RM02

LIGO-T990160-00-D

SUBSTRATE

A. DCN: LIGO- T970023-01-D **LIGO DETECTOR OPTICS** Page __ of
B. LIGO S/N: RM02-B **Incoming Inspection Check-off Sheet**
Core Optics Polished Substrate

The purpose of this sheet is to verify material physical dimensions, perform visual and microscopic inspection, and to facilitate material traceability of LIGO Detector optics. This sheet is to be included in the LIGO Quality Assurance traceability file. Complete a check-off sheet for each optic blank received and inspected.

C. LIGO Contract/Purchase No.: PC 167159 D. Substrate Polisher: CSIRO
E. Core optic Material: BS / FM / 2ITM / 4ITM / ETM / (RM) F. Date Received: _____

G ☑ Verify glass polisher's Certification with LIGO Component Specification No. E960092-B-D. Attach the completed LIGO Component Specification Verification Sheet.

H ☑ Attach a copy of the glass polisher's Certification Document and data sheet to check-off sheet.

I. ☑ Verify receipt of an IBM PC compatable disc in ASCII format of all Surface Data per the applicable LIGO Component Specification sheet available at CSIRO ftp site

J ☑ Attach the surface maps supplied by vendor per above Component Specifications to the check off sheet.

K ☑ Visually inspect for shipping container damage. If applicable, describe damage on attached sheet and notify the Cognizant Engineer

L ☑ Visually inspect the polished substrate for shipping damage, for chips on surfaces and edges, or for other defects. If applicable, describe damage/defects on attached sheet and notify Cognizant Engineer.

M ☑ Verify polished substrate's physical dimensions per applicable LIGO drawing.

☑	Inspection of material diameter.	Diameter	9.88 in	250.83 mm
☑	Inspection of material thickness	Thickness	3.84 in	97.43 mm
☑	Wedge Angle 2° 24"			

N ☑ Verify that the Serial Number is present in the proper format as required by LIGO Component Specification.

O ☑ Verify that the Registration Mark (line with arrow pointing toward surface #1) is present as required by LIGO Component Specification.

P ☐ Inspect the sides and bevels with the naked eye in normal room light and against a black background to verify that there is no gray, scuffs or scratches per the applicable LIGO Component Specification.

Q ☐ Use a dark field microscope at 5X magnification to inspect the polished optic for scratches and defects over the central 80 mm diameter per the applicable LIGO Component Specification.

R ☐ Sign and date original packing slip (shipper) and distribute per paragraph 3.R.

Inspection By: _____ Date Inspected: _____

Reviewed and/or accepted by:

Cognizant Engineer: _____ Date: _____

LIGO QA Officer or Designee: _____ Date: _____

FM300

Figure 1

LIGO DETECTOR OPTICS
Incoming Inspection Check-off Sheet

Core Optics Polished Substrate

COMMENTS/DISCREPANCIES: (Disposition damage/discrepancies per LIGO Quality Assurance Plan (LIGO M960076-00-P) paragraphs 5.12 and 5.12.1.) _____

SKETCHES:

DISPOSITIONS: _____

Substrate, Recycling Mirror		Serial Number: RMØ2-B	Specification	Reported Value	✓
	Surface 1	Surface Figure Over Central 200mm	Spherical, Concave	concave	✓
		Radius of Curvature Tolerance	14,900m +750m −150m	14,980 m ± 240	✓
		Astigmatism	< 10nm p-v	2.4 nm p-v	✓
	Surface 2	Surface Figure Over Central 200mm	Flat	concave	✓
		Radius of Curvature	> 160 Km	> 550 Km	✓
		Astigmatism	< 32nm p-v	0.5 nm p-v	✓
	Surface Errors	Low Spatial Frequency Band Central 80mm	≤ 4.3 cm^{-1} σ_{rms} < 1.6nm	0.44 nm	✓
		Low Spatial Frequency Band Central 200mm	≤ 4.3 cm^{-1} σ_{rms} < 3.2nm	0.88 nm	✓
		High Spatial Frequency Band Central 80 & 200 mm	≤ 4.3 – 7,500 cm^{-1} σ_{rms}<0.4nm	0.21 nm 0.22 nm	✓

Scratches, Point Defects & Polish		Specification	Certification	✓
	Scratches	NOTE: ROC in spec 10 m above min. diameter shall not	Hand Sketch w/dimensions	✓
		diameter shall not	Hand Sketch w/dimensions	✓
	Point Defects	the central 80mm	Hand Sketch w/dimensions	✓
		entire surface. s are treated like t defects of radius less than 2.5 micrometers are disregarded.	Hand Sketch w/dimensions	✓
	Side/Bevel Polish	Sides and bevels shall be polished from a three micrometer grit finish. These surfaces shall appear transparent with no gray, scuffs or scratches visible to the naked eye when viewed in normal room light against a black background. S1 Height 2.22 45°20' S2 Height 2.30 44°28'	Inspection Report	✓

LIGO Component Specification Verification Sheet
Recycling Mirror

This Certification Package relates to the following substrate: **Recycling Mirror**

Serial number: RM02B

The Package consists of the following documents:

1. Printed documents

HABA - LIGO - C - PD:	Certification of Physical Dimensions and Registration Mark location, orientation and dimensions
HABA - LIGO - C - SB:	Certification of Side and Bevel Polish
HABA - LIGO - C - SP:	Certification of Scratches and Point Defects
HABA - LIGO - C - SN:	Certification of Serial Number location, dimensions
HABA - LIGO - C - SF:	Certification of Surface Figure for Sides 1 and 2
HABA - LIGO - C - SL:	Certification of Surface Errors - Low Frequency, for Sides 1 and 2
HABA - LIGO - C - SH:	Certification of Surface Errors - High Frequency, for Sides 1 and 2
Attachment 1	Hard copy print out of LADI data for Side 1 with piston, tilt removed and also for piston, tilt, power, astigmatism removed
Attachment 2	Hard copy print out of LADI data for Side 2 with piston, tilt, removed and also for piston, tilt, power, astigmatism removed
Attachment 3	Hard copy printouts of TOPO 2D data obtained with 2.5X and 40X heads at three central positions (side 1)
Attachment 4	Hard copy printouts of TOPO 2D data obtained with 2.5X and 40X heads at three central positions (side 2)

2. Electronic data

Surface maps for sides 1 and 2 are available at the CSIRO ftp site under the following file names:

LADI data:	RM2B1.ZIP (Side 1)	RM2B2.ZIP (Side 2)
TOPO data: (2.5X)	T2RM021A.ASC (Side 1)	T2RM022A.ASC (Side 2)
	T2RM021B.ASC	T2RM022B.ASC
	T2RM021C.ASC	T2RM022C.ASC
(40X)	T4RM021A.ASC	T4RM022A.ASC
	T4RM021B.ASC	T4RM022B.ASC
	T4RM021C.ASC	T4RM022C.ASC

1	**Substrate Type:**	**Recycling Mirror**
2	**Serial Number:**	**RM-02B**
3	**Physical quantity certified:**	**Physical Dimensions and Registration Mark**
4	**LIGO specification reference:**	**D960785-B-D**
5	**CSIRO measurement/inspection procedure reference:**	**HABA-LIGO-M-PD**
6	**Variations to the measurement/inspection procedure:** (indicate Yes/No and attach separate sheet if Yes)	**No**
7	**CSIRO Log Book Reference**	**LN00028 p. 21**
8	**Team member responsible for measurement/inspection:**	**Carl Sona**
9	**Measurement/inspection results reviewed by:**	**Bob Oreb**

10. Results

[Measurement errors (± 1σ) shown only where they are comparable to tolerances specified or when measurement is within 2σ of boundary of acceptability]

Physical Quantity	Result
Diameter	250.83 mm
Cylindricity	0.02 mm
Thickness (maximum - for FM, RM, ETM) (minimum - for BS)	97.43 mm
Bevel as per drawing (height, angle):	(S1) Height: 2.22 Angle: $45^0$20' (S2) Height: 2.30 Angle: $44^0$28'
Wedge angle:	$2^0$24'
Location of registration mark (± angle with respect to minimum part thickness):	-1'
Location of other 3 marks (with respect to registration mark at minimum thickness)	$89^0$59', $179^0$58', $269^0$59'
Registration mark dimensions (OK/ not OK)	OK

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager: Chris Walsh

Date: 6.11.97

1	**Substrate Type:**	**Recycling Mirror**
2	**Serial Number:**	**RM-02B**
3	**Physical quantity certified:**	**Side and Bevel Polish**
4	**LIGO specification reference:**	**E960092-B-D**
5	**CSIRO measurement/inspection procedure reference:**	**HABA-LIGO-M-SB-A**
6	**Variations to the measurement/inspection procedure:** (indicate Yes/No and attach separate sheet if Yes)	**No**
7	**CSIRO Log Book Reference**	**LN00024**
8	**Team member responsible for measurement/inspection:**	**E Pavlovic /J Seckold**
9	**Measurement/inspection results reviewed by:**	**A Leistner**

10. Results

Defects, if any, in the side and bevel polish compared to the LIGO specification (4 above) are detailed below *(team member to note defects here; if none seen, note "no defects observed").*

No defects observed.

