NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C.

October 23, 1998

Report of Testing

Factual Report of Testing
by Erin M. Gormley

A. ACCIDENT DCA98RA013

Location	: Palembang, Indonesia
Date	: December 19, 1997
Time	: 0809 UTC
Aircraft	: Boeing B737-300

B. GROUP REPRESENTATION

N/A

C. SUMMARY

On December 19, 1997, an Indonesian B737-300 operated by Silkair crashed in Palembang, Indonesia. The flight data recorder (FDR), a Sundstrand Data Control[1] Universal Flight Data Recorder (UFDR), was recovered from the crash site and sent to the Vehicle Recorder Division's laboratory in Washington, DC for readout and evaluation. The details of the FDR readout performed are presented in the Group Chairman's Factual Report - Flight Data Recorder. The FDR tape appeared to have received extensive damage most probably resulting from crash impact forces and extensive immersion in water. Normal recovery of the data was hampered because of the damage. Waveform analysis of the data indicated a reduced signal strength which the tape manufacturer, Quantegy, was unable to resolve. An alternate method was proposed of using Magnetic Force Microscopy (MFM) to optically view the tape to determine if recorded magnetic data were present in the damaged area. The UFDR tape was brought to Digital Instruments of Santa Barbara, California to determine if the MFM technique could resolve additional data.

[1] Sundstrand Data Control (SDC) is now operating under the name Allied Signal Inc.

D. DETAILS OF TESTING

1. UFDR Recording Operation

The Flight Data Acquisition Unit (FDAU) receives data sent from various sources throughout the aircraft. The FDAU converts these analog and digital signals into a serial binary data stream of zeros and ones which are recorded onto the tape in the form of Harvard Bi-Phase waveforms. A zero is represented by a wave making a single transition across a bit cell where as a one shows a wave reversal during a bit cell. The information is recorded by arranging the magnetic oxide particles on the tape to represent the waveform.

Twelve consecutive bits comprise a word of data. A normal UFDR recording process writes 64 12-bit words a second (called a subframe) which occupies .36 inches of tape. After each subframe, an Inter-Record Gap (IRG) is written which is .06 inches in length. The UFDR records 25 hours of data on 8 separate tracks. After completing a track, an optical end-of-tape sensor passes a window, the recorder reverses and begins recording in the opposite direction on the next track. As the tape progresses, it passes over a head that erases previously recorded data before coming in contact with the write head which writes the data being processed by the FDAU. There is approximately 3 inches between the erase head and write head. This produces a 3 inch section of the tape, called an erase band, located between the newest recorded data and the 25-hour old recorded data.

2. MFM Instrumentation

MFM involves moving a ferromagnetic probe tip over a sample and mapping the magnetic fields present. The Dimension 5000 Scanning Probe Microscope (SPM) uses this technique to examine a 100 micron sample of tape at once. The magnetized tip is positioned with the northern pole closest to the sample. As the tip taps the sample, it is attracted to the south poles and repelled by the north poles of the magnetic particles that make up the recorded data. The photographic images that are produced from the viewing represent this relationship (Attachment I-1). The dark sections show where the tip was attracted and the bright sections show where the tip was repulsed. The width of the band differentiates a zero from a one, a zero being the wider of the two. As the tip moves along the sample, it also maps the surface topography and produces an image. The program used to capture the images can also perform a section analysis. By placing markers at certain points, the peak-to-peak amplitude and period of the signal may be measured (Attachment I-2).

3. Silkair Tape Examination

Visual inspection of the accident aircraft's FDR tape revealed that the unreeled section that was exposed to water appeared damaged compared to the reeled tape which appeared normal. The tape was broken in one section presumably from crash impact forces. It had also been stretched and frayed in other sections. These sections were spliced together for reinforcement. A physical image of the tape, in the most damaged section, revealed a loss of oxide, roughness, and crater-like pockets on the surface. A random section of undamaged tape was placed under the microscope to identify presumably normal data. The bars of varying brightness, representing bits of zeros and ones, appeared as expected. The amplitude in this area measured about 5 volts peak-to-peak which is considered normal. By examining another random section of tape in the damaged section, no such pattern was visible.

