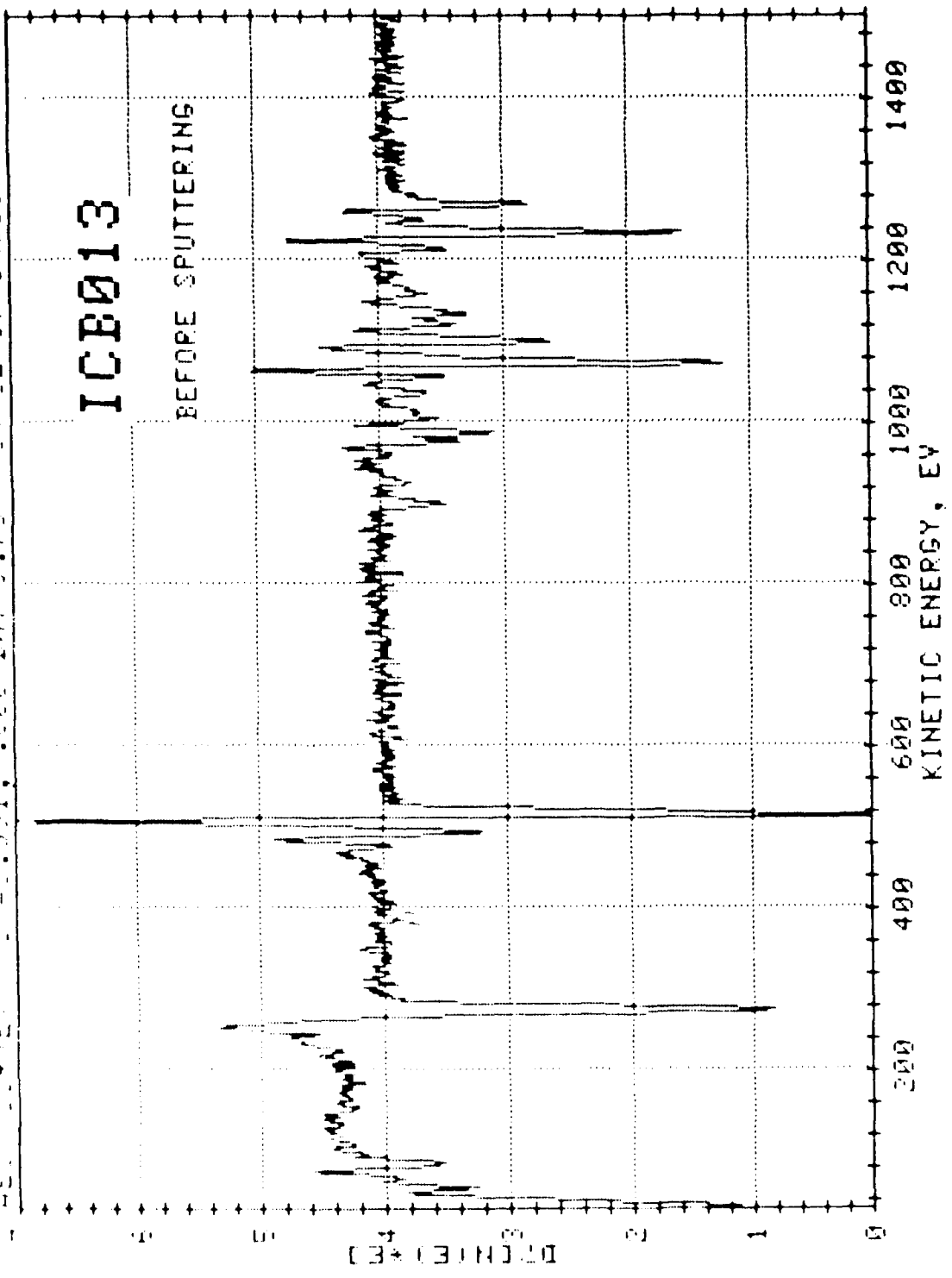
x80,000

TEM Micrographs in Direction Normal to Surface

000 000000 0000.591, .000 DAT=9.73 04 02/87 CPC157 P-D

ICB013

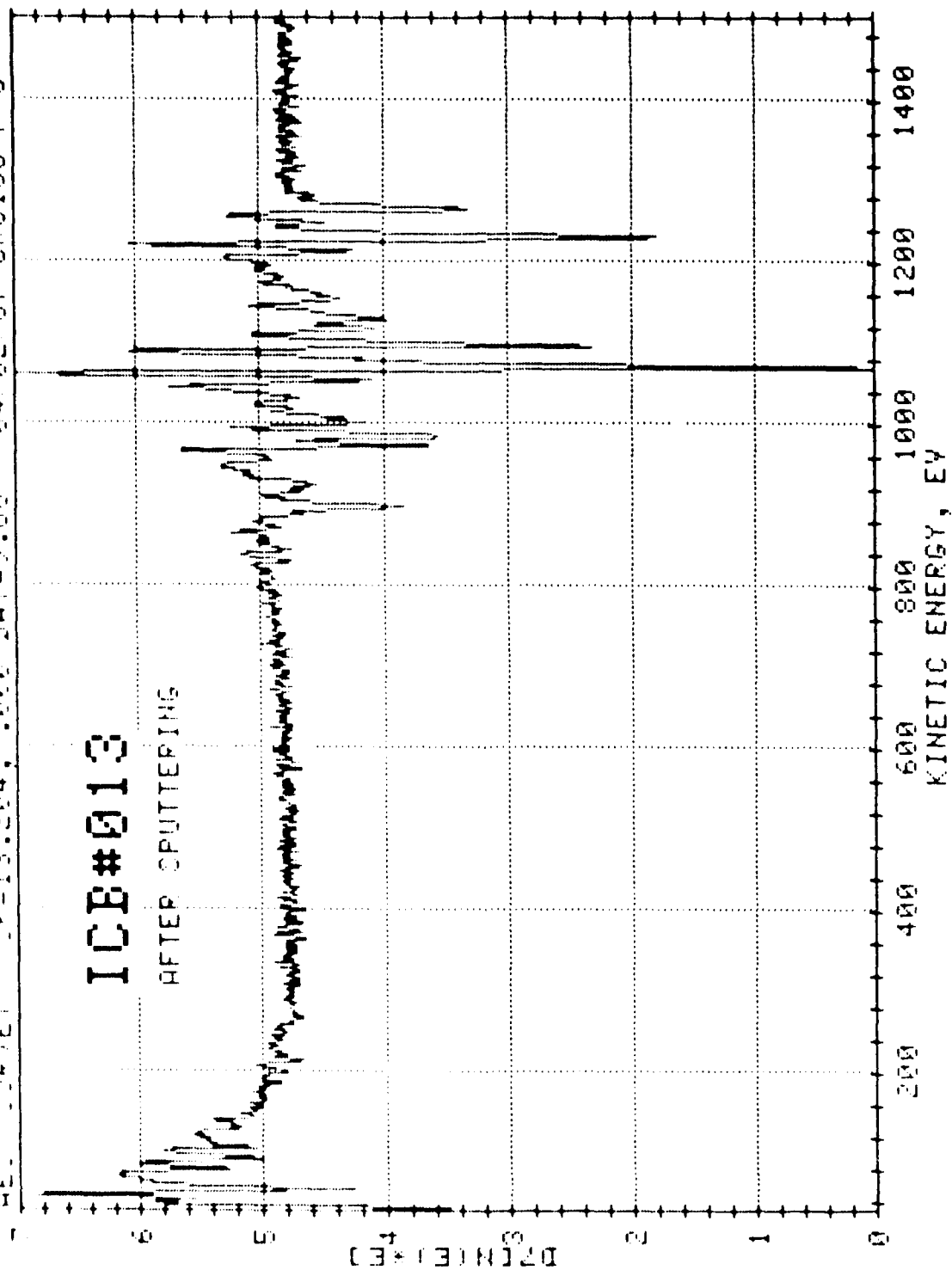
BEFORE SPUTTERING



REC SURVEY IF=13.204, .000 DAT=9.88 04/02/87 CRC163 P-C

ICB#013

AFTER CRUTTERING

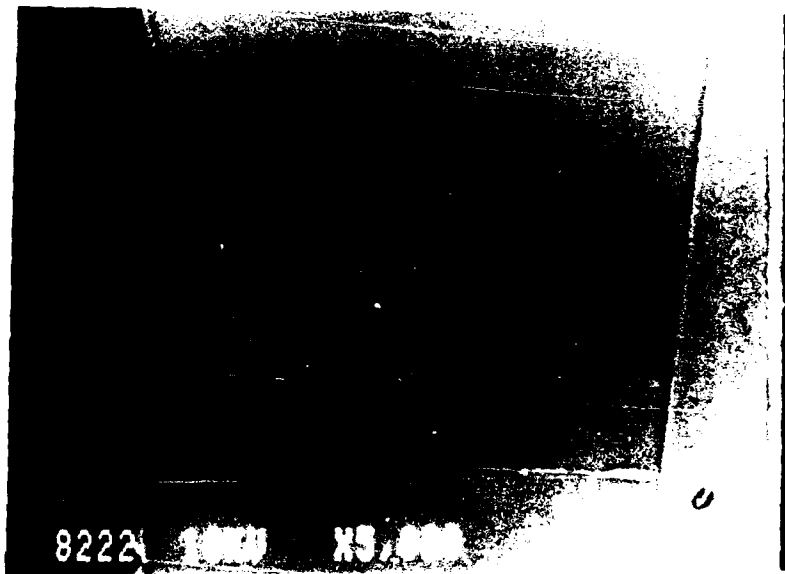


RUN NO. 014

SAMPLE #014



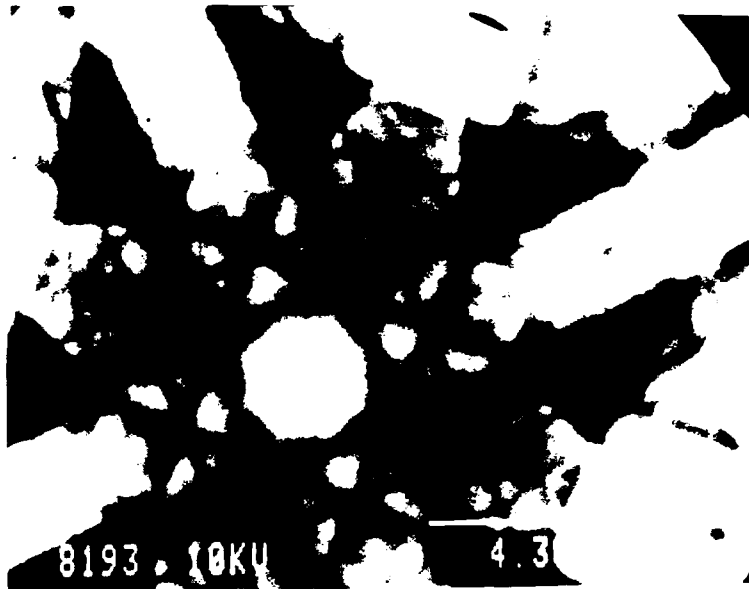
Film
Surface



Cleave
Cross
Section

Film
Thickness
Approximately ?