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager:  Chris Walsh

Date: 6.11.97

1	**Substrate Type:**	**Recycling Mirror**
2	**Serial Number:**	**RM-02B**
3	**Physical quantity certified:**	**Serial Number and location**
4	**LIGO specification reference:**	**E960092-B-D**
5	**CSIRO measurement/inspection procedure reference:**	**HABA-LIGO-M-SN-A**
6	**Variations to the measurement/inspection procedure:** (indicate Yes/No and attach separate sheet if Yes)	**No**
7	**CSIRO Log Book Reference**	**LN00024**
8	**Team member responsible for measurement/inspection:**	**E Pavlovic / J Seckold**
9	**Measurement/inspection results reviewed by:**	**A Leistner**

10. Results

Quantity inspected	Result of Inspection (OK / not OK)
Location of serial number as per drawing (sec. 4)	OK
Orientation of serial number as per drawing (sec. 4)	OK
Height of lettering	OK

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager:  Chris Walsh

Date: 6·11·97

1	**Substrate Type:**	**Recycling Mirror**
2	**Serial Number:**	**RM-02B**
3	**Physical quantity certified:**	**Scratches and Point Defects**
4	**LIGO specification reference:**	**E960092-B-D**
5	**CSIRO measurement/inspection procedure reference:**	**HABA-LIGO-M-SP-A**
6	**Variations to the measurement/inspection procedure:** (indicate Yes/No and attach separate sheet if Yes)	**No**
7	**CSIRO Log Book Reference**	**LN00024**
8	**Team member responsible for measurement/inspection:**	**E Pavlovic / J Seckold**
9	**Measurement/inspection results reviewed by:**	

10. Results

	Numbers of point defects		**Total Area of scratches (square micrometres)**	
	Inside central 80 mm	**Entire surface (235 mm)**	**Inside central 80 mm**	**Outside central 80 mm (235 mm)**
Surface 1	**none**	**none**	**none**	**none**
Surface 2	**none**	**none**	**none**	**none**

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager: Chris Walsh

Date: 6.11.97

1	**Substrate Type:**	**Recycling Mirror**
2	**Serial Number:**	**RM-02B**
3	**Physical quantity certified:**	**Surface Figure**
4	**LIGO specification reference:**	**E960092-B-D**
5	**CSIRO measurement/inspection procedure reference:**	**HABA-LIGO-M-SF-A**
6	**Variations to the measurement/inspection procedure:** (indicate Yes/No and attach separate sheet if Yes)	**No**
7	**CSIRO Log Book Reference**	**LN00061, pp. 8-10**
8	**Team member responsible for measurement/inspection:**	**D Farrant**
9	**Measurement/inspection results reviewed by:**	**B Oreb**

10. Results

	Radius of Curvature in km	**Astigmatism (nm)**	**Electronic data file reference**
Surface 1	**14.98 ± 0.24 (concave)**	**2.4**	**RM2B1.ZIP**
Surface 2	**>550 (concave)**	**0.5**	**RM2B2.ZIP**

Hardcopies of the phase maps are attached to this certification as part of Attachment 1 for Side 1 and Attachment 2 for Side 2. Phase map data is stored in electronic format at the CSIRO ftp site under the filenames shown in the third column.

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager: Chris Walsh

Date: 6.11.97

1	**Substrate Type:**	**Recycling Mirror**
2	**Serial Number:**	**RM-02B**
3	**Physical quantity certified:**	**Surface Errors - Low Spatial Frequency**
4	**LIGO specification reference:**	**E960092-B-D**
5	**CSIRO measurement/inspection procedure reference:**	**HABA-LIGO-M-SL-A**
6	**Variations to the measurement/inspection procedure:** (indicate Yes/No and attach separate sheet if Yes)	**No**
7	**CSIRO Log Book Reference**	**LN00061, pp 8-10**
8	**Team member responsible for measurement/inspection:**	**D Farrant**
9	**Measurement/inspection results reviewed by:**	**B Oreb**

10. Results

	Low Frequency Surface Errors (nm)	
	80 mm aperture	**200 mm aperture**
Surface 1	0.44	0.88
Surface 2	0.49	0.73

Hardcopies of the phase maps over the central 200 mm with piston, tilt, power and astigmatism removed are attached to this certification in Attachment 1 for Side 1 and Attachment 2 for Side 2.

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager: Chris Walsh

Date: 6.11.97

1	**Substrate Type:**	**Recycling Mirror**
2	**Serial Number:**	**RM-02B**
3	**Physical quantity certified:**	**Surface Errors - high spatial frequency**
4	**LIGO specification reference:**	**E960092-B-D**
5	**CSIRO measurement/inspection procedure reference:**	**HABA-LIGO-M-SH-B**
6	**Variations to the measurement/inspection procedure:** (indicate Yes/No and attach separate sheet if Yes)	**No**
7	**CSIRO Log Book Reference**	**LN00066, pp.74-77, 82-84, 90-92, 106-109**
8	**Team member responsible for measurement/inspection:**	**F Lesha**
9	**Measurement/inspection results reviewed by:**	**C Walsh**

10. Results

10.1 Surface errors in nanometres averaged over sampling locations within central 80 mm:

Side 1: **0.21**

Side 2: **0.29**

10.2 Surface errors in nanometres averaged over all sampling locations on surface:

Side 1: **0.22**

Side 2: **0.29**

10.3 Surface errors in nanometres at different positions A through H on surface:

	A	B	C	D	E	F	G	H
Surface 1	**0.20**	**0.24**	**0.23**	**0.19**	**0.21**	**0.20**	**0.27**	**0.20**
Surface 2	**0.27**	**0.30**	**0.30**	**0.31**	**0.28**	**0.34**	**0.31**	**0.27**

Two - dimensional surface maps at three central locations are available at the CSIRO ftp site under filenames of the form TORM0YZA.asc, where O is the objective used (O=2 for 2.5X, 4 for 40X), RM is the substrate type, 0Y is the number, Z = 1 or 2 is the side and A = A, B, C, ... is the sampling position. Hard copies of the data are at Attachment 3 (Side 1) and Attachment 4 (Side 2).

11. Certification

The measurements and inspection data presented in this report were obtained using the procedures outlined in the relevant CSIRO procedures document (sec. 5). These results have been reviewed against the LIGO specifications (sec. 4). Taking into account the variations (if any) from these measurement procedures noted in sec.6, CSIRO certifies the substrate to comply with the LIGO specification for this physical quantity.