The DFDR data, as contained in the Chairman's Factual Report - Flight Data Recorder, were transcribed from the tape using specialized NTSB laboratory equipment and computers. The procedure includes passing the tape over read heads and storing the data to a hard disk. This automated process makes it impossible to correlate the last data bit recovered by the tape heads and stored by the system with the physical location on the tape. On a normal tape, the last recovered bit is followed by a 3 inch erase band and then 25 hour old data. Since this location was unknown, the microscope could not be focused on a particular section. It was necessary to find the last data as previously recovered so additional data (if they existed) as well as the transition to the erase band could be identified. In order to find that point, the tape was secured on the mounting platform of the microscope and a spot on the tape was designated as an x-y zero reference point. The probe was moved in the y-direction to view the section of tape calculated to be Track 3, the accident track. Starting at that point, data were seen and an amplitude of .5 volts peak-to-peak were measured, considerably less than the normal 5 volts peak-to-peak signal measured in the good area. Progressing towards the damaged section of data, the signal fluctuated but generally became weaker. Attachment I-3 contains a plot of lateral position moving towards the damaged section versus weakening amplitude of the recorded data. Attachments I-4 to I-6 show the degradation in clarity of the bits as the probe progressed laterally. At one test point, there were no data visible. Some specks of magnetic particles were apparent but not in an arranged pattern that would indicate bits (Attachment I-7). This section was not considered characteristic of an erase band. An example of a typical erase band is shown in Attachment I-8. At this point, the probe was moved vertically to view 2 other tracks and data were not found. This may indicate that there were no data present on any of the tracks throughout that section. Since the microscope focuses on such a small area of tape it was difficult to determine exactly where the data went from a weak signal to virtually non-existent.

E. FURTHER TESTING

The degradation in signal amplitude observed with the MFM technology was greater than that observed with the waveform analysis performed on the signal readout with the tape head. In order to determine if additional bits do exist beyond those already recovered, further MFM analysis is required. A special rig with a measurement device must be constructed to accommodate the reels of tape and regulate the movement of the sample. The data, beginning at a known reference point, would have to be mapped out along the weakening signal until they completely disappear. These waveforms must be translated into the binary format comprised of zeros and ones. The resulting words must then be compared with the output of the NTSB software to determine which were the last bits the tape head resolved. Each additional bit after this point would be considered newly recovered. Once this point is physically noted on the tape, it would be useful to determine if the last bit of data is followed by the expected 3 inch erase band. Also, other tracks should be checked to determine if data are present as would be expected.

Quantegy, the tape manufacturer, indicated after originally examining the tape, that a destructive test could be performed. This test would destroy the tape so it could no longer be read by a tape head. The magnetic particles on the tape, which comprise the signal, are situated homogeneously throughout the layer coating the mylar base. The side of the tape that was examined was damaged and the particles depleted in sections. The test procedure would involve separating the layer containing the magnetic particles from the mylar and trying to examine the signal from the opposite side in the event the magnetic particles situated there were not affected as much by the damage to the tape. Since both sides of the tape exhibit damage, it is unlikely any more data could be recovered using this method. Regardless, it would be beneficial to see if the procedure yields any additional information concerning the signal degradation that occurred.

[redacted]