SAMPLE #014



ECP
(Film)

8193. 10KV 4.3

SAMPLE #014



x36,000

TEM Micrograph of Cross-Section



x36,000



x80,000

TEM Micrographs in Direction Normal to Surface

000 1.00E+01 1000.000, 1000 DAT=19.45 04/02/87 CPC156 P-C

ICB014

BEFORE SPUTTERING

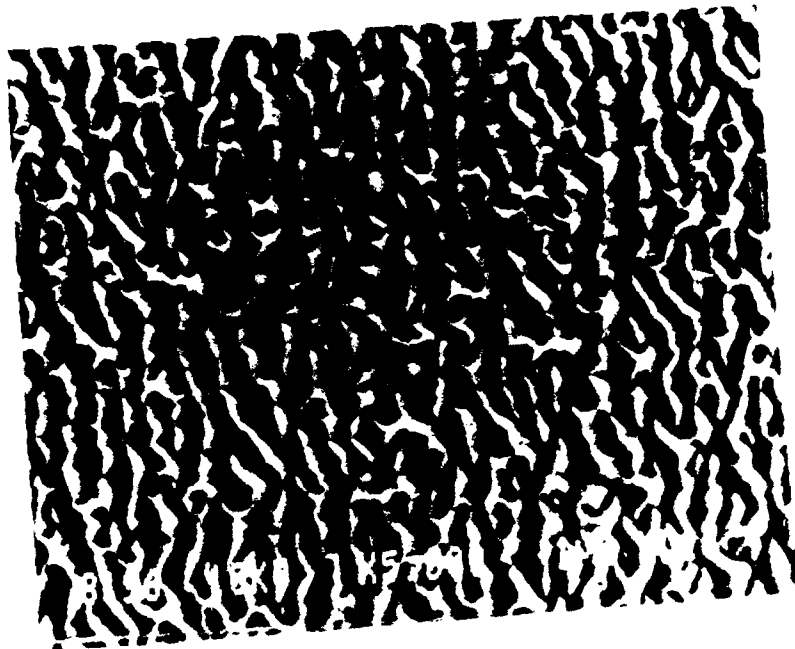
DZ[NIE]*E]

KINETIC ENERGY, EV

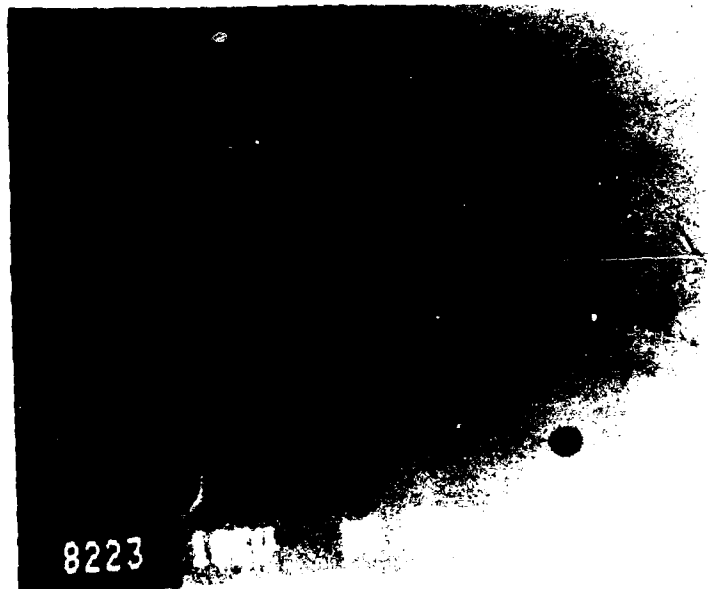
RUN NO. 015

R-83

SAMPLE #015



Film
Surface



Cleave
Cross
Section

Film
Thickness
Approximately ?

SAMPLE #015



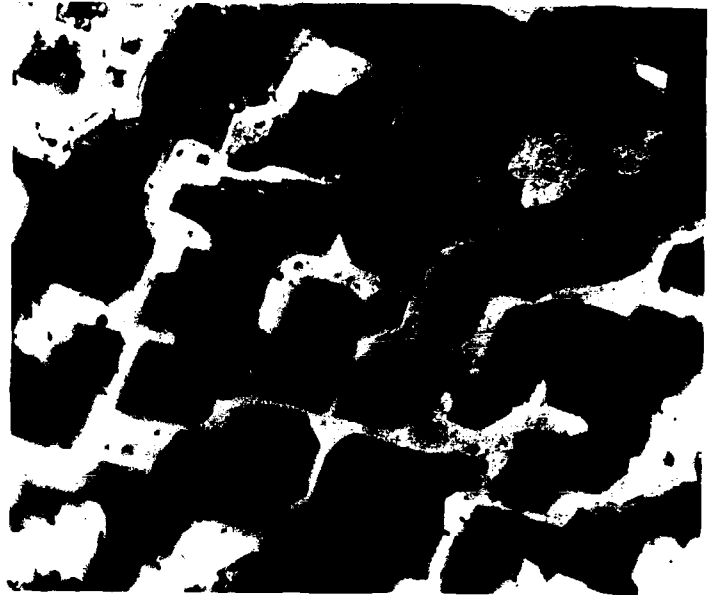
ECP
(Film)

B-95

SAMPLE #015



x6,000



x17,000



x36,000



x80,000

TEM Micrographs in Direction Normal to Surface

B-26

SAMPLE #015



x60,000



x60,000

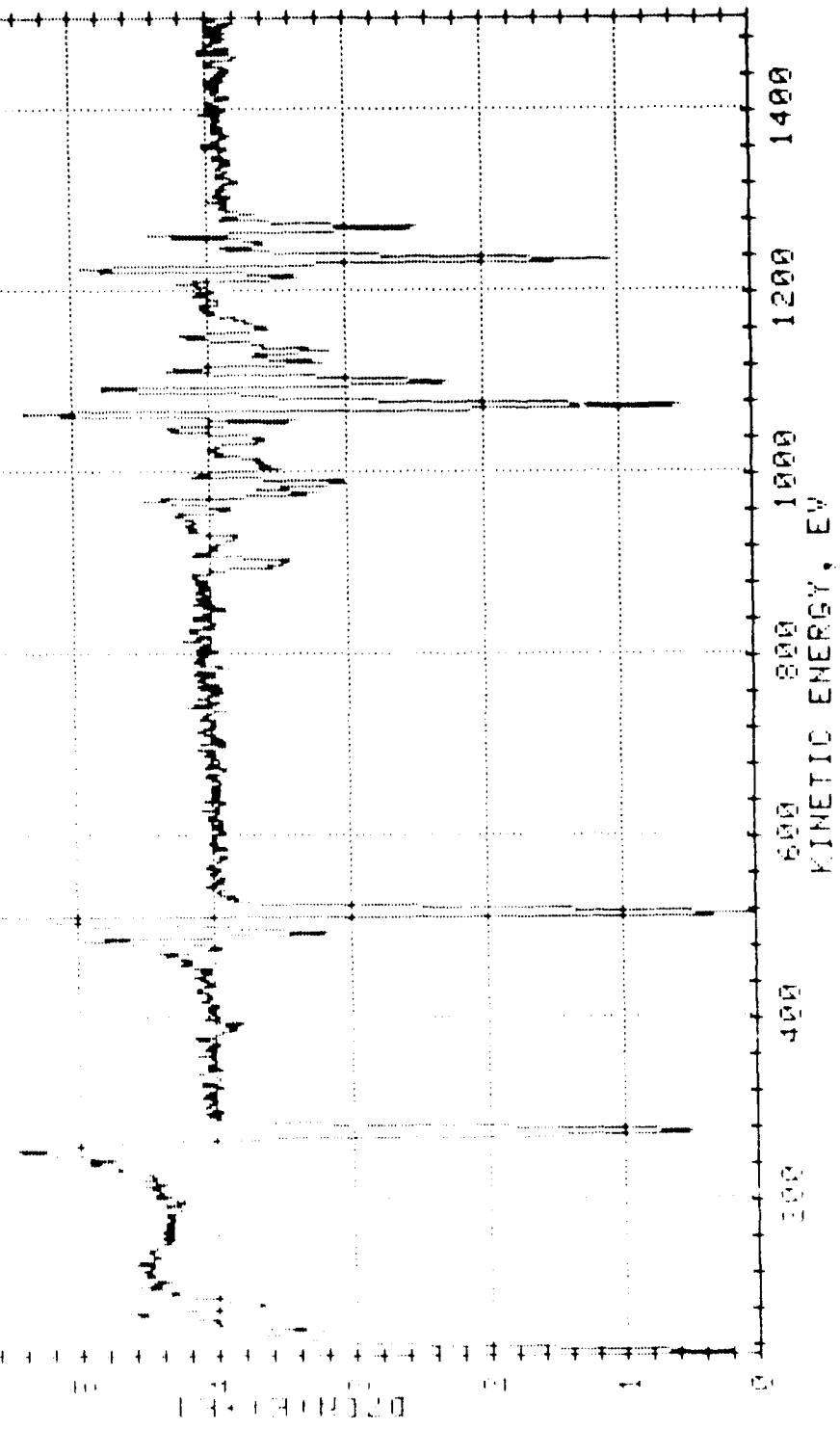
TEM Micrographs of Cross-Section

D-87

[illegible]

