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MEASUREMENTS OF EROSION CHARACTERISTICS FOR METAL AND POLYMER SURFACES USING PROFILOMETRY

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SUMMARY

The surfaces of many materials exposed in low earth orbit are modified due to interaction with atomic oxygen. Chemical changes and surface roughening effects can occur which alter optical and other properties (ref.1). The experiment A0114 contained 128 solid surface samples, half of which were exposed on the front and half on the rear of LDEF. Each sample has been subjected to many analyses, but this paper will only describe the methods and techniques used to measure the changes in roughness, erosion depths and material growth using profilometry.

INTRODUCTION

The effect of atomic oxygen on materials is highly variable. No method of measuring the effects is optimum for all materials. We have developed several techniques found valuable in analyzing a wide range of materials, varying from minute effects on the level of atomic dimensions to heavily etched surfaces. One of the most effective techniques has been to utilize the measurement of etched steps at interfaces between exposed and unexposed, or masked, areas by stylus profilometry. Stylus profilometers typically measure the vertical displacement of a stylus (usually a fine pointed diamond) as it is scanned horizontally across the surface. Highly magnified vertical displacements are plotted against horizontal positions greatly exaggerating surface detail. This technique has the ability to measure a wide range of etch steps, from below 1 nm to 1 mm. For measurements below 1 nm it is essential that optically flat surfaces be used and that the steps be measurable over very short lateral distances. As shown elsewhere (ref.2), to produce etch steps over short lateral distances requires very thin masks, preferably thin film patterns resistant to atomic oxygen that are strongly bonded to the substrate being exposed, or at least knife-edged masks essentially in contact with the surface; these types of mask avoid structures which

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accurate measurements of the spikes or plateaus that form at locations of slower etch, and provides an estimate of the maximum etch depth.

Polymethylmethacrylate, PMMA, is a plastic which is readily etched by atomic oxygen, forming a large number of small spikes at the bottom of the etch and a large etch step, as shown in Figure 10, and Figure 11. Figure 10, was traced on a sample mounted on the ambient temperature plate and Figure 11 is for a sample mounted on a separate thermally isolated plate of semipolished aluminum. The purpose was to examine the etch rate as a function of temperature. The small increase in etch in Figure 11 may be due to slightly higher temperature of the hot plate sample. The smooth plateau at the right of the etched area in Figure 10 is due to an artefact caused by the stylus catching on the large etch step and dragging the sample a short distance; heavily etched samples need to be secured for this reason.

CONCLUSION

Stylus profilometry is a very effective non destructive or minimal scratching technique to measure roughness, erosion depth and material growth of metals, polymers and carbons exposed to the atomic oxygen.

We have demostrated that these instruments (Talystep and Talysurf), used in combination with some of the techniques mentioned (scratching, step and transition measurements), have a wide range of resolutions, from ~1Å to a few hundred microns.

Examples, like iridium film, show the reliability of the instrument, giving the same thickness value for the transition in any direction scanned.

Stylus profilometry, by indicating decreases, or increases, in film thicknesses enables interpretations of changes in optical density measurements, i.e. whether thinning of the film or an increase in thickness with optical property changes are responsible for optical density changes.

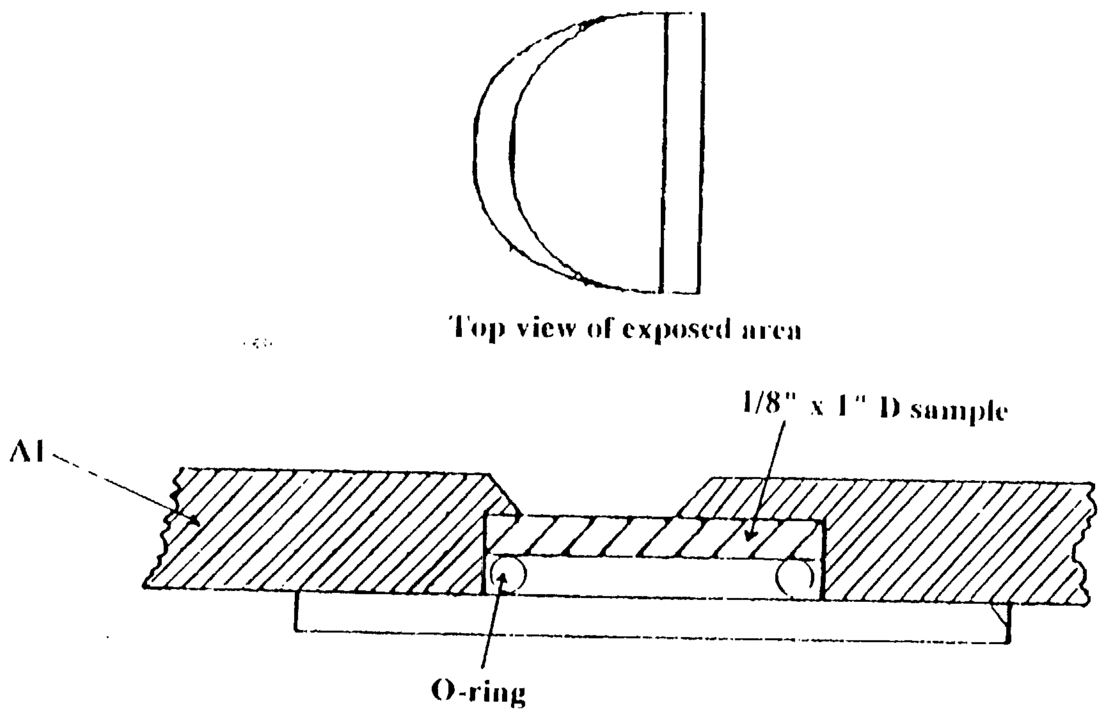


Figure 1. Cross-section of sample holder between exposed and unexposed areas