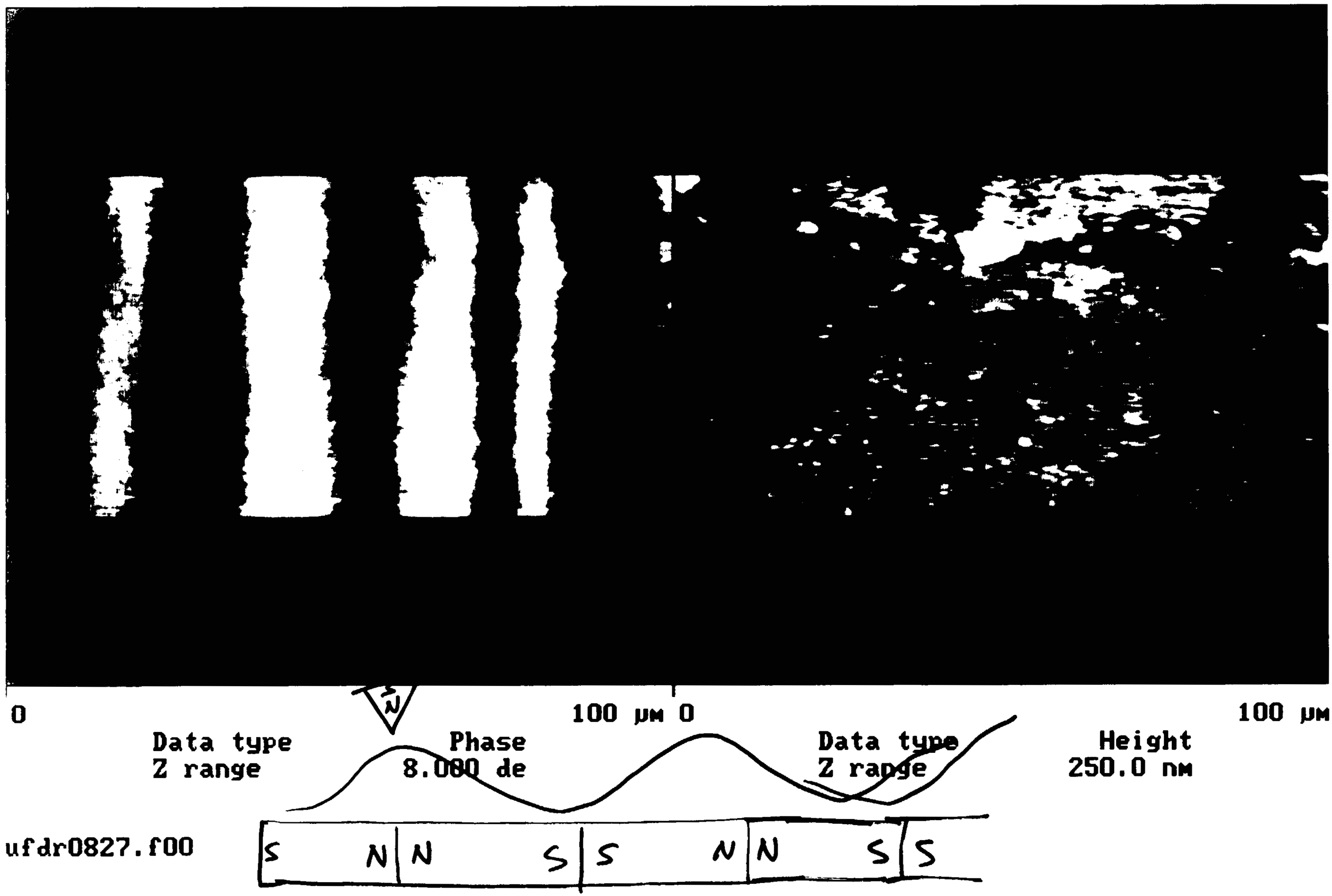
Erin M. Gormley
Aerospace Engineer
Vehicle Recorders Division

List of Attachments:

Attachments I-1 to I-8: MFM Images

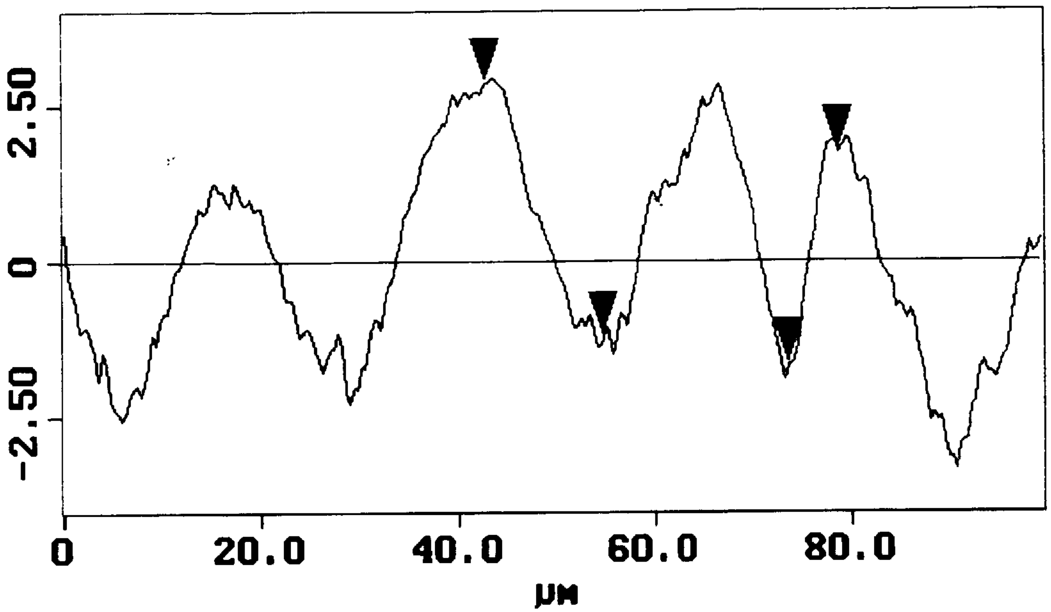
Attachment I
MFM Images

I-1

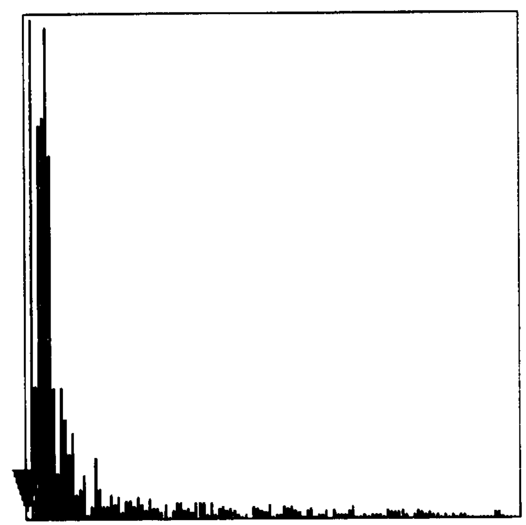

0
100 µm 0
100 µm
Data type
Phase
Z range
8.000 de
Data type
Height
Z range
250.0 nm
ufdr0827.f00
N
S N N S S N N S S

Cursor Marker Spectrum Zoom Center Line Offset Clear

Section Analysis



L	5.078 μm
RMS	1.362 deg
lc	DC
Ra(lc)	0.184 deg
Rmax	1.137 deg
Rz	0.838 deg
Rz Cnt	4
Radius	17.629 μm
Sigma	4.826 nm

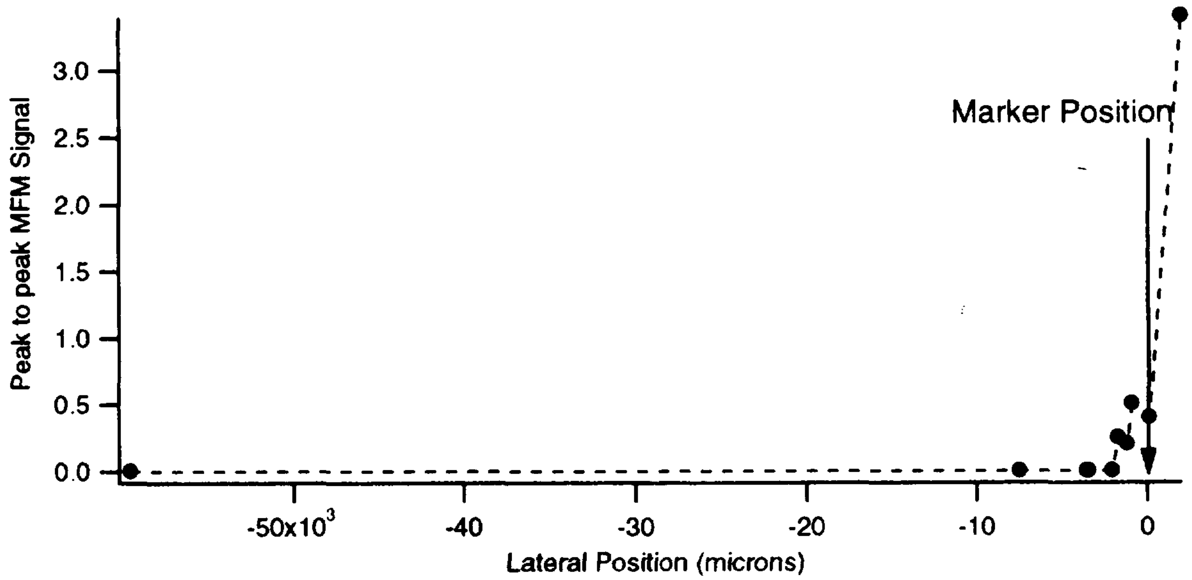


Surface distance	2009.3
Horiz distance(L)	12.109 μm
Vert distance	4.018 deg
Angle	
Surface distance	1403.2
Horiz distance	5.078 μm
Vert distance	3.425 deg
Angle	
Surface distance	
Horiz distance	
Vert distance	
Angle	
Spectral period	DC
Spectral freq	0 Hz
Spectral RMS amp	0.00001 nm