51501

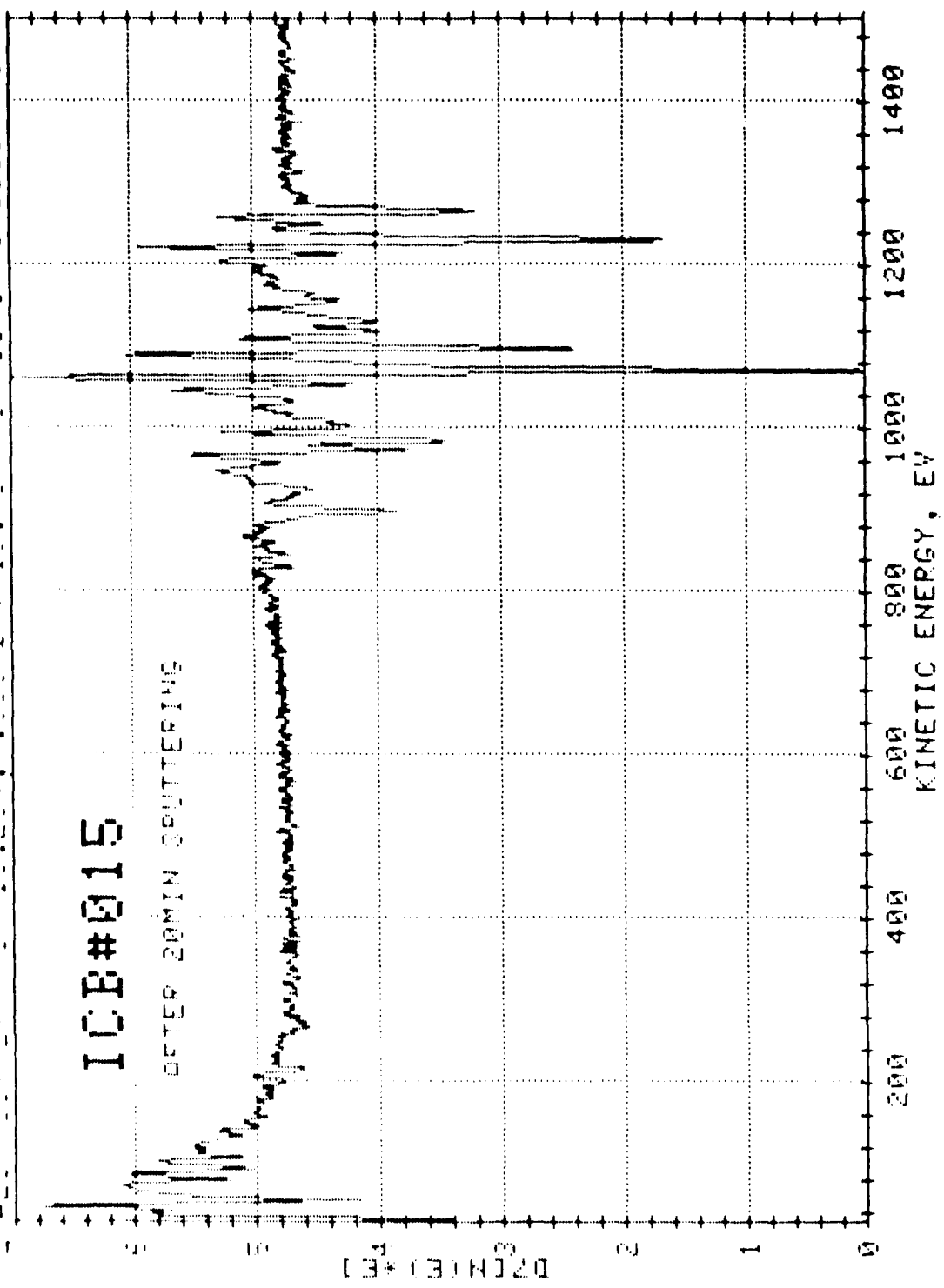
SHIRLEY S. SUGGS



051 115 EV IF=12.204, .000 D07=12.45 04/03/87 CRC180 P-C

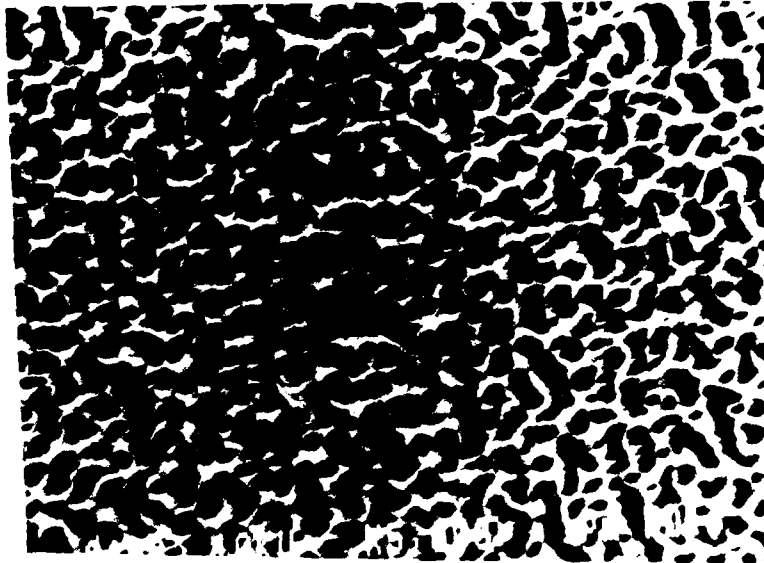
ICB#015

05100 20MIN SPUTTERING

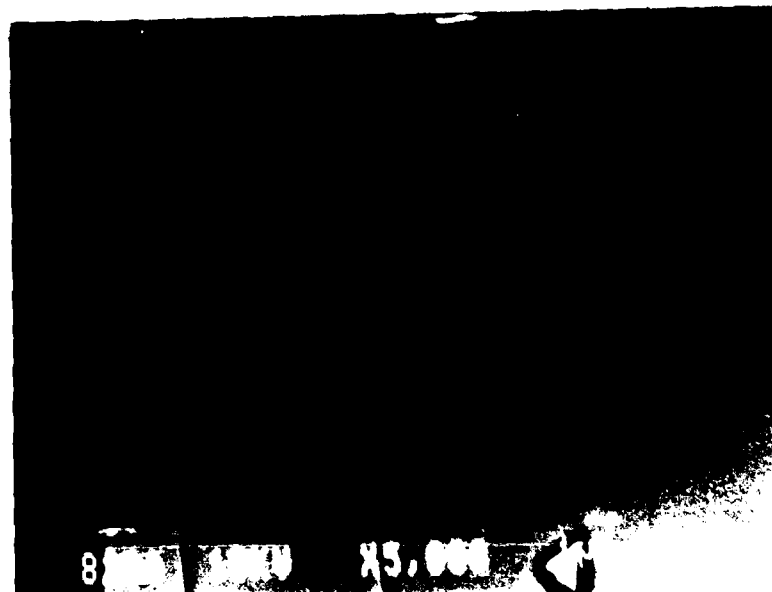


RUN NO. 016

SAMPLE #016



Film
Surface



Cleave
Cross
Section

Film
Thickness
Approximately ?

SAMPLE #016



ECP
(Film)

8197 10KV

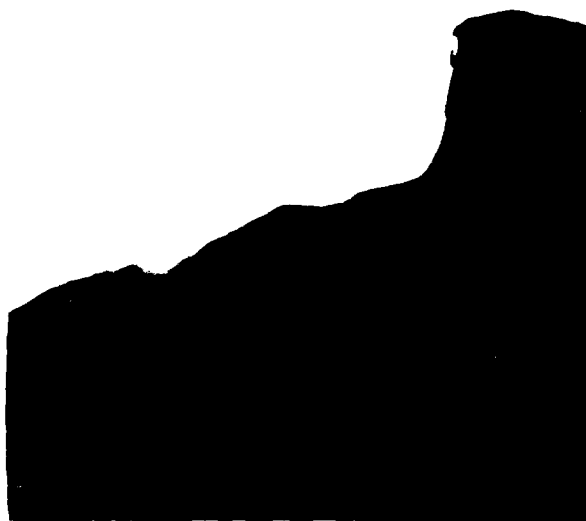
B-92

SAMPLE #016



x36,000

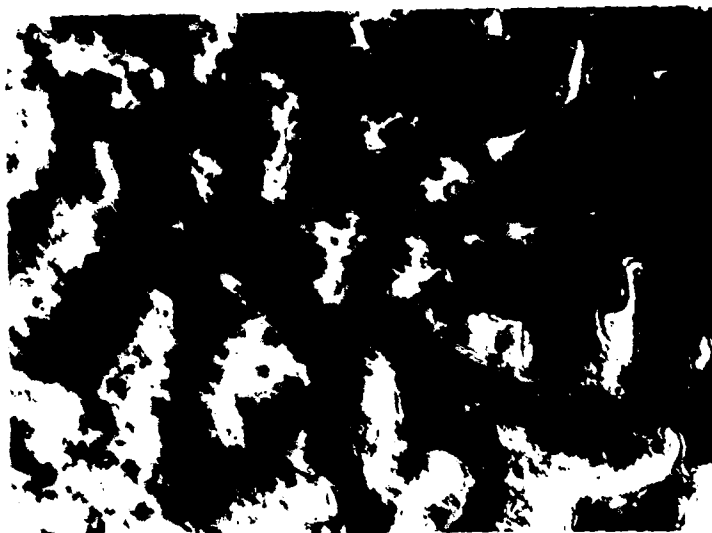
TEM Micrographs of Cross-Section



x60,000

B-93

SAMPLE #016



x17,000



x36,000



x80,000

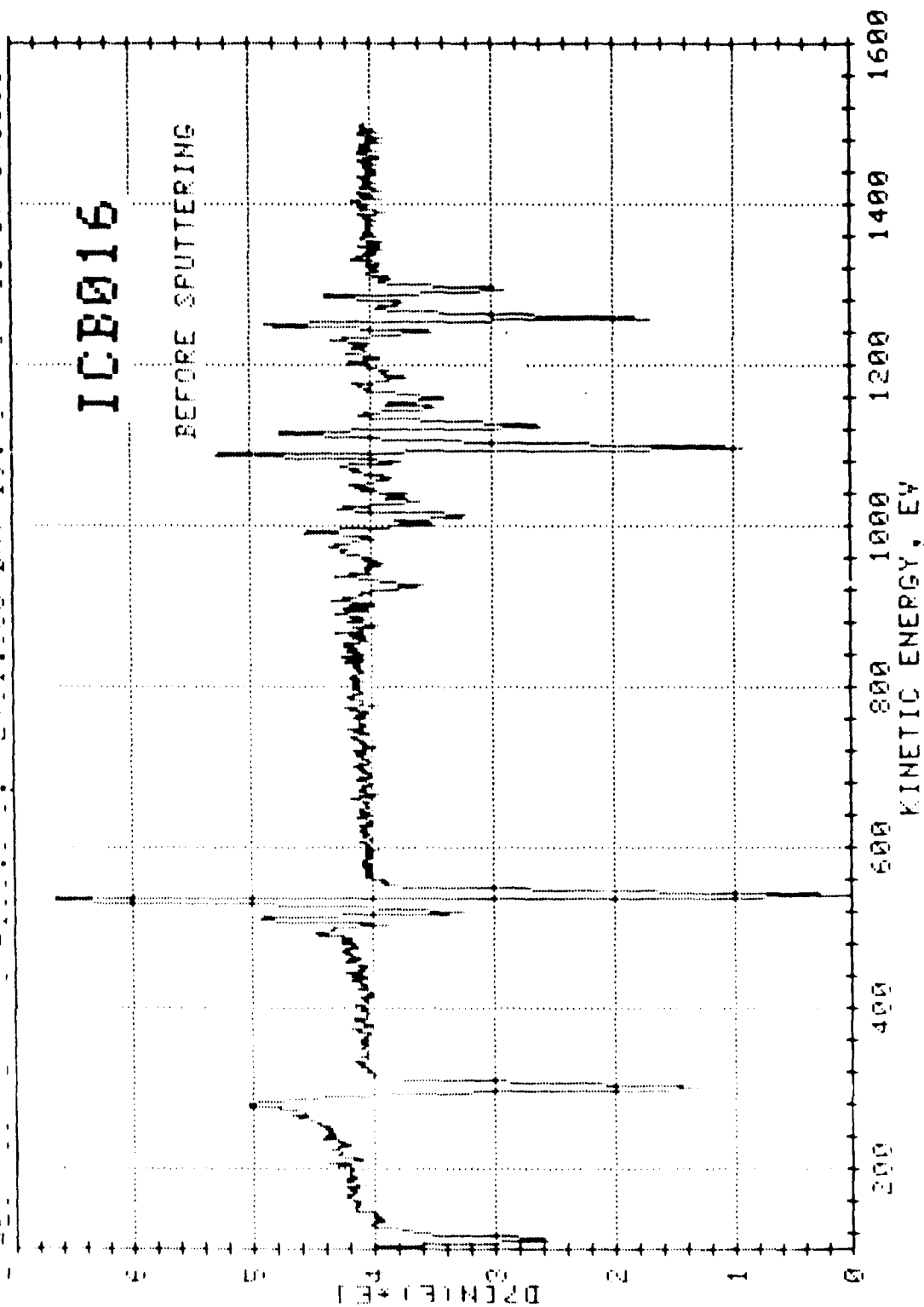
TEM Micrographs in Direction Normal to Surface