Project Manager: Chris Walsh

Date: 6.11.97

Att.1

LADI CERTIFICATION DATA

CSIRO

Title: RM2B1

Date: 10/28/97

Diameter: 200 mm

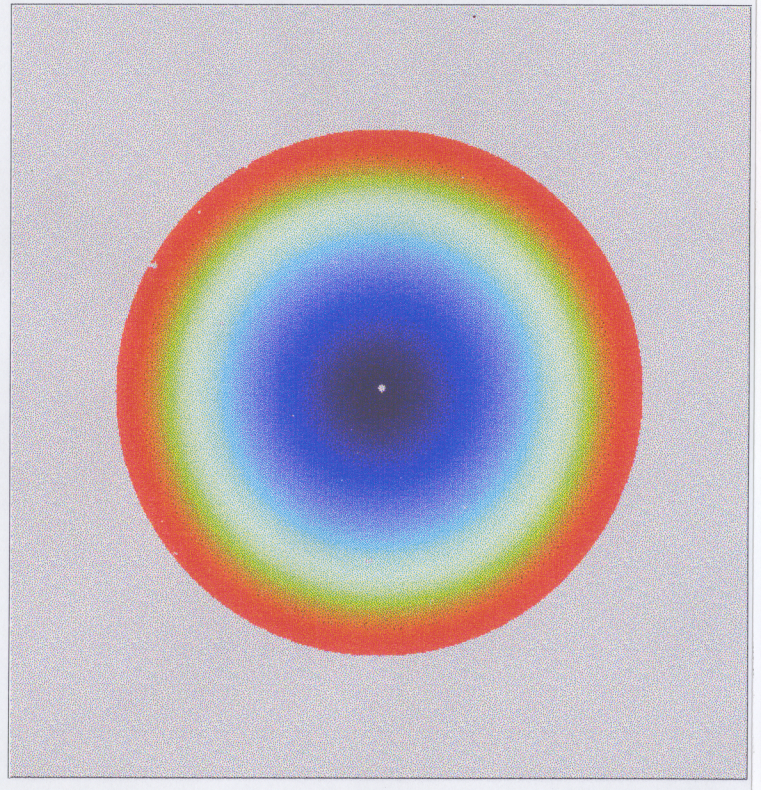
Astig: 2.4 nm

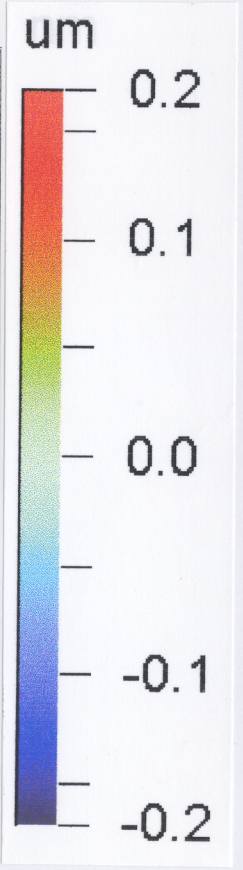
Power: 333.7 nm

PV: 6.6 nm

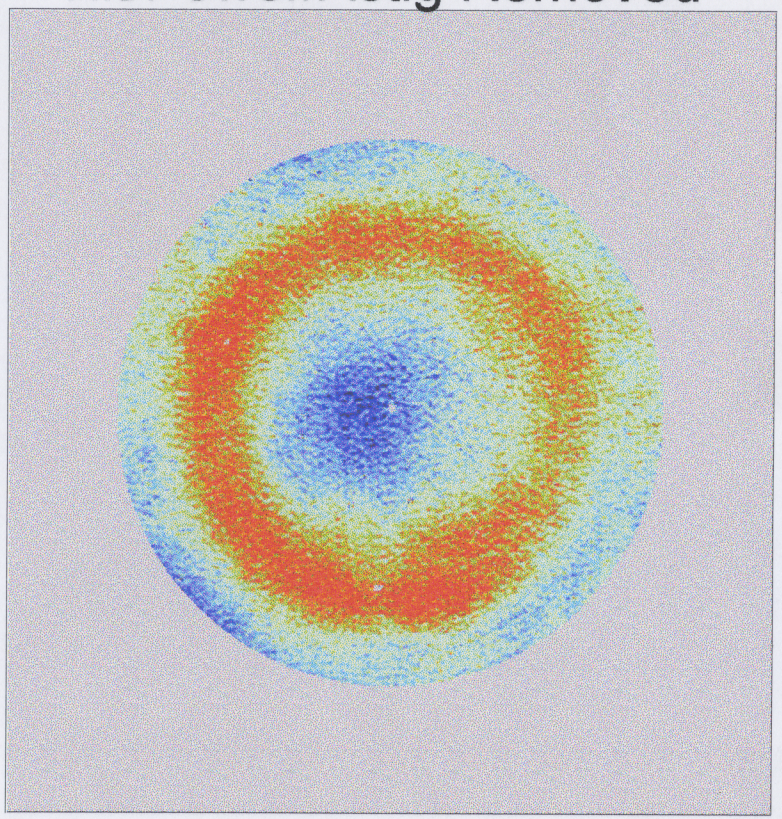
RMS: 0.9 nm

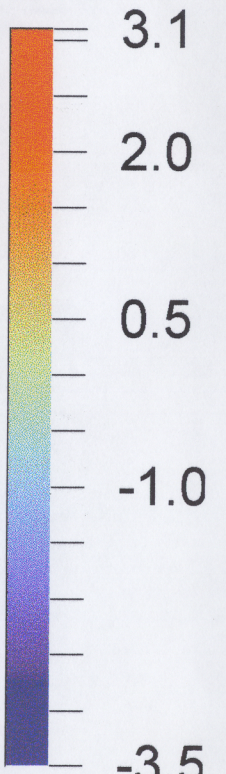
Tilt Removed





Tilt/Power/Astig Removed