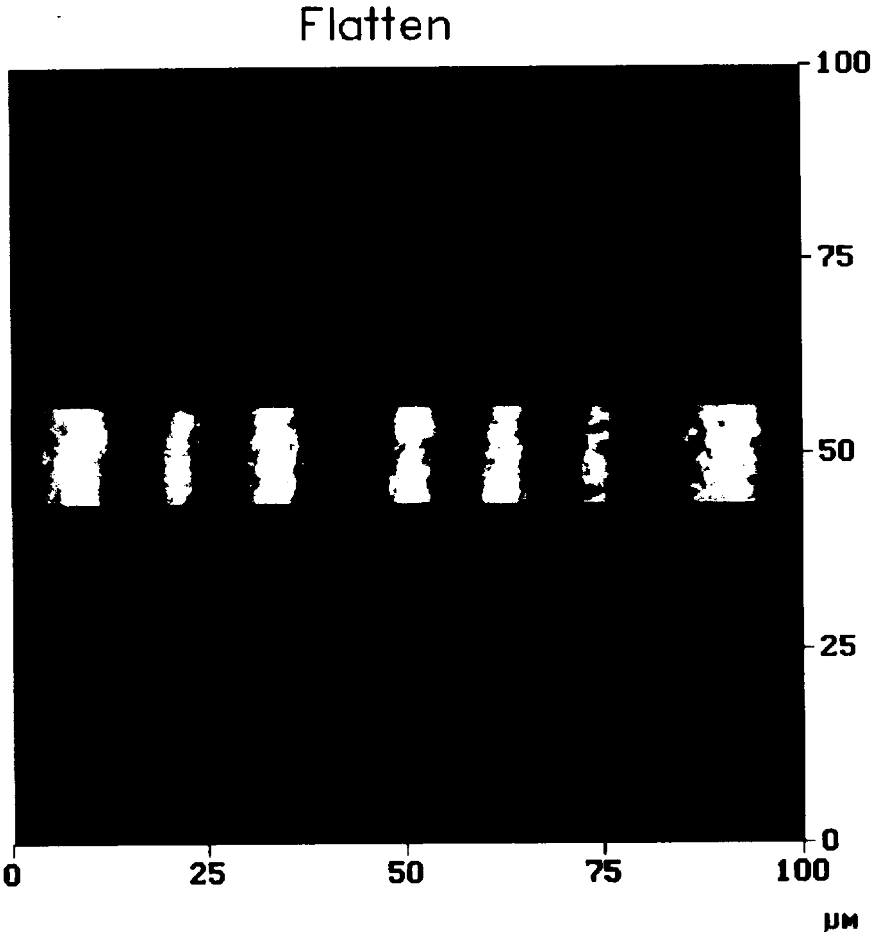
ufdr0827.f00

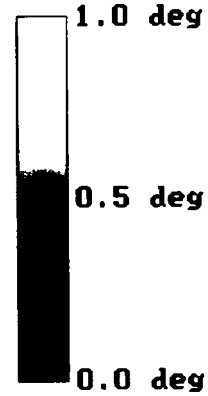
Cursor: fixed Zoom: 1:1 Cen line: Off Offset: Off