B-94

CE: 1.0 E CF=131.57E, -0451.865 DGT=19.46 04/08/87 CPC183 V/F

ICB016

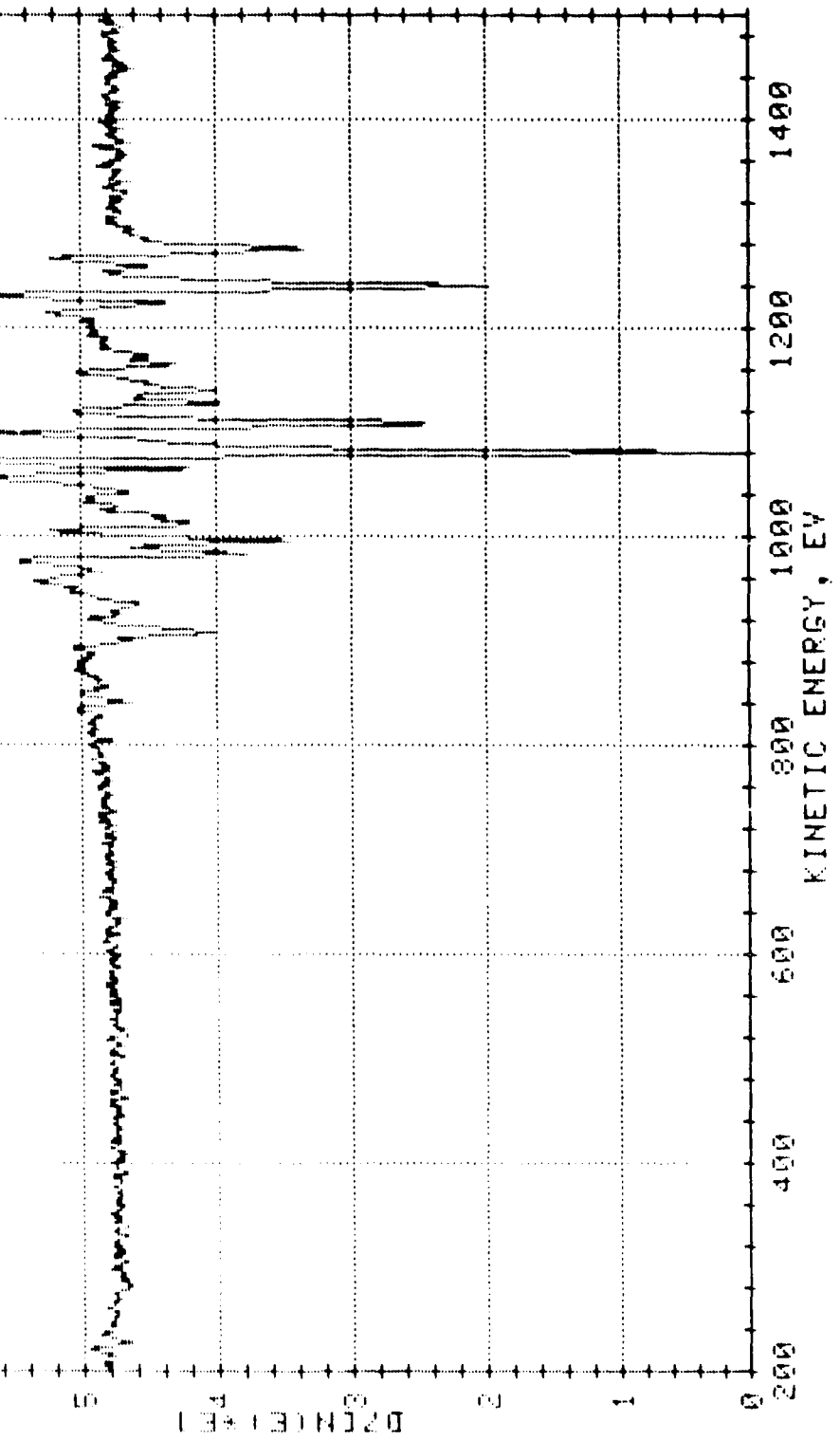
BEFORE SPUTTERING



15-014.251, .002 DAT=2.75 04/08/87 CP0189 W/F

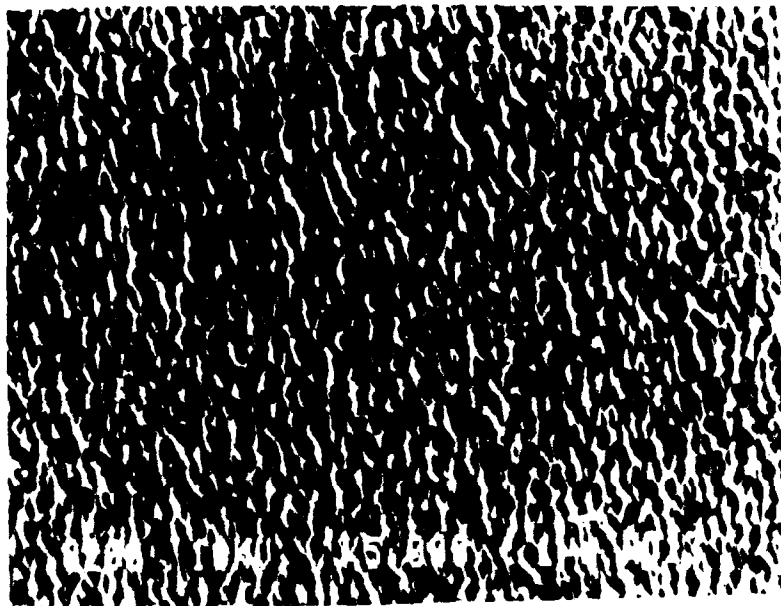
ICB016

20 MIN COUNTS

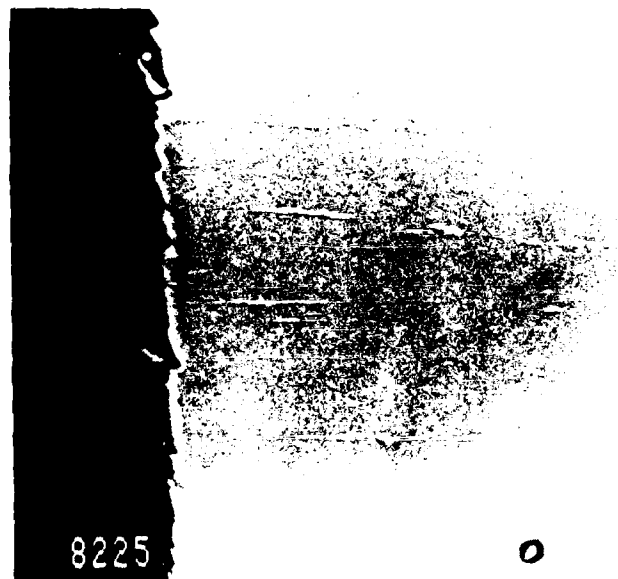


RUN NO. 017

SAMPLE #017



File:
Surface

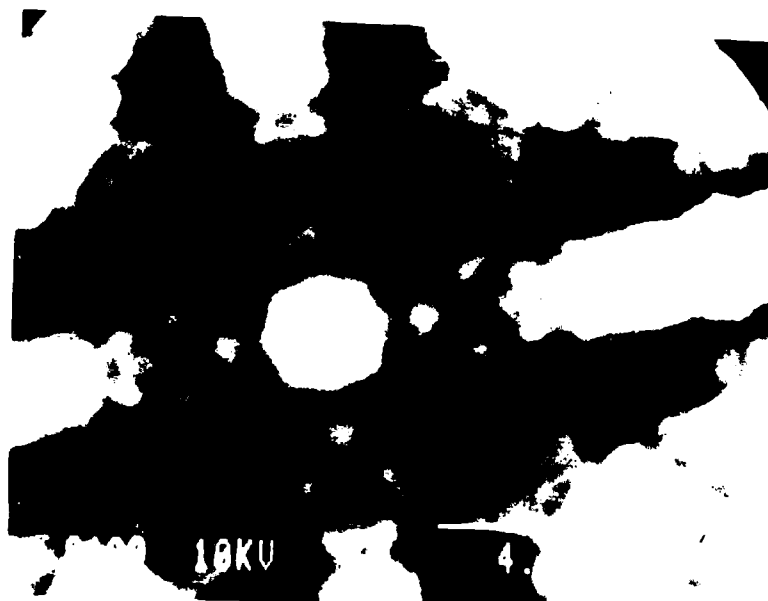


Cleave
Cross
Section

File:
Thickness
Approximate: 2

B-98

SAMPLE #017



EGF
(1981)

10KV

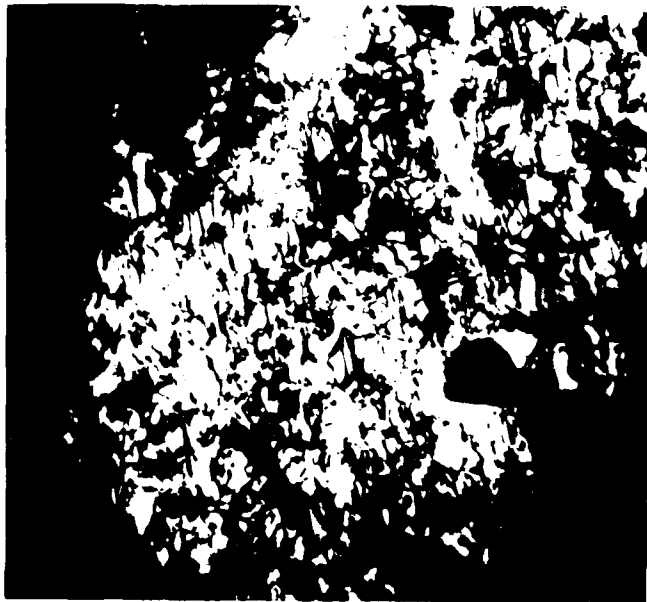
4

SAMPLE #017

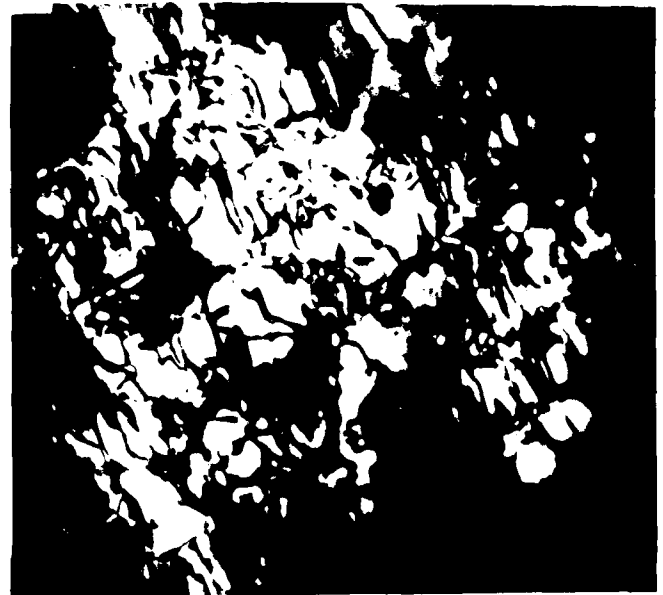


x80,000

TEM Micrograph of Cross-Section



x36,000



x80,000

TEM Micrographs in Direction Normal to Surface

B-100

AE3 11.60EY CF=252.021, -1919.631 DAT=24.33 04/08/87 CRC191 V/F

ICB017

BEFORE SPUTTERING

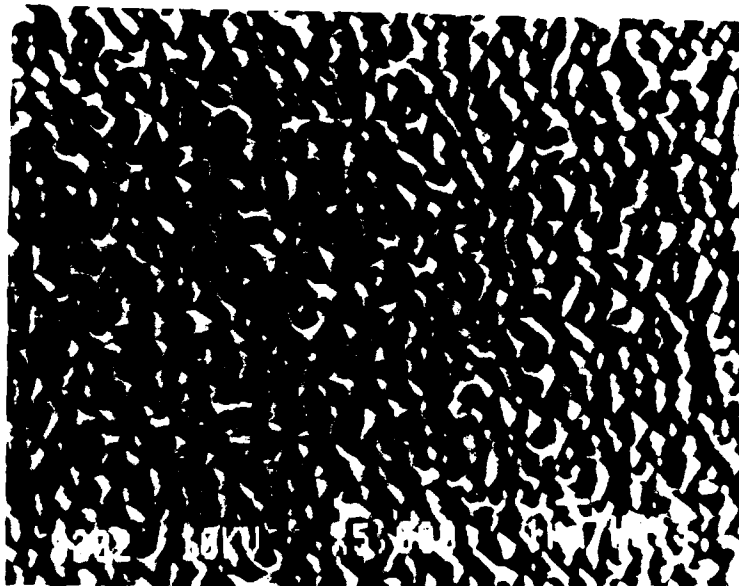
INTENSITY (E)

KINETIC ENERGY, EV

RUN NO. 018

B-103

SAMPLE #018



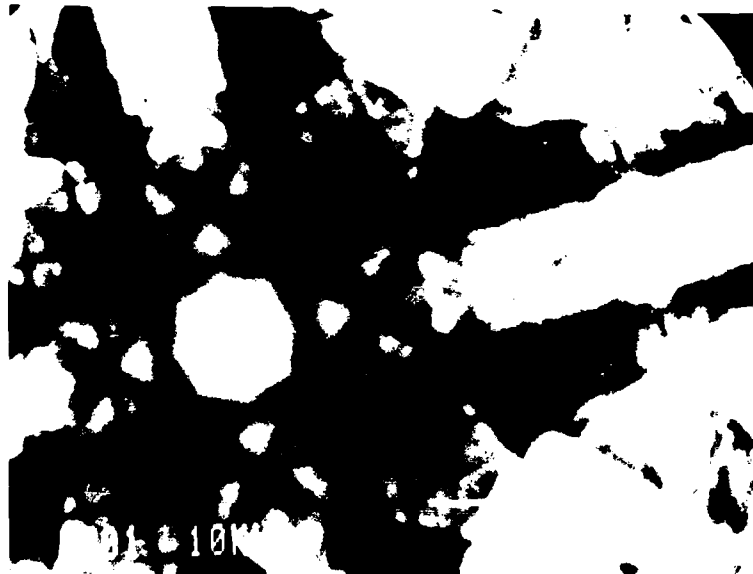
Film
Surface



Cleave
Cross
Section

Film
Thickness
Approximately ?

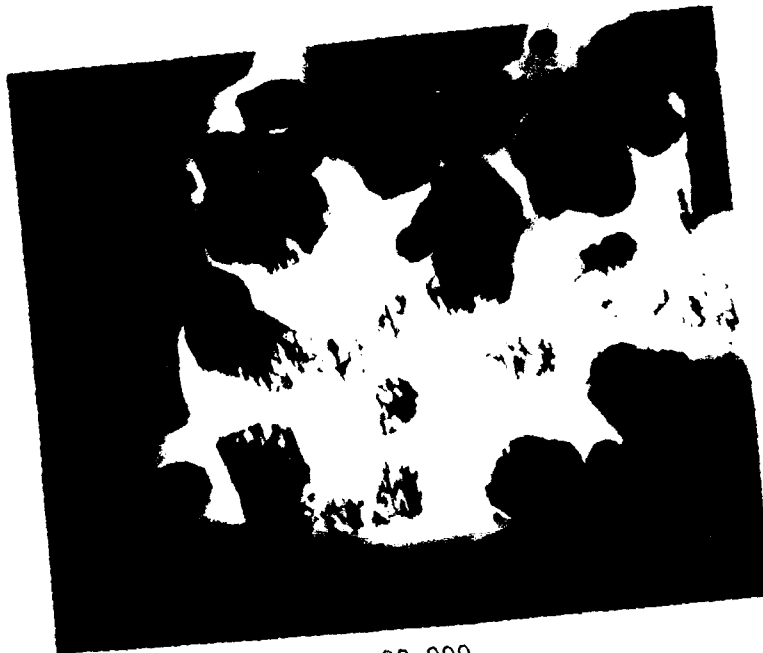
SAMPLE #018



ECP
(Film)