Att. 2

LADI CERTIFICATION DATA

CSIRO

Title: RM2B2

Date: 10/28/97

Diameter: 200 mm

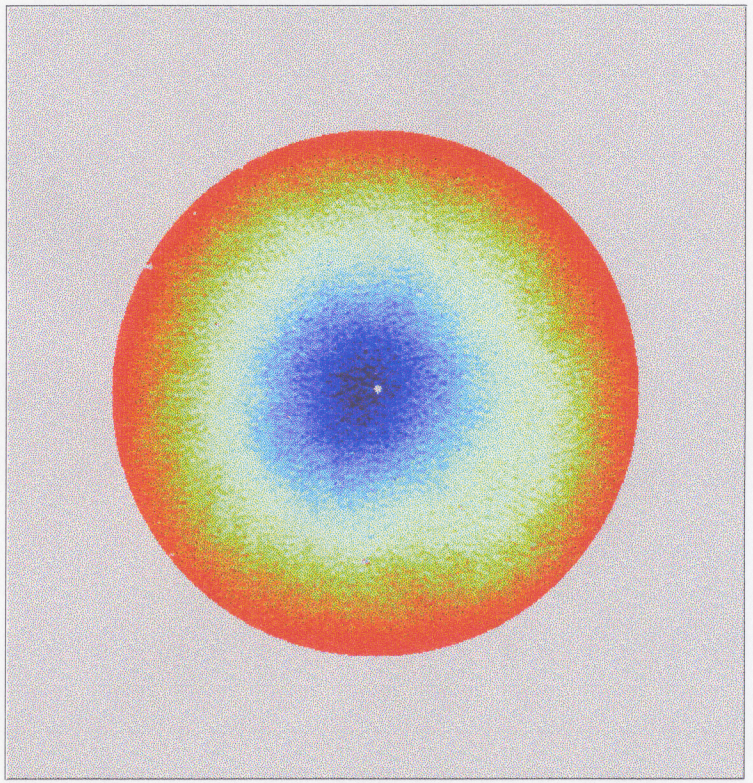
Astig: 0.5 nm

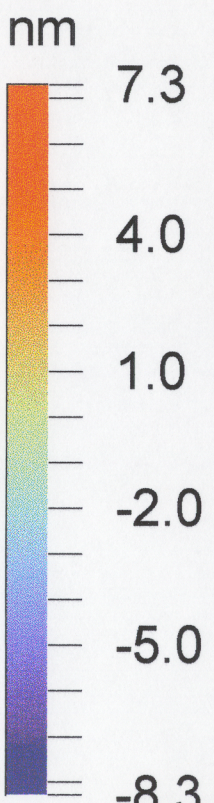
Power: 8.9 nm

PV: 8.0 nm

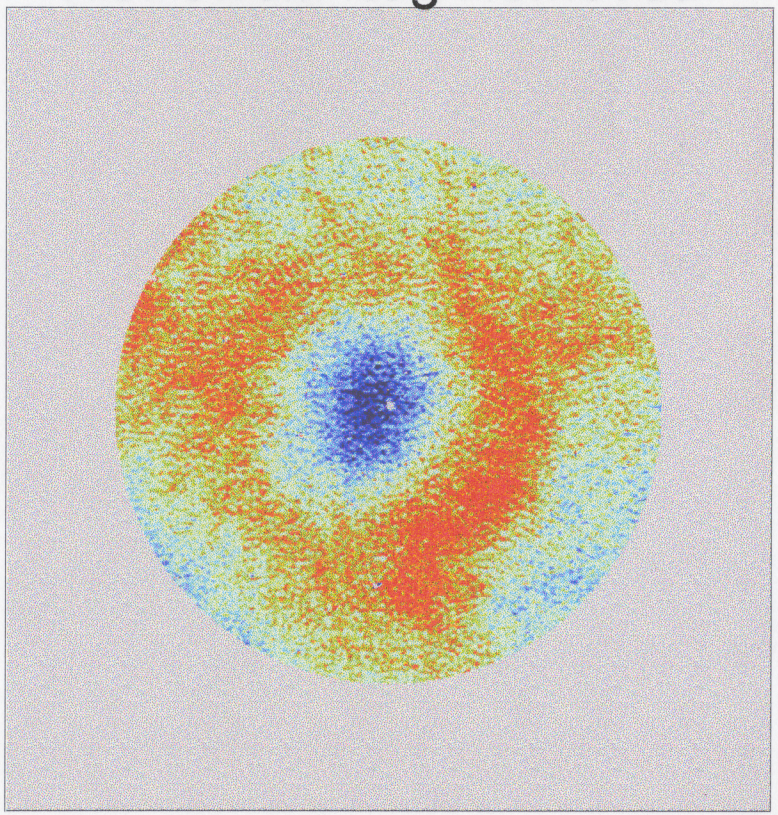
RMS: 0.7 nm

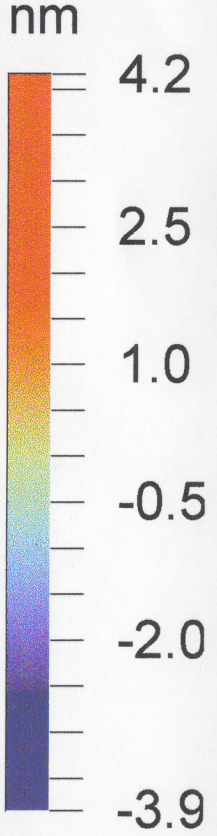
Tilt Removed

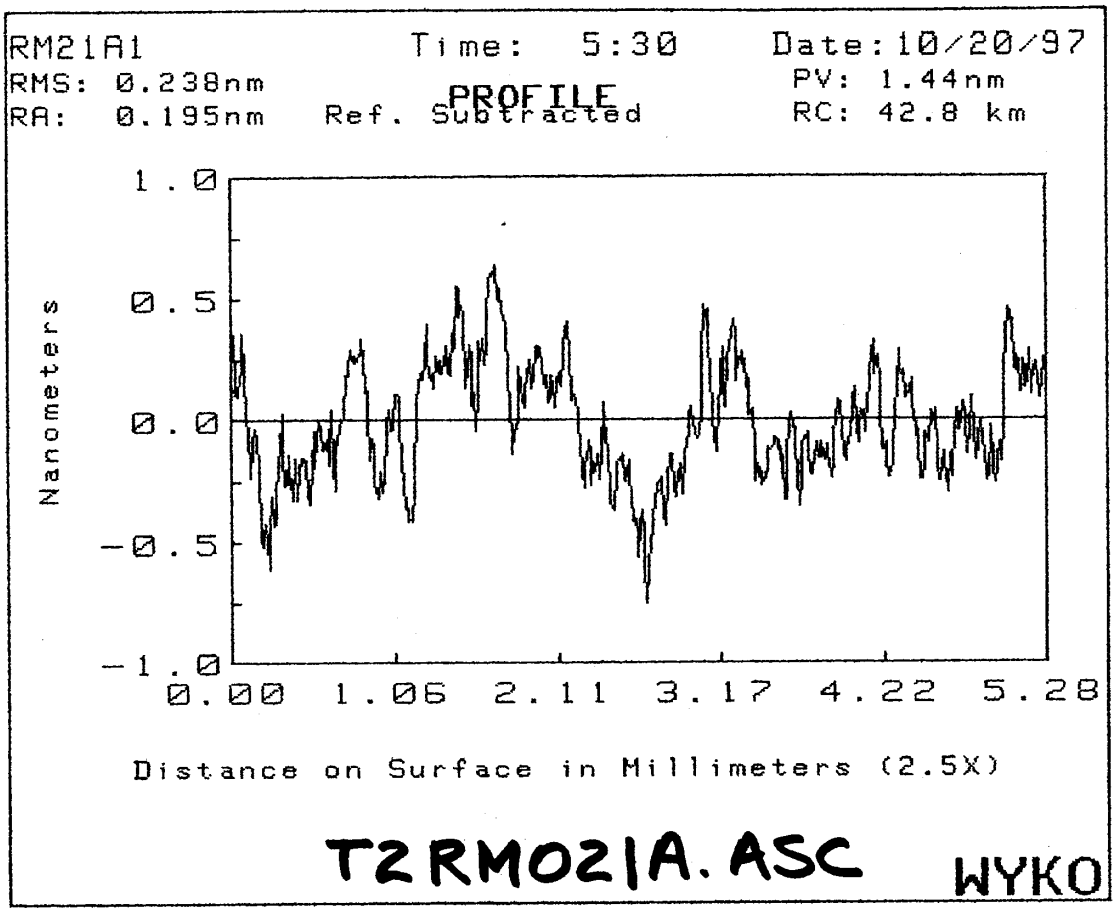




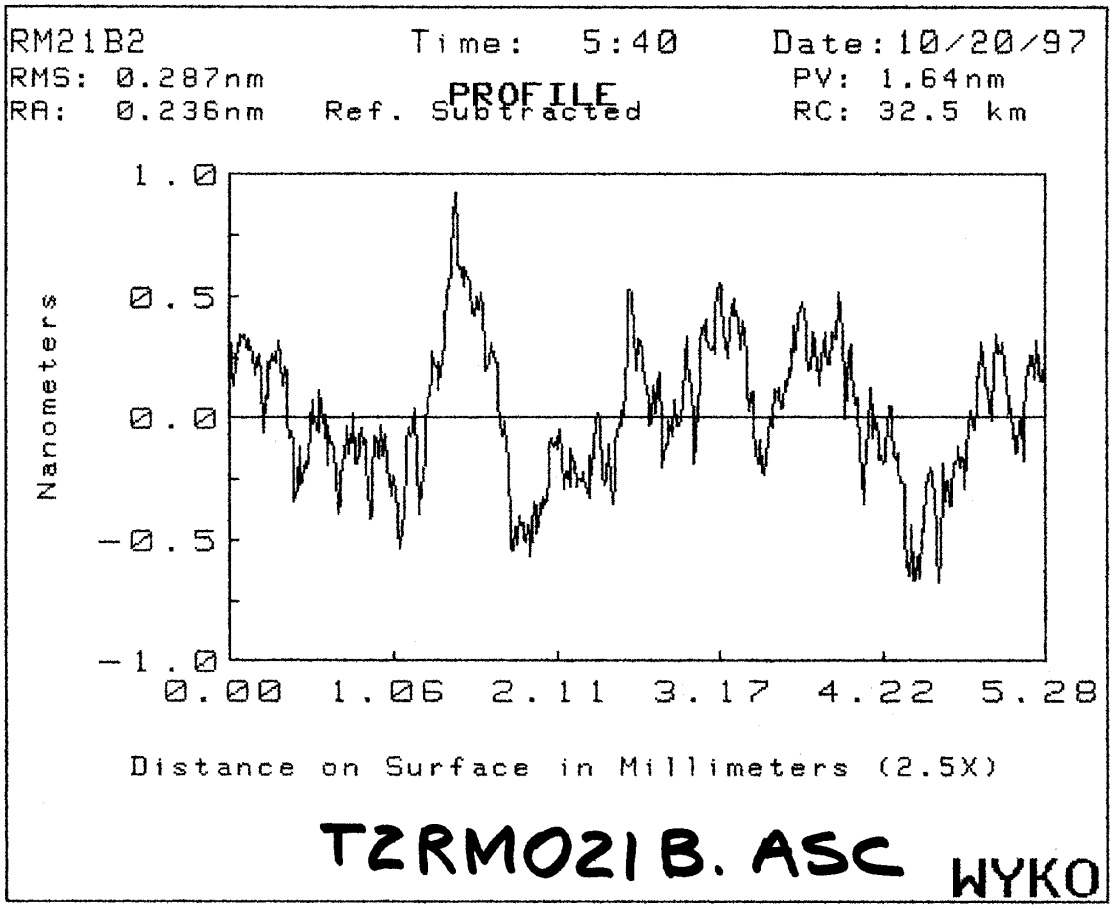