MFM Signal vs. Lateral Position



Clear Execute Undo



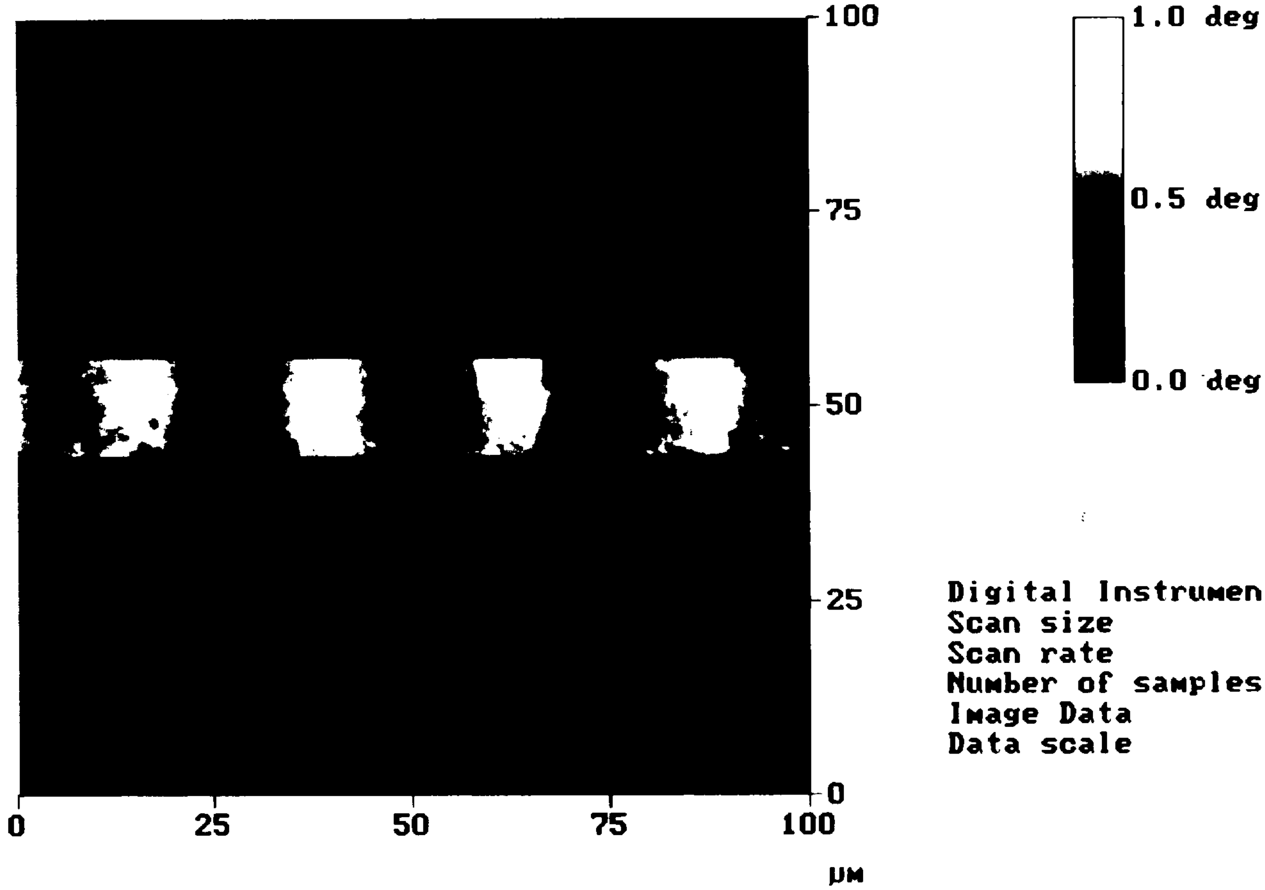


Digital Instruments NanoScope	
Scan size	100.0 μm
Scan rate	0.5008 Hz
Number of samples	256
Image Data	Phase
Data scale	1.000 deg