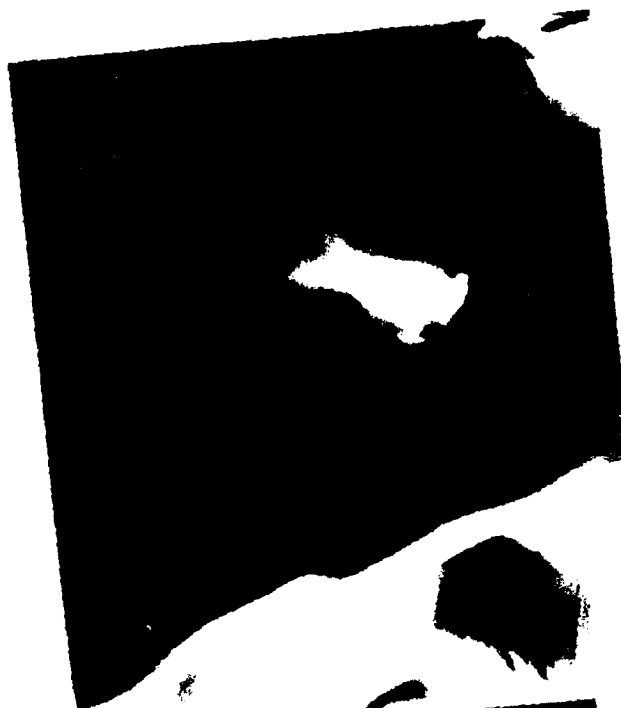
B-105

SAMPLE #018



x22,000

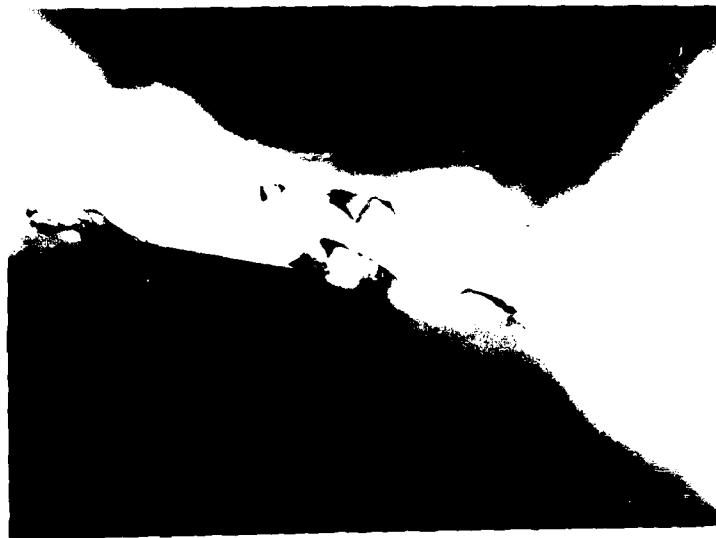
TEM Micrographs in Direction Normal to Surface