Tilt/Power/Astig Removed

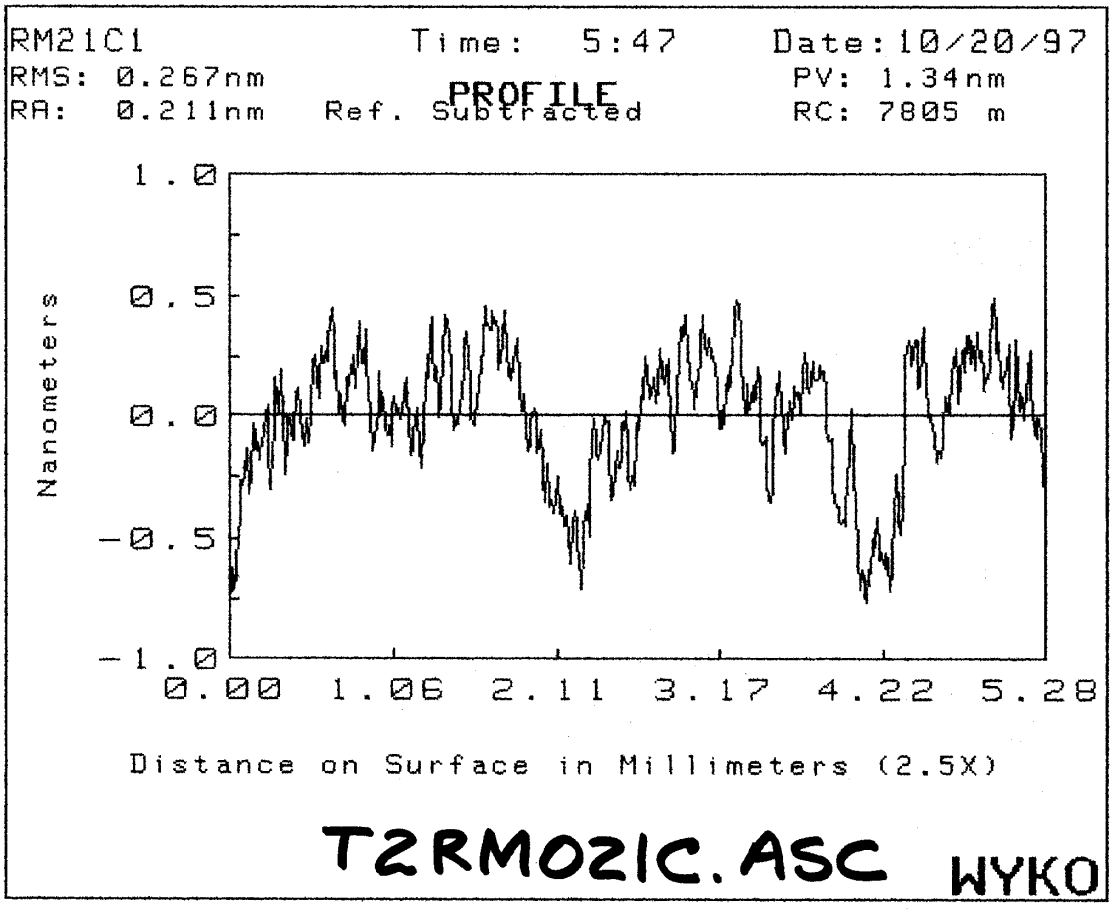


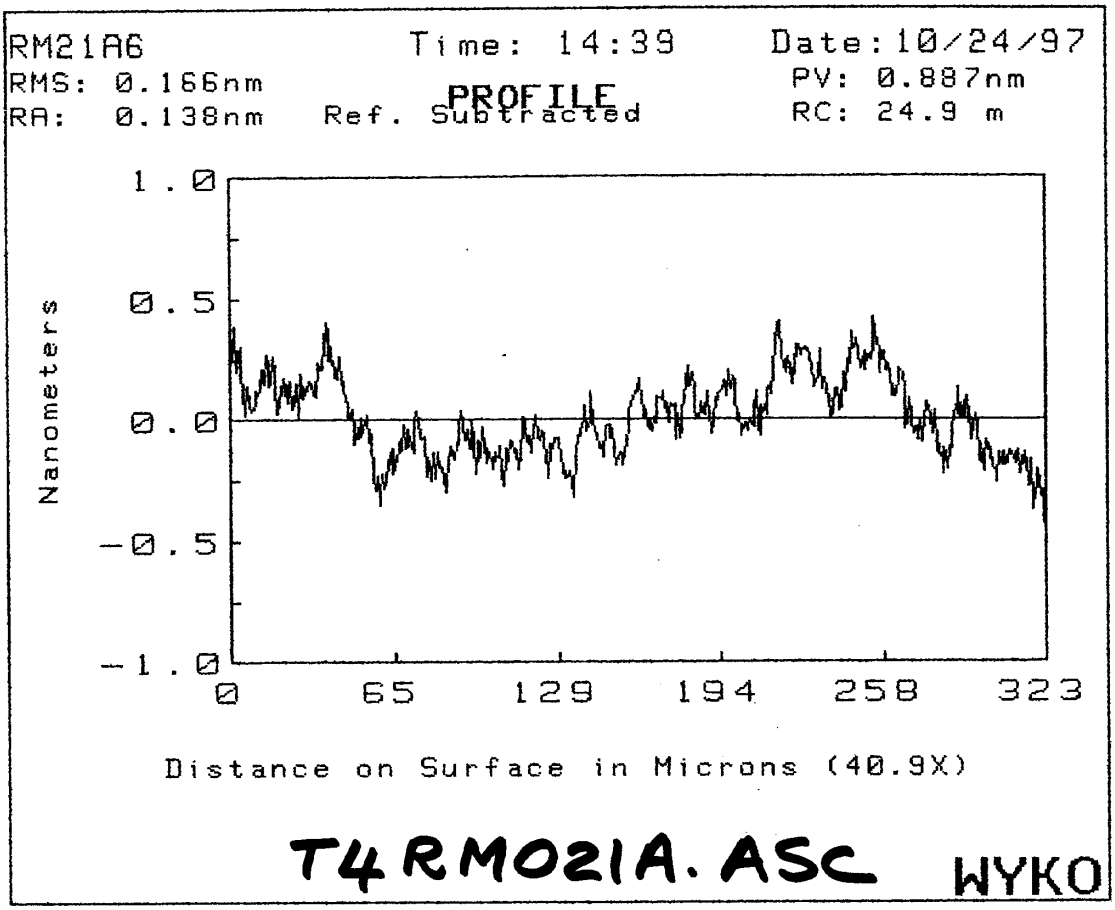


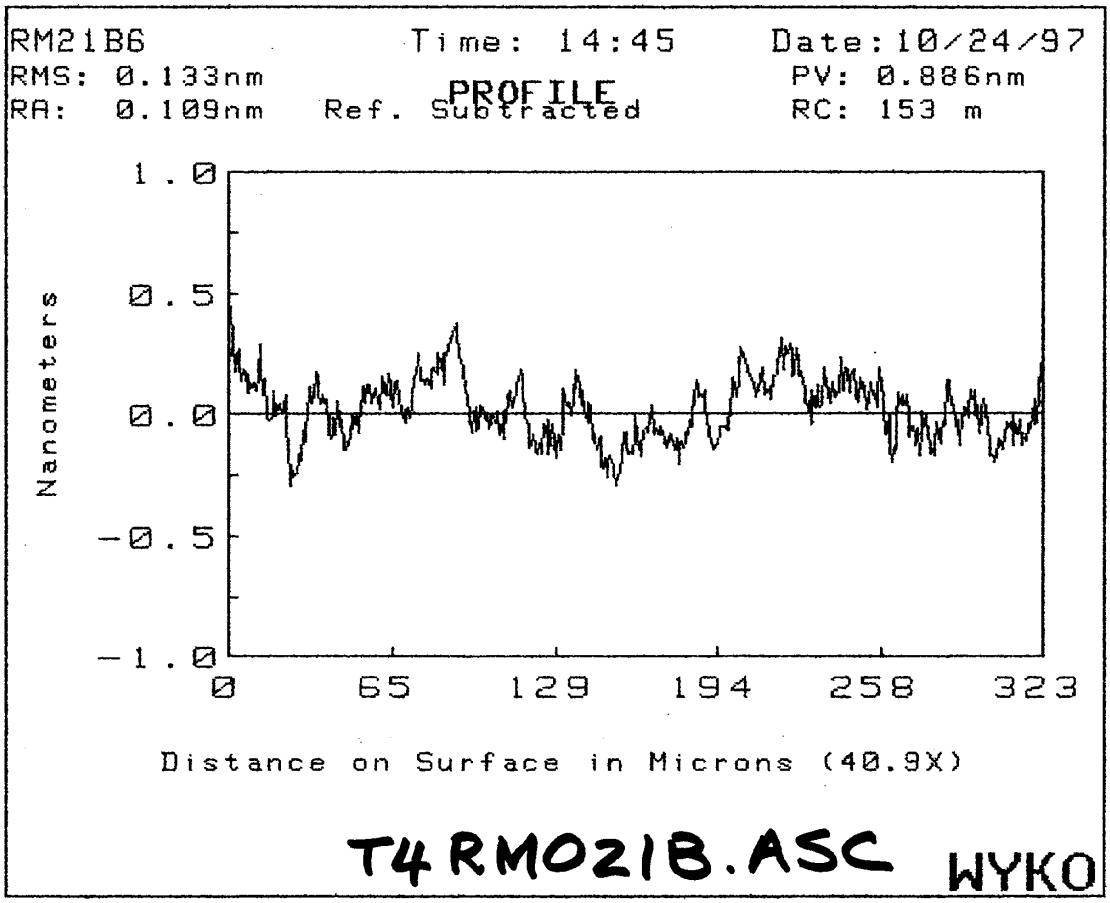

RM21A1
Time: 5:30
Date:10/20/97
RMS: 0.238nm
PROFILE
PV: 1.44nm
RA: 0.195nm
Ref. Subtracted
RC: 42.8 km
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0.00
1.06
2.11
3.17
4.22
5.28
Distance on Surface in Millimeters (2.5X)
T2RM021A.ASC
WYKO