ufdr0828.005

Clear Execute Undo

Flatten

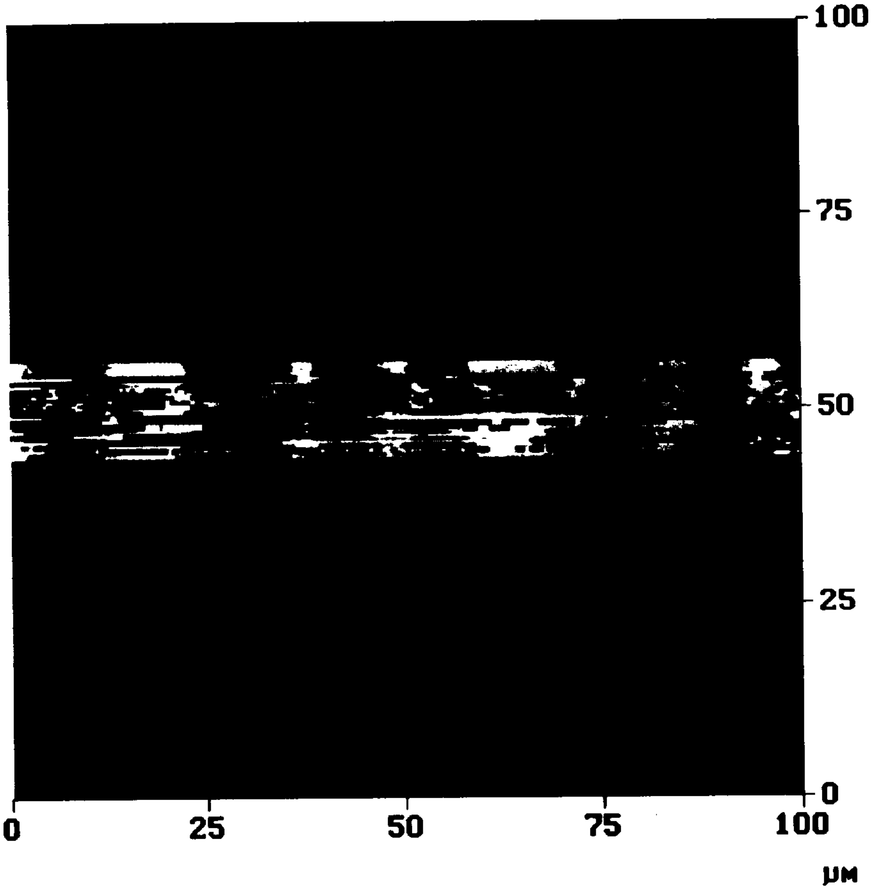


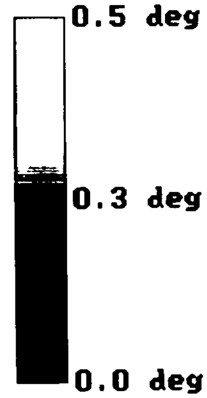
Digital Instruments NanoScope
Scan size 100.0 µ
Scan rate 0.5008 H
Number of samples 256
Image Data Phase
Data scale 1.000 deg

ufdr0828.006

Clear Execute Undo

Flatten





Digital Instruments NanoScope	
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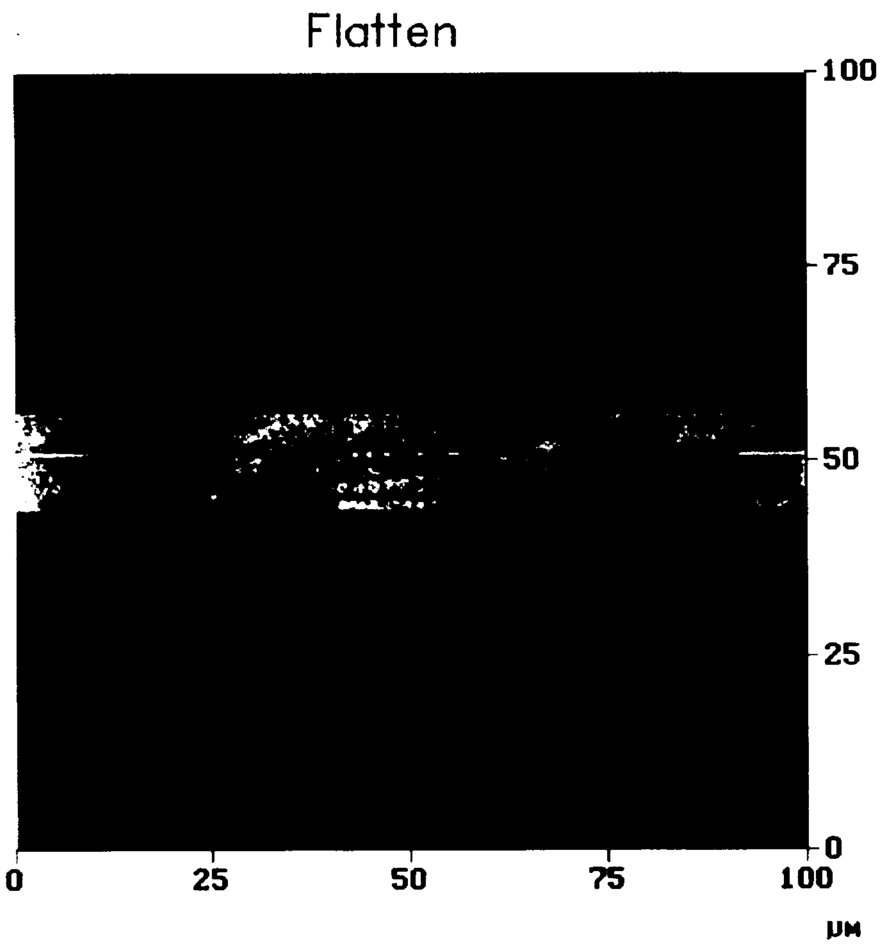
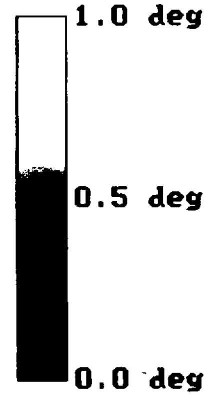
Number of samples	256
Image Data	Phase
Data scale	500.0 mdeg