x80,000

B-106

SAMPLE #018



x22,000



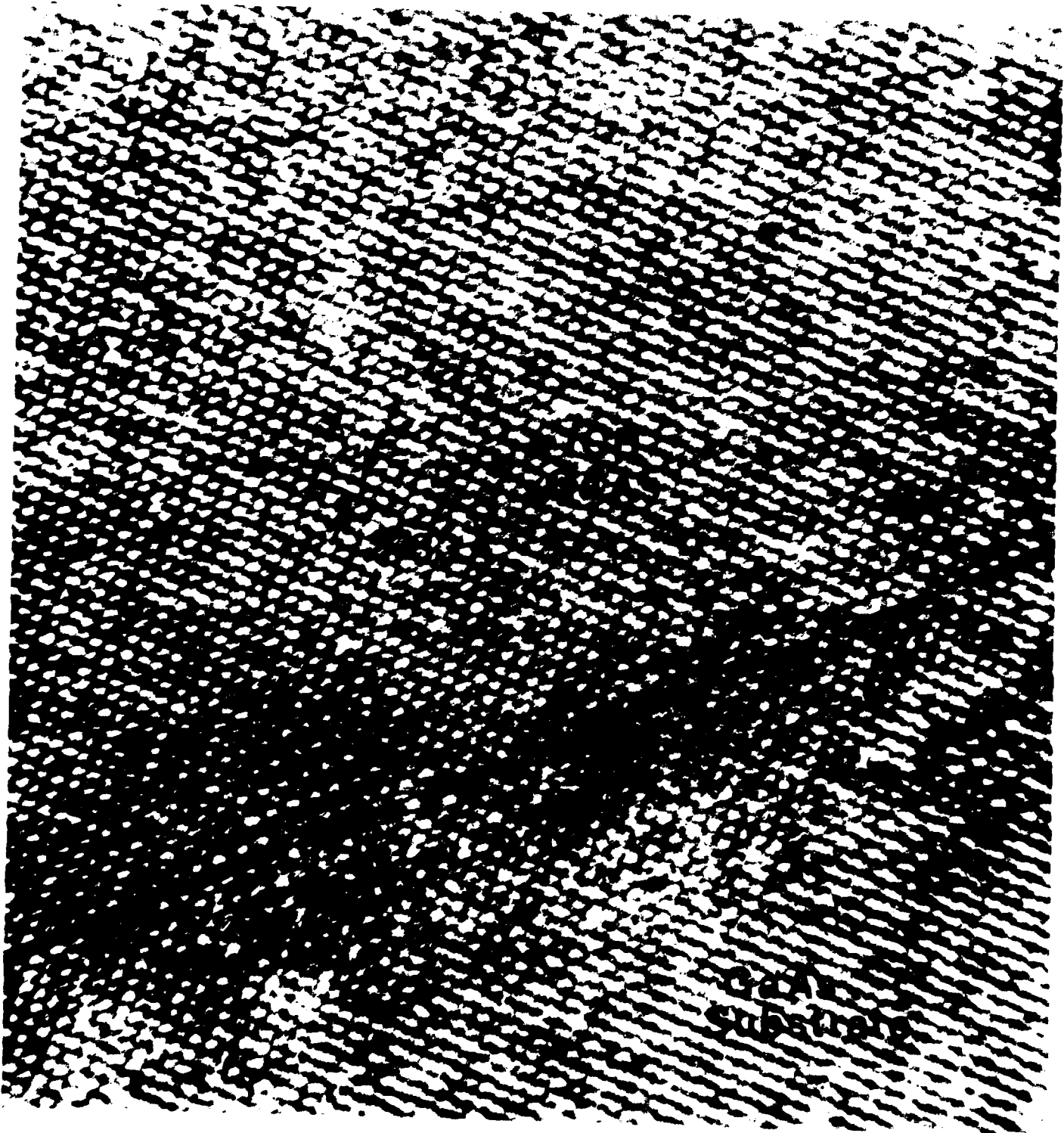
x60,000



x130,000

B-107

SAMPLE #018

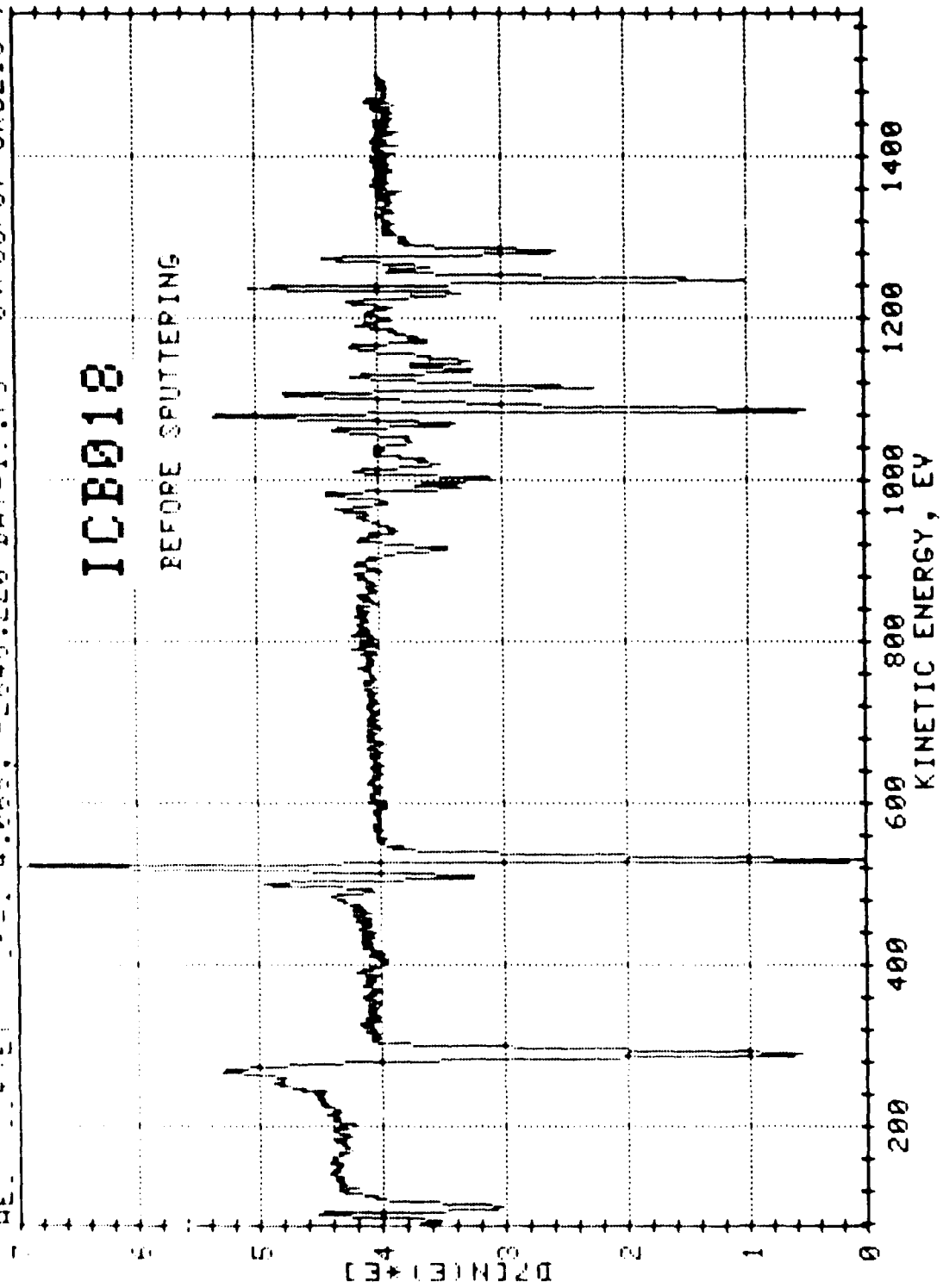


High Resolution TEM Micrograph of GaAs/GaAs Interface

050 00000000 05=174.065, -2646.220 DAT=19.73 04/08/87 CPC210 V/F

ICB018

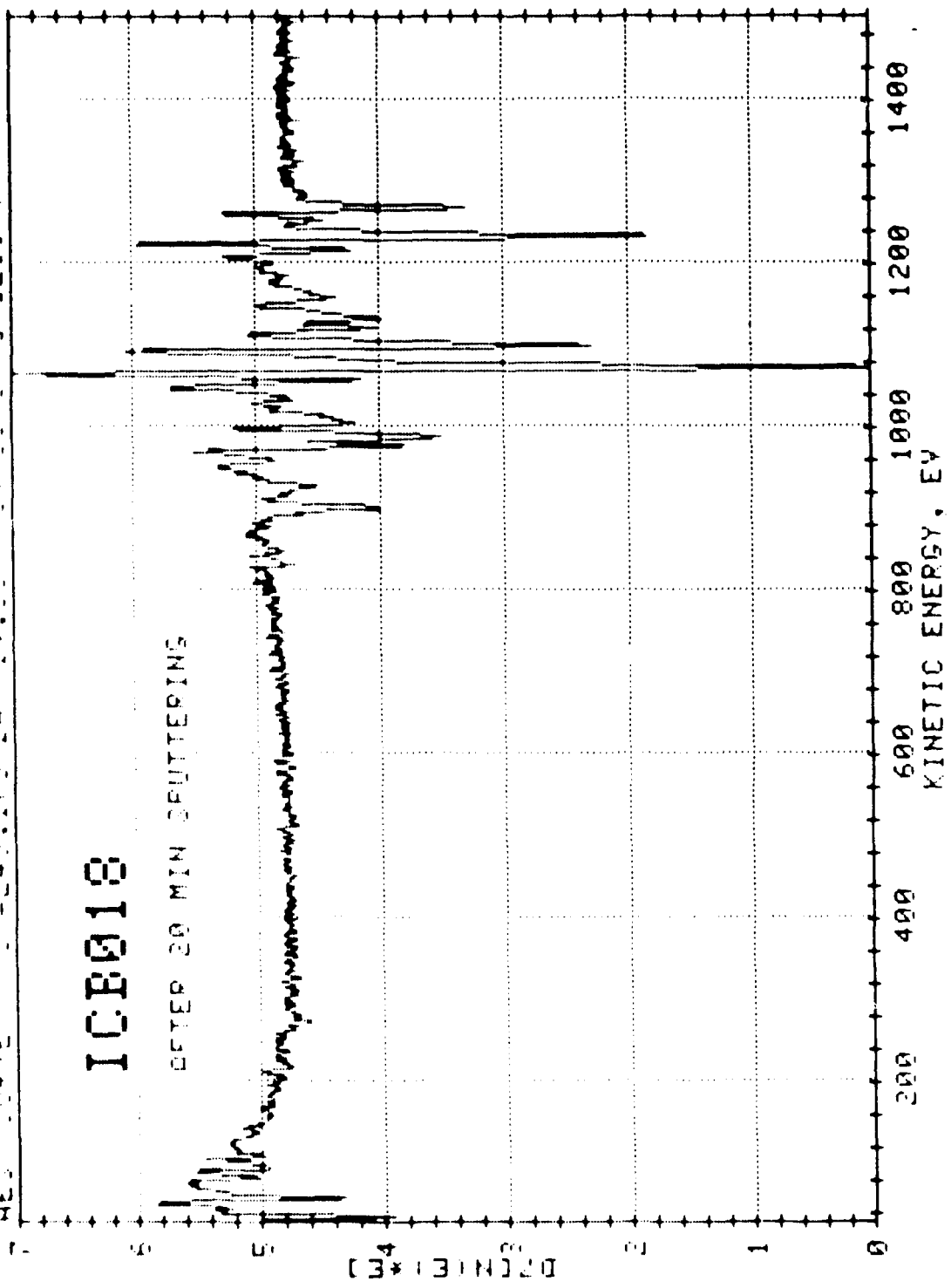
BEFORE SPUTTERING



REC RUNNER 15-2349.173 207=14.80 04-09-87 090216 Y/F

ICB018

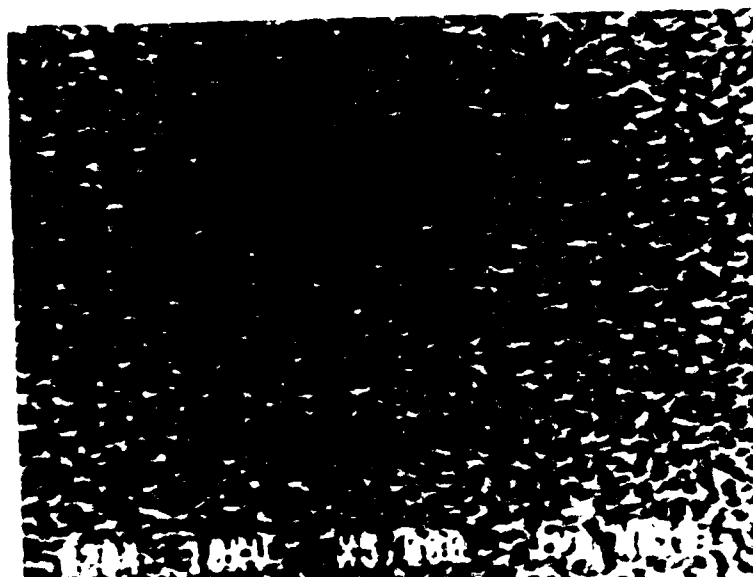
AFTER 20 MIN SPUTTERING



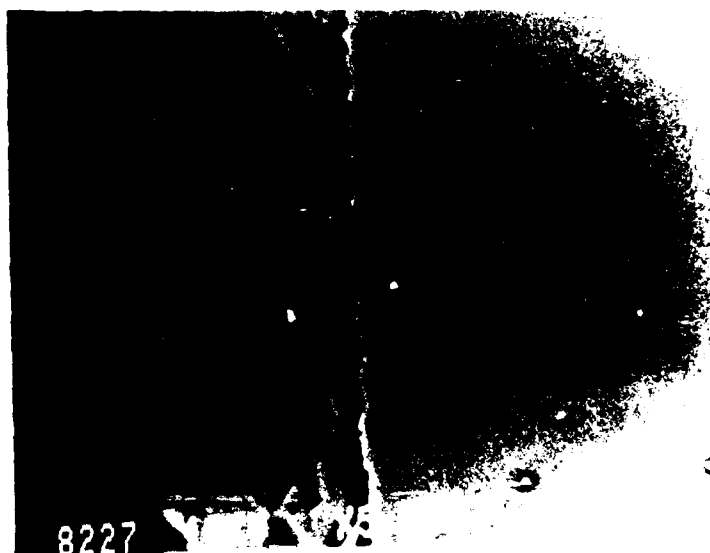
RUN NO. 019

B-111

SAMPLE #019



Film
Surface



Chem
Surf
Surf

10
The
The

SAMPLE #019



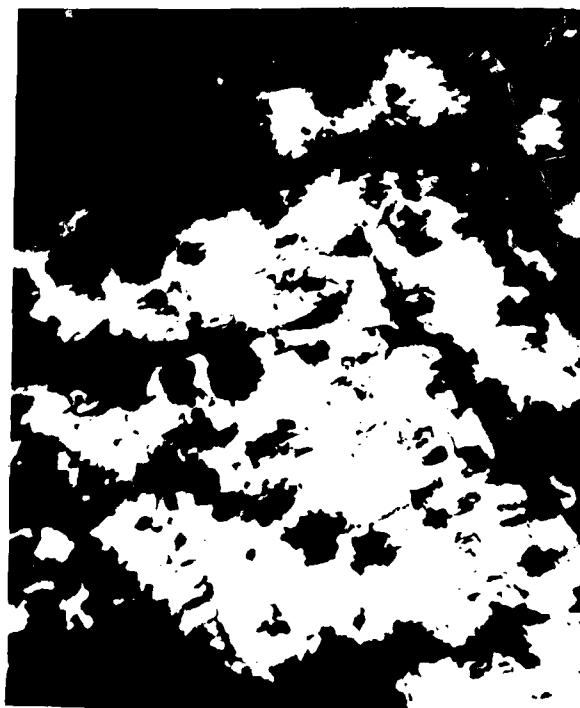
ECP
(F11r)

SAMPLE #019



x100,000

TEM Micrograph of Cross-Section



x36,000

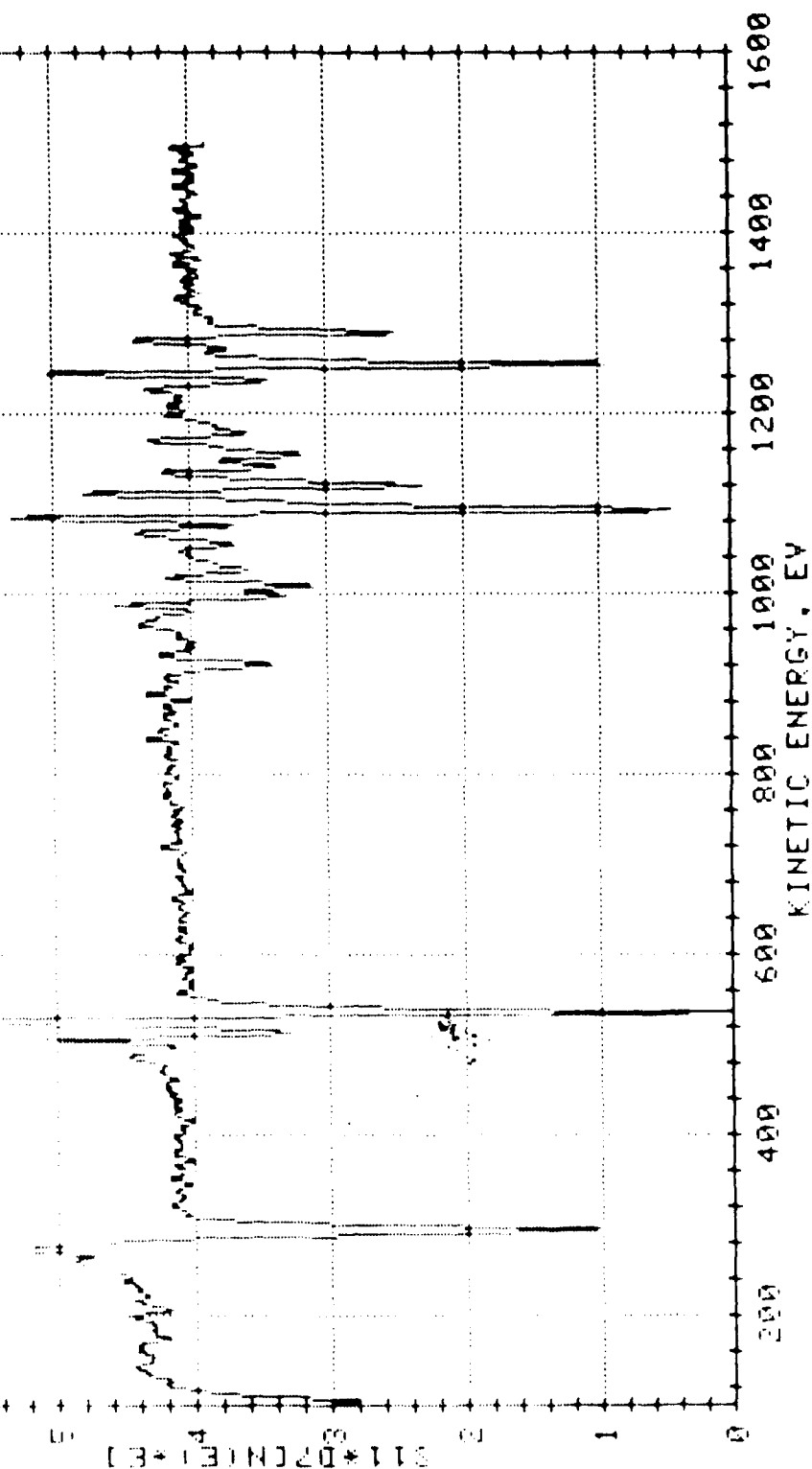


x86,000

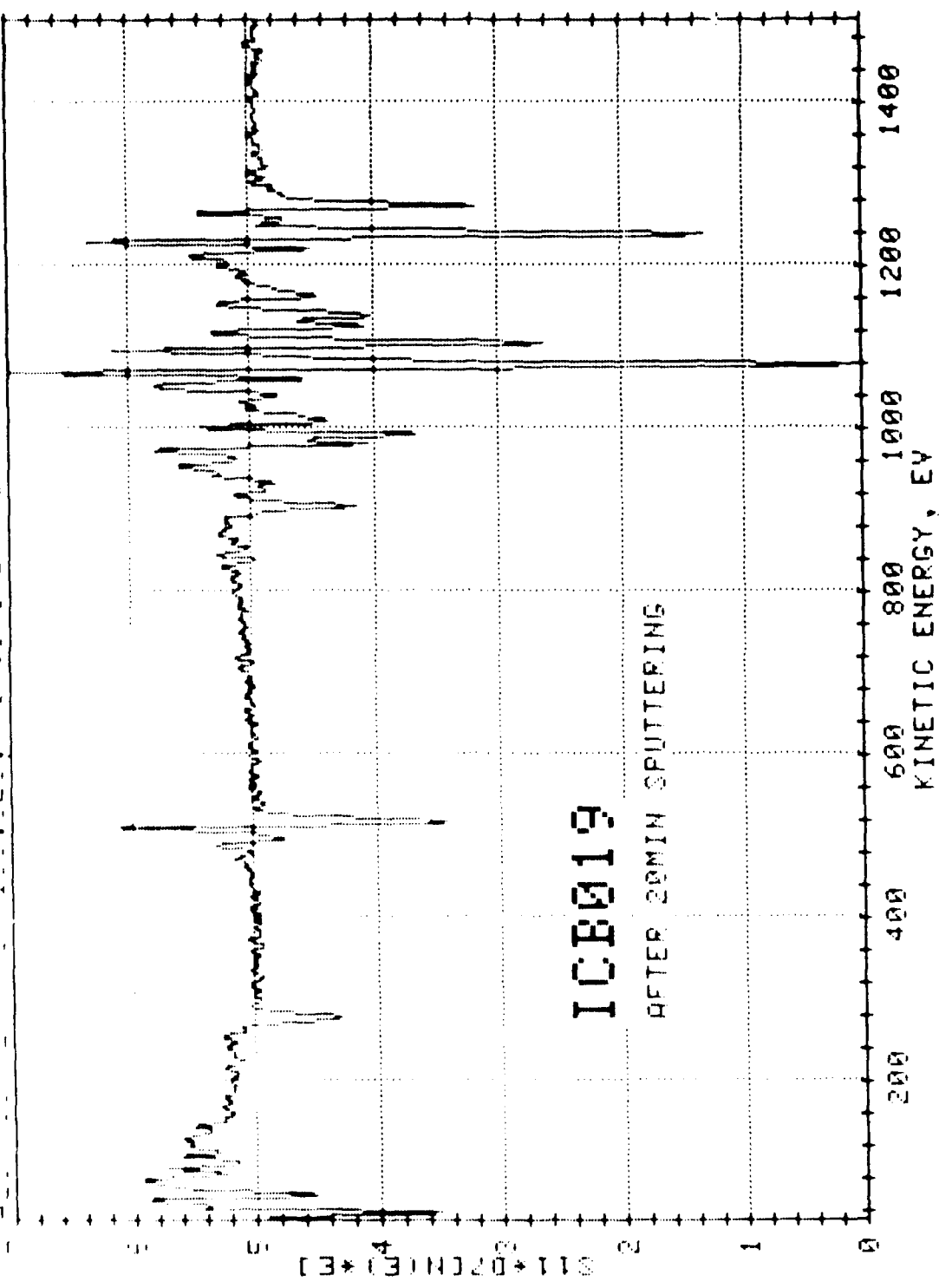
TEM Micrographs in Direction Normal to Surface

04/14/87 090218 V.F

ICB019



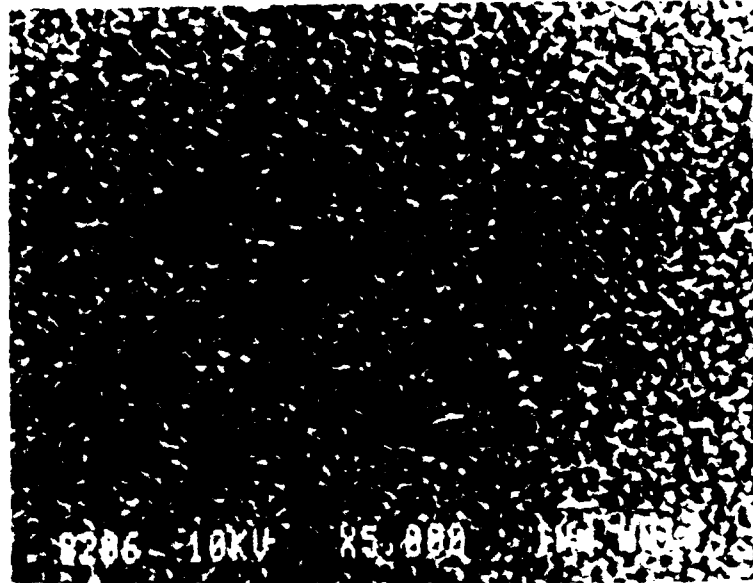
04/14/87 090224 V/F



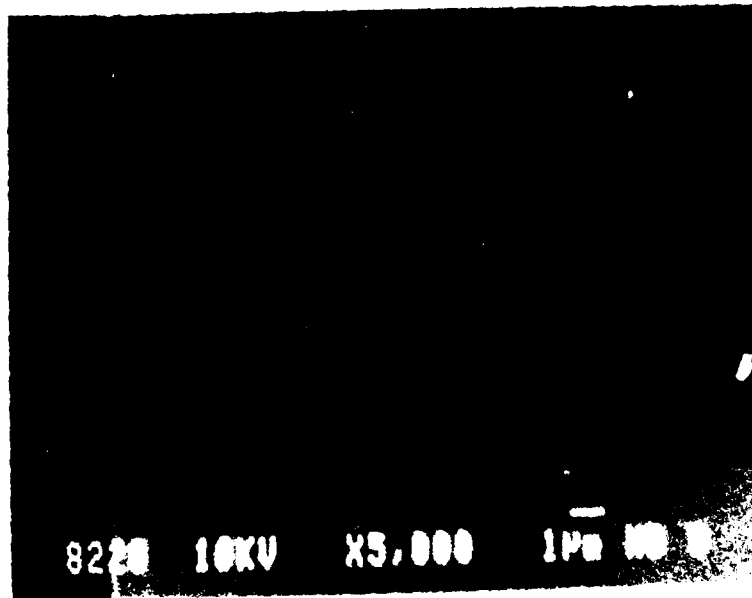
RUN NO. 020

B-117

SAMPLE #020



Film
Surface



Cleave
Cross
Section

Film
Thickness
Approximately ?

SAMPLE #020



x80,000

TEM Micrograph of Cross-Section



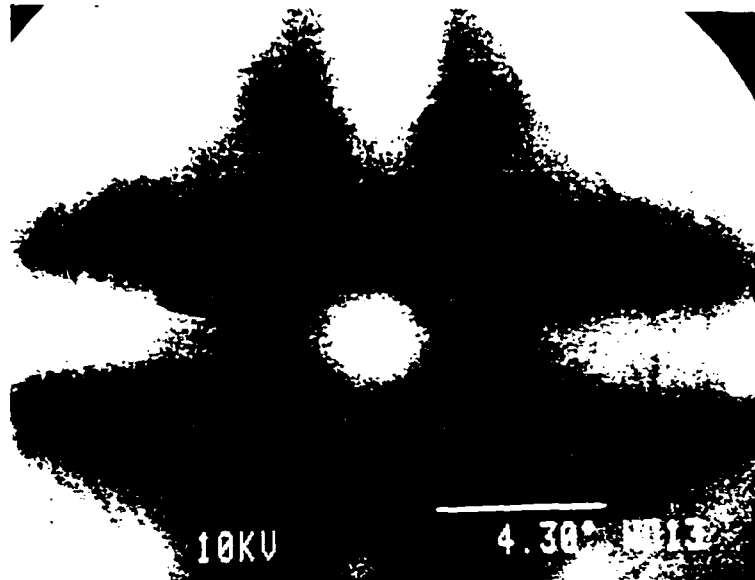
x36,000



x80,000

TEM Micrographs in Direction Normal to Surface

SAMPLE #020



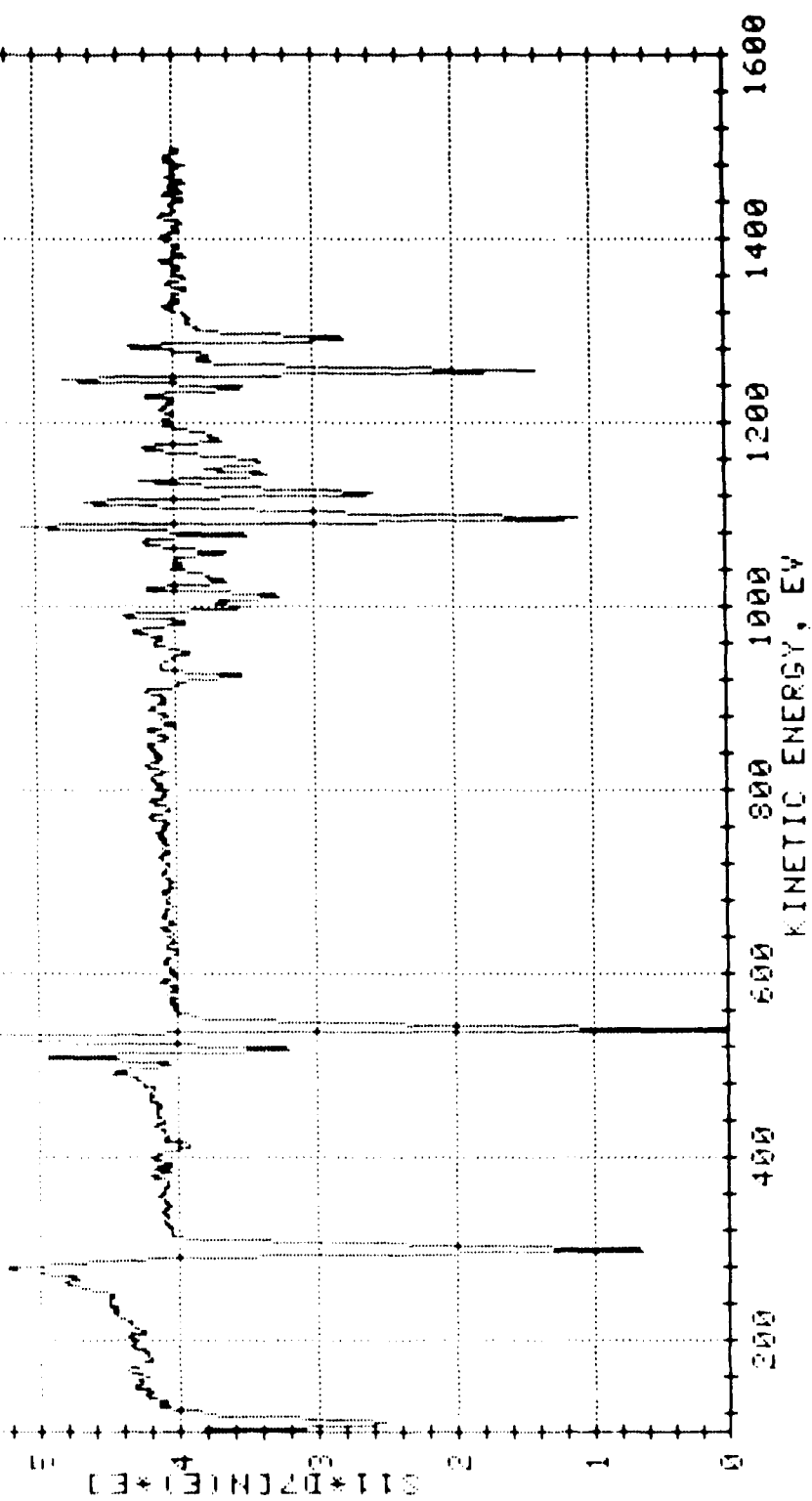
ECP
(Film)

B-119

SEP 19 8 17:13.153. -1531.600 DAT=14.20 04 14 87 CPC227 V/F

ICB020

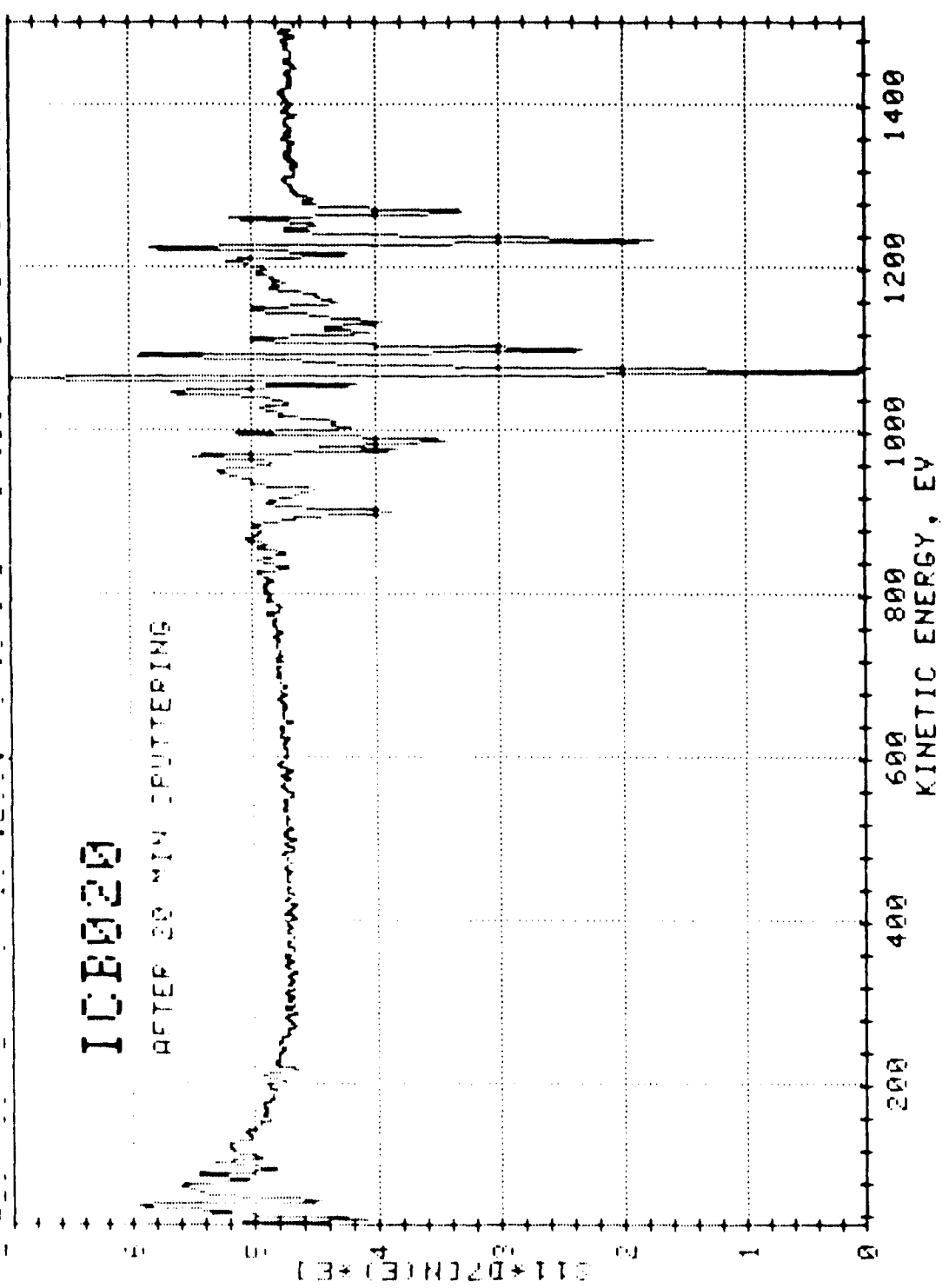
BEFORE SPUTTERING



0000 1.00 E 15=17.375, -17.375 DAY=14.80 04/14/87 090233 VAF

ICR0020

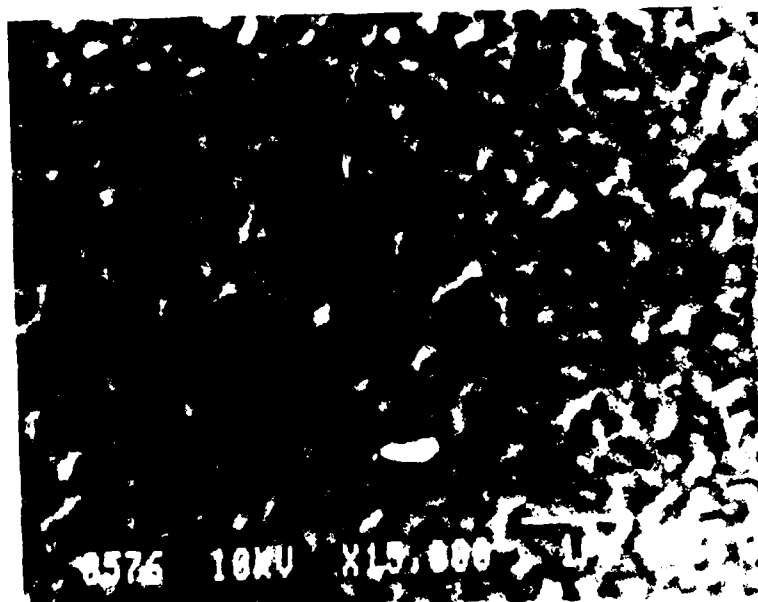
AFTER 30 MIN SPUTTERING



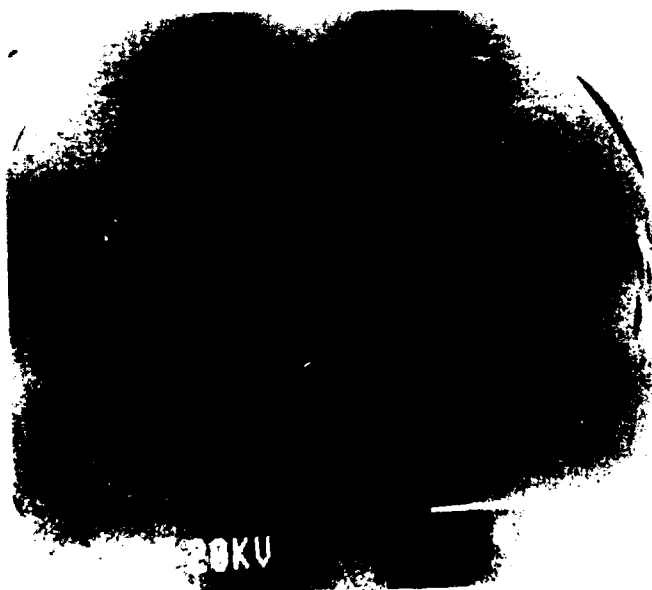
RUN NO. 021

B-123

SAMPLE #021



SEM Micrograph of Film Surface



Electron Channeling Pattern from Film Surface

SAMPLE #021



x130,000

TEM Micrograph of Cross-Section



x36,000

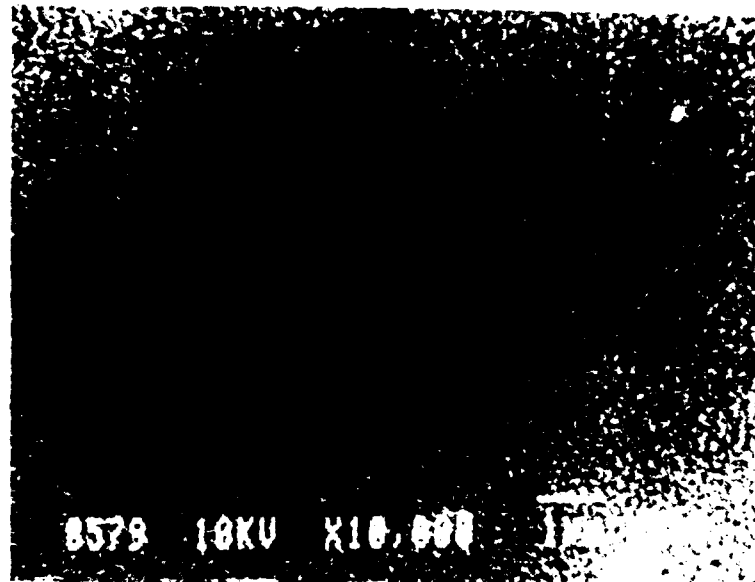


x80,000

TEM Micrographs in Direction Normal to Surface

RUN NO. 022

SAMPLE #022



SEM Micrograph of Film Surface



Electron Channeling Pattern from Film Surface

SAMPLE #022



x100,000

TEM Micrograph of Cross-Section



x36,000



x80,000

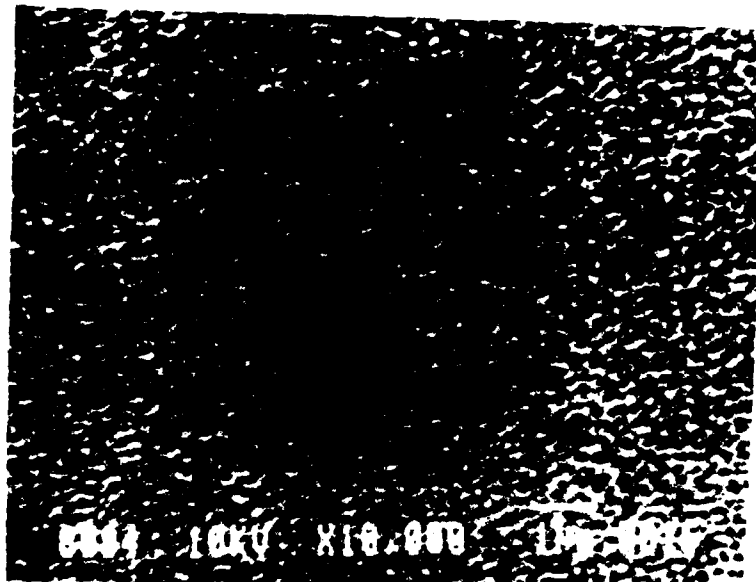
TEM Micrographs in Direction Normal to Surface

B-12R

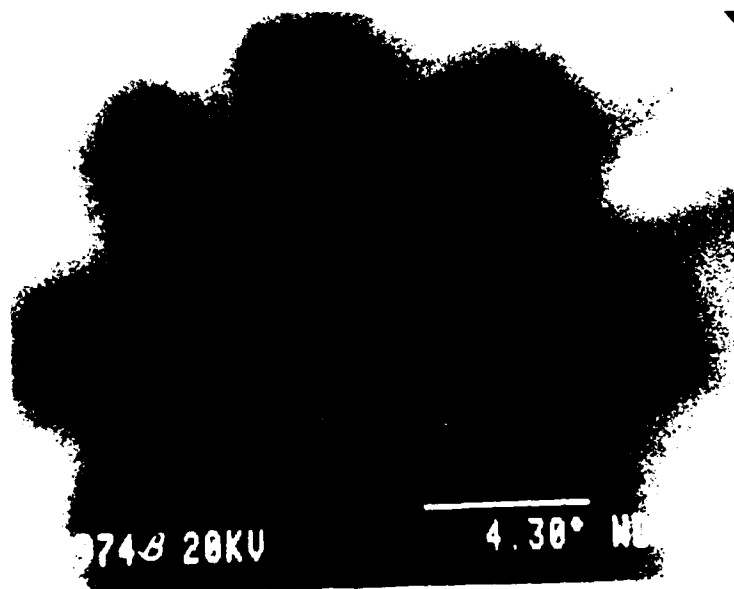
RUN NO. 023

B-129

SAMPLE #023



SEM Micrograph of Film Surface



Electron Channeling Pattern from Film Surface

SAMPLE #023



x80,000

TEM Micrograph of Cross-Section

B-131

SAMPLE #023



x2,800



x36,000



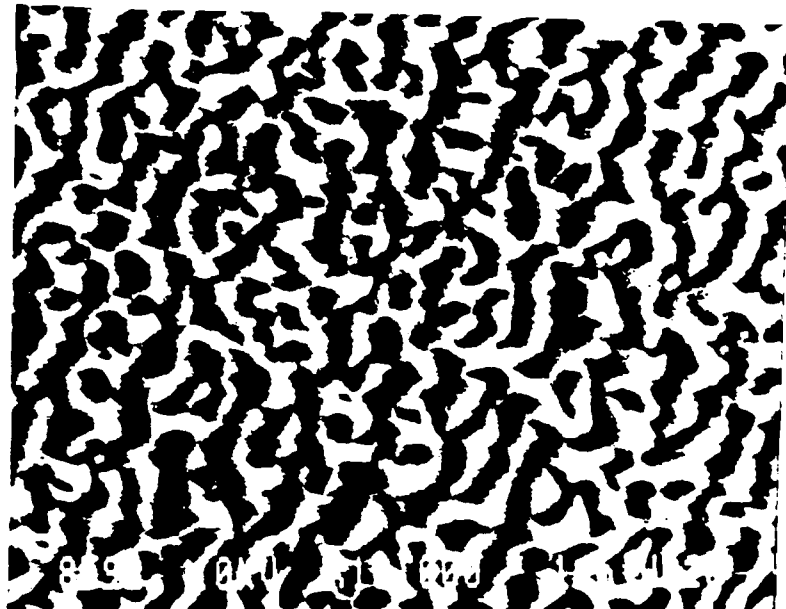
x170,000

TEM Micrographs in Direction Normal to Surface

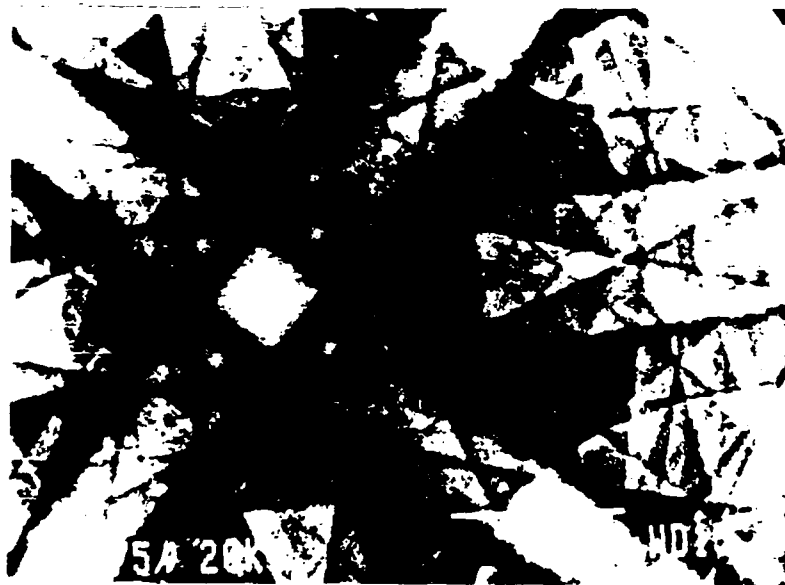
RUN NO. 024

B-133

SAMPLE #024



SEM Micrograph of Film Surface



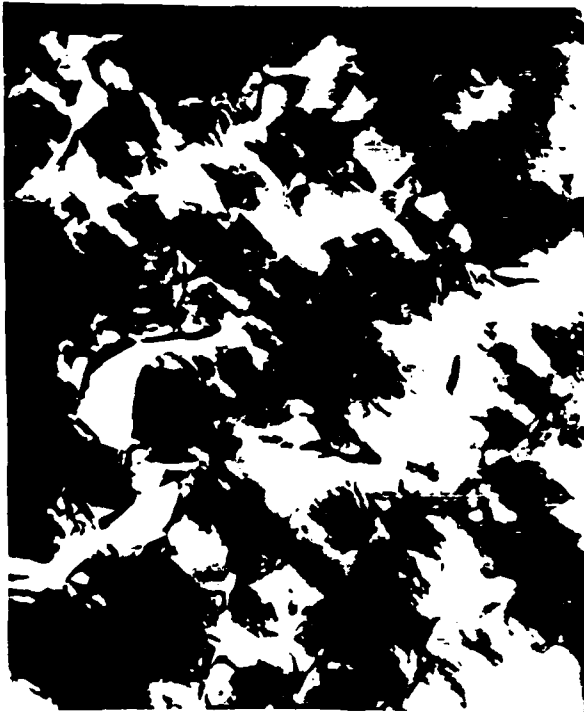
Electron Channeling Pattern from Film Surface

SAMPLE #024



x4.135

TEM Micrograph of Cross-Section



x36,000



x80,000

TEM Micrographs in Direction Normal to Surface