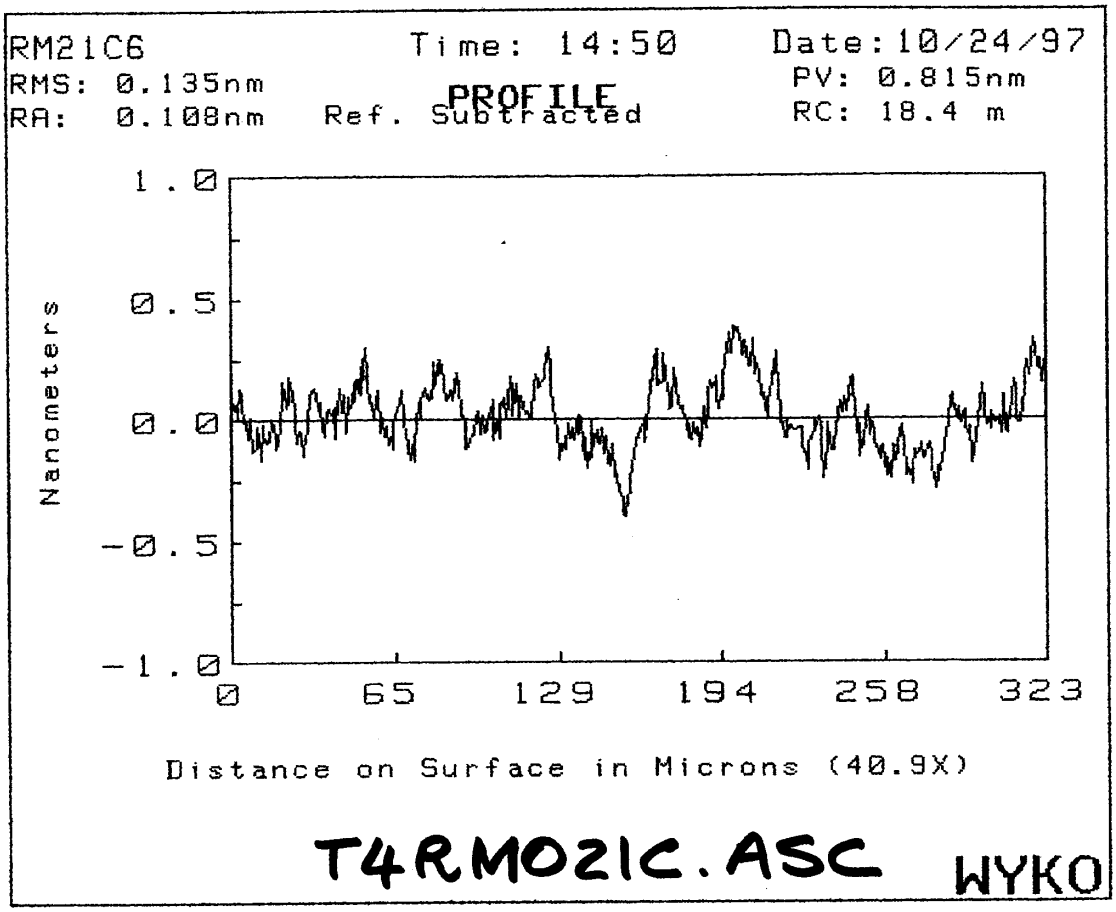
Attach. 3

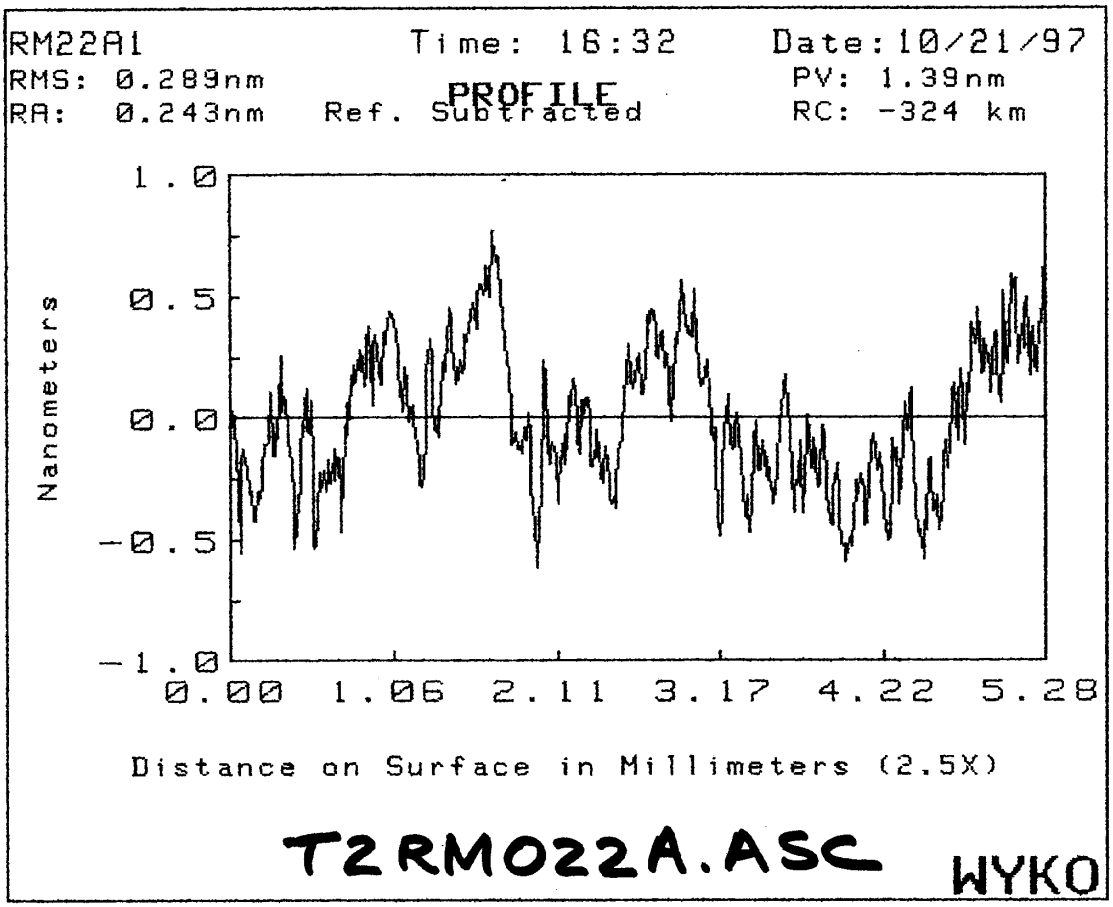

RM21B2
Time: 5:40
Date:10/20/97
RMS: 0.287nm
PROFILE
PV: 1.64nm
RA: 0.236nm
Ref. Subtracted
RC: 32.5 km
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0.00 1.06 2.11 3.17 4.22 5.28
Distance on Surface in Millimeters (2.5X)
T2RM021B.ASC
WYKO


RM21C1
Time: 5:47
Date:10/20/97
RMS: 0.267nm
PROFILE
PV: 1.34nm
RA: 0.211nm
Ref. Subtracted
RC: 7805 m
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0.00 1.06 2.11 3.17 4.22 5.28
Distance on Surface in Millimeters (2.5X)
T2RM021C.ASC
WYKO

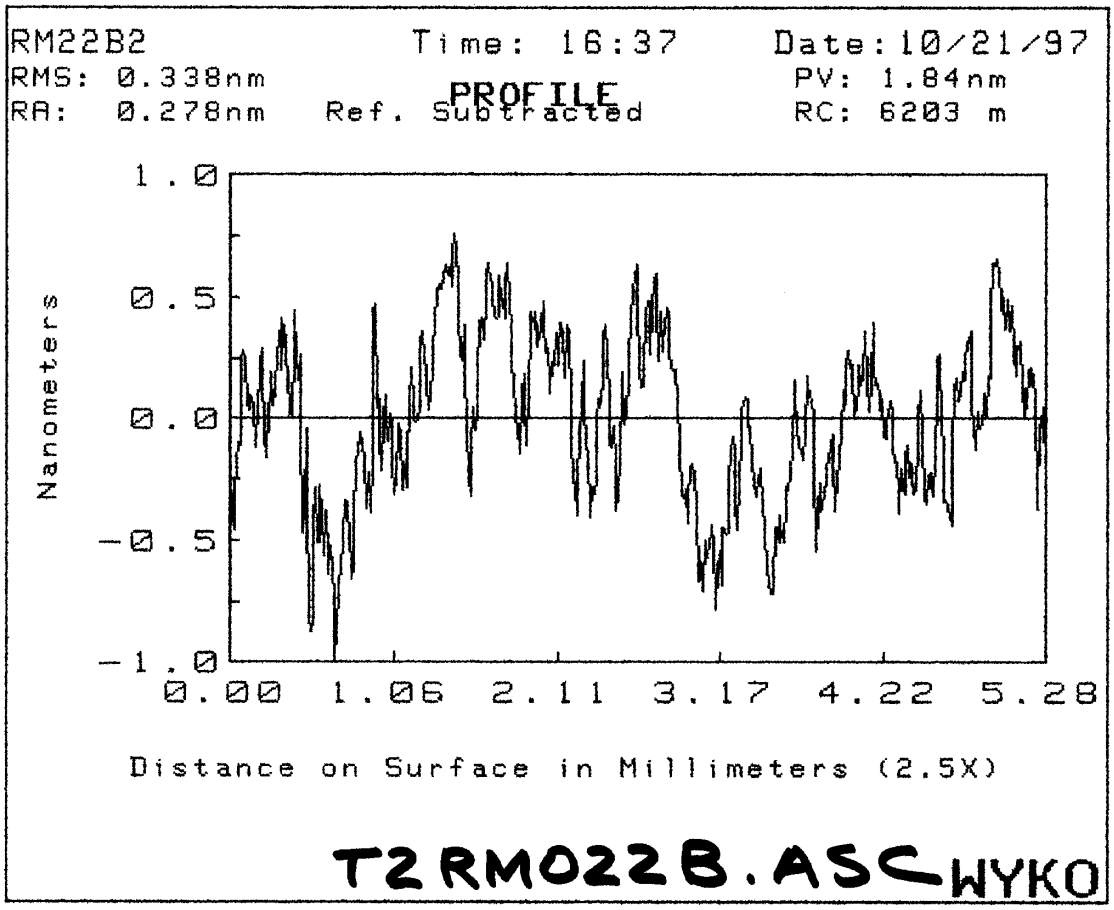

RM21A6
Time: 14:39
Date:10/24/97
RMS: 0.166nm
PROFILE
PV: 0.887nm
RA: 0.138nm
Ref. Subtracted
RC: 24.9 m
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0
65
129
194
258
323
Distance on Surface in Microns (40.9X)
T4RM021A.ASC
WYKO

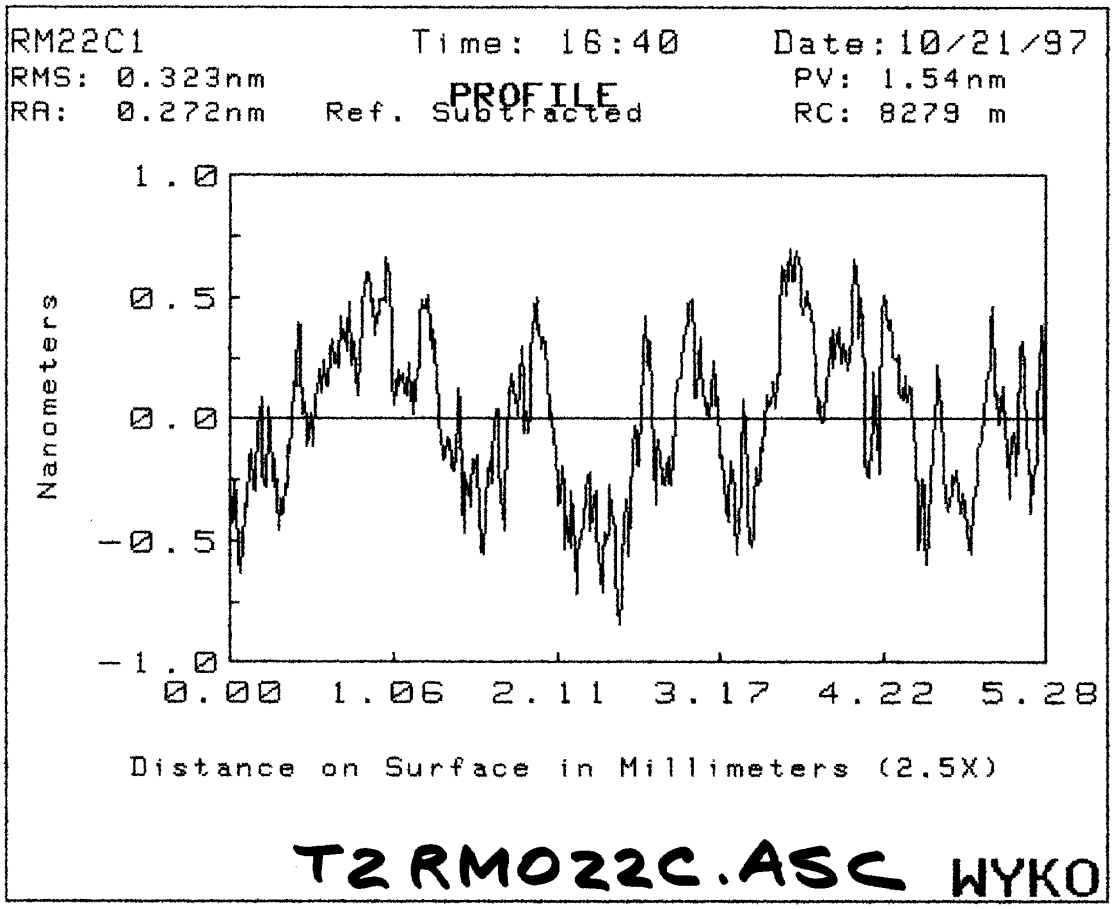

RM21B6
Time: 14:45
Date:10/24/97
RMS: 0.133nm
PROFILE
PV: 0.886nm
RA: 0.109nm
Ref. Subtracted
RC: 153 m
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0
65
129
194
258
323
Distance on Surface in Microns (40.9X)
T4RM021B.ASC
WYKO

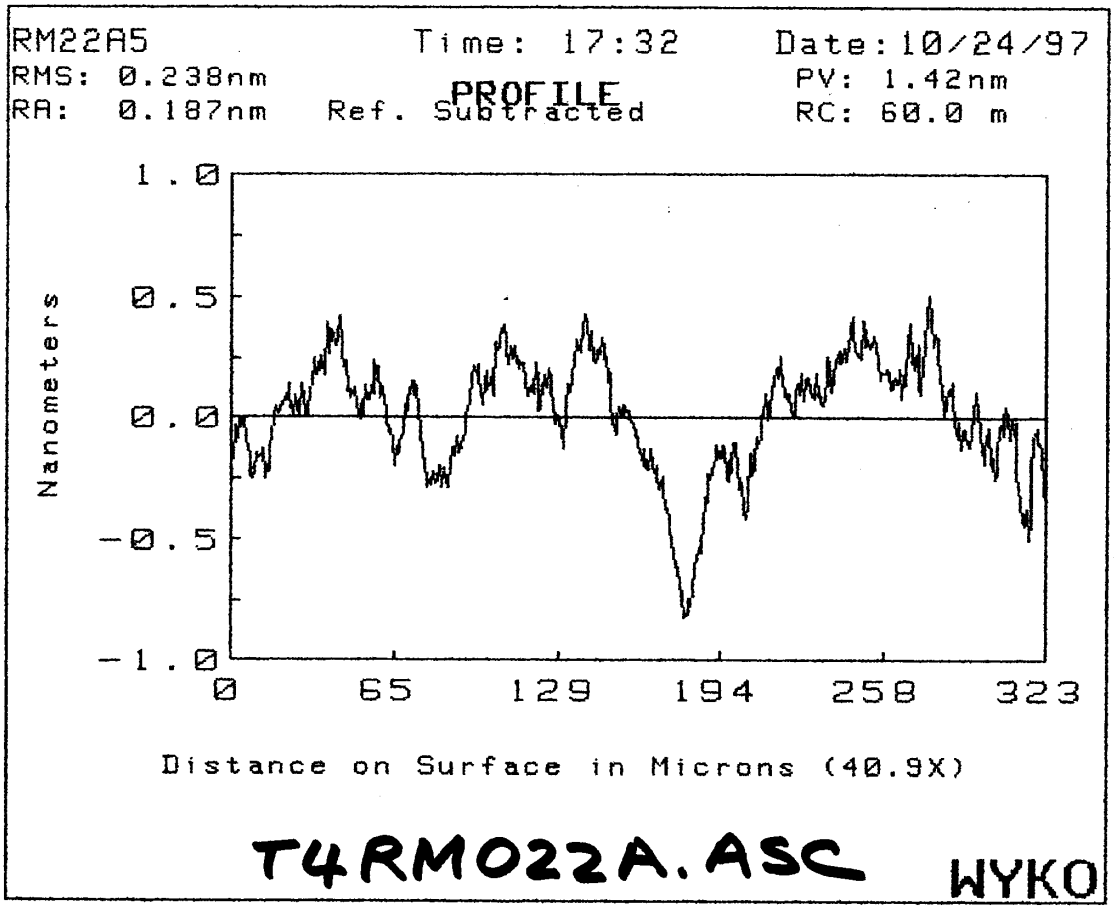

RM21C6
Time: 14:50
Date:10/24/97
RMS: 0.135nm
PROFILE
PV: 0.815nm
RA: 0.108nm
Ref. Subtracted
RC: 18.4 m
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0
65
129
194
258
323
Distance on Surface in Microns (40.9X)
T4RM021C.ASC
WYKO

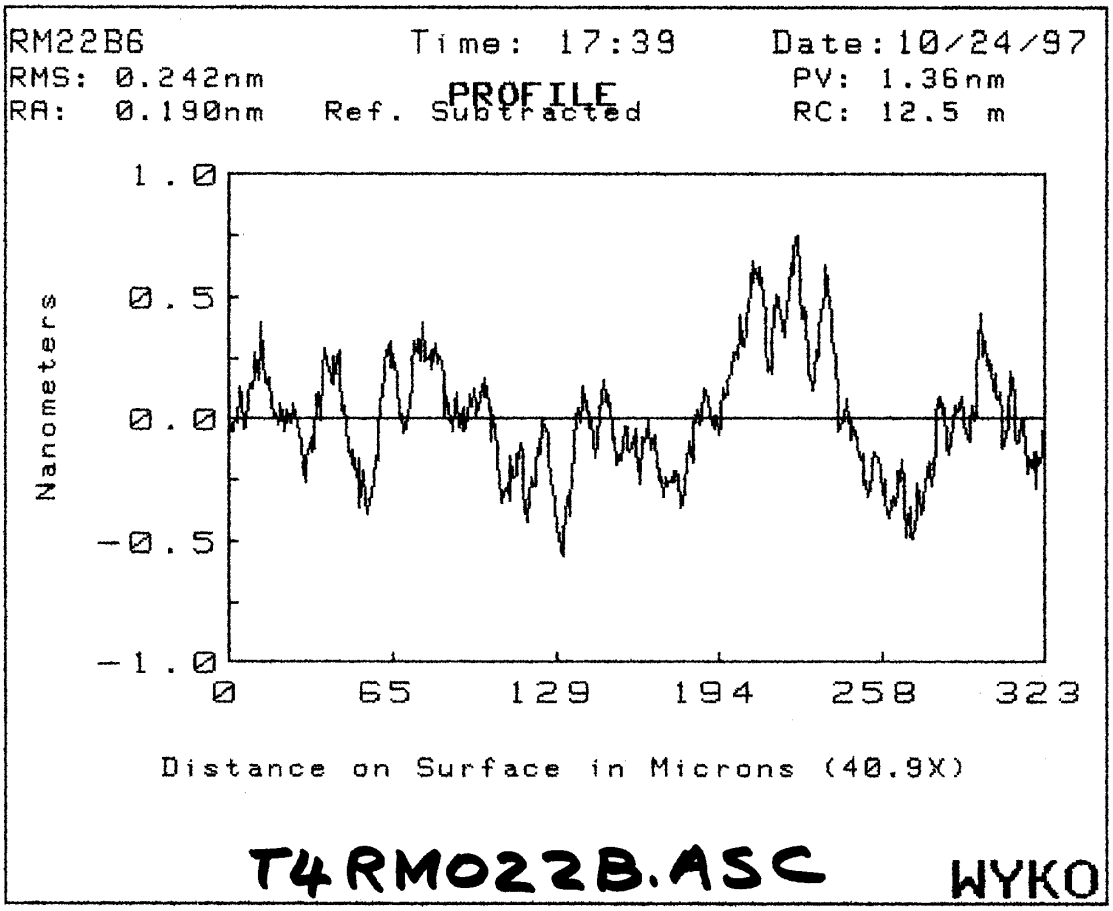

RM22A1
Time: 16:32
Date:10/21/97
RMS: 0.289nm
PROFILE
PV: 1.39nm
RA: 0.243nm
Ref. Subtracted
RC: -324 km
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0.00
1.06
2.11
3.17
4.22
5.28
Distance on Surface in Millimeters (2.5X)
T2RM022A.ASC
WYKO

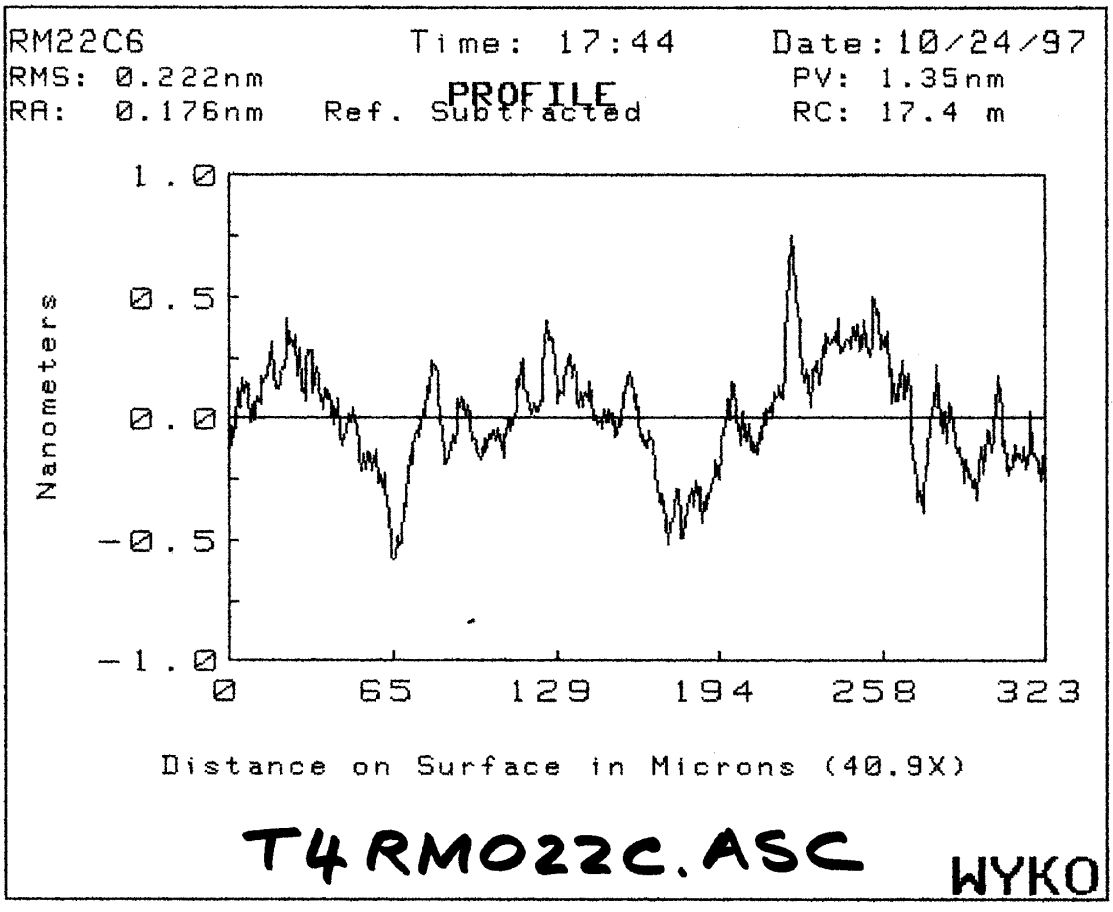
Attach. 4


RM22B2
Time: 16:37
Date:10/21/97
RMS: 0.338nm
PROFILE
PV: 1.84nm
RA: 0.278nm
Ref. Subtracted
RC: 6203 m
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0.00 1.06 2.11 3.17 4.22 5.28
Distance on Surface in Millimeters (2.5X)
T2RM022B.ASC WYKO


RM22C1
Time: 16:40
Date:10/21/97
RMS: 0.323nm
PROFILE
PV: 1.54nm
RA: 0.272nm
Ref. Subtracted
RC: 8279 m
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0.00 1.06 2.11 3.17 4.22 5.28
Distance on Surface in Millimeters (2.5X)
T2RM022C.ASC WYKO


RM22A5
Time: 17:32
Date:10/24/97
RMS: 0.238nm
PROFILE
PV: 1.42nm
RA: 0.187nm
Ref. Subtracted
RC: 60.0 m
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0
65
129
194
258
323
Distance on Surface in Microns (40.9X)
T4RM022A.ASC
WYKO


RM22B6
Time: 17:39
Date:10/24/97
RMS: 0.242nm
PROFILE
PV: 1.36nm
RA: 0.190nm
Ref. Subtracted
RC: 12.5 m
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0
65
129
194
258
323
Distance on Surface in Microns (40.9X)
T4RM022B.ASC
WYKO


RM22C6
Time: 17:44
Date:10/24/97
RMS: 0.222nm
PROFILE
PV: 1.35nm
RA: 0.176nm
Ref. Subtracted
RC: 17.4 m
1.0
0.5
0.0
-0.5
-1.0
Nanometers
0
65
129
194
258
323
Distance on Surface in Microns (40.9X)
T4RM022C.ASC
WYKO