ufdr0828.007

Clear Execute Undo

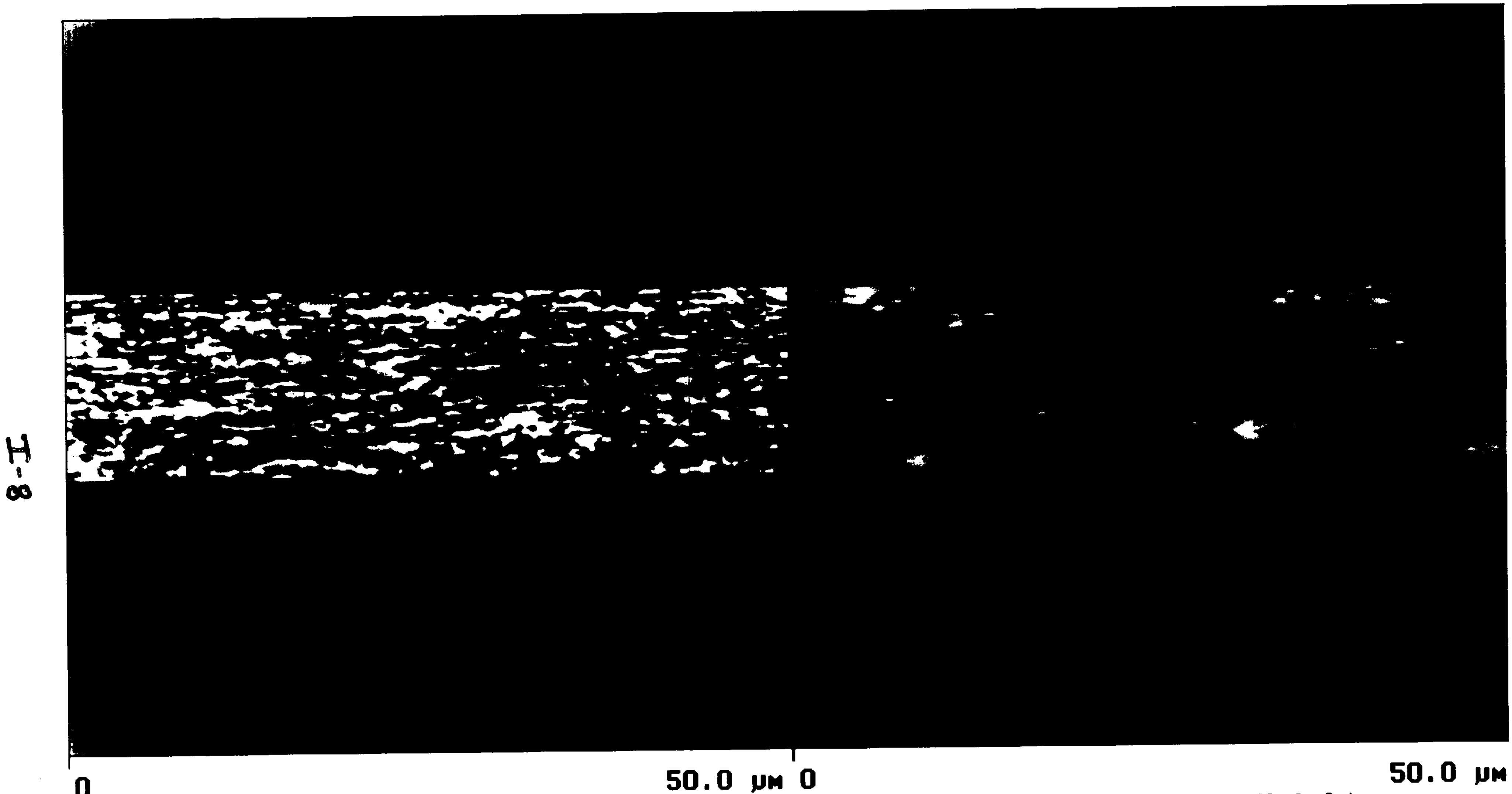




Digital Instruments NanoScope	
Scan size	100.0 μ
Scan rate	1.002 H
Number of samples	256
Image Data	Phase
Data scale	1.000 deg

ufdr0828.009

Erased Data



Data type Phase
Z range 2.500 de

Data type Height
Z range 500.0 nm

ufdr0828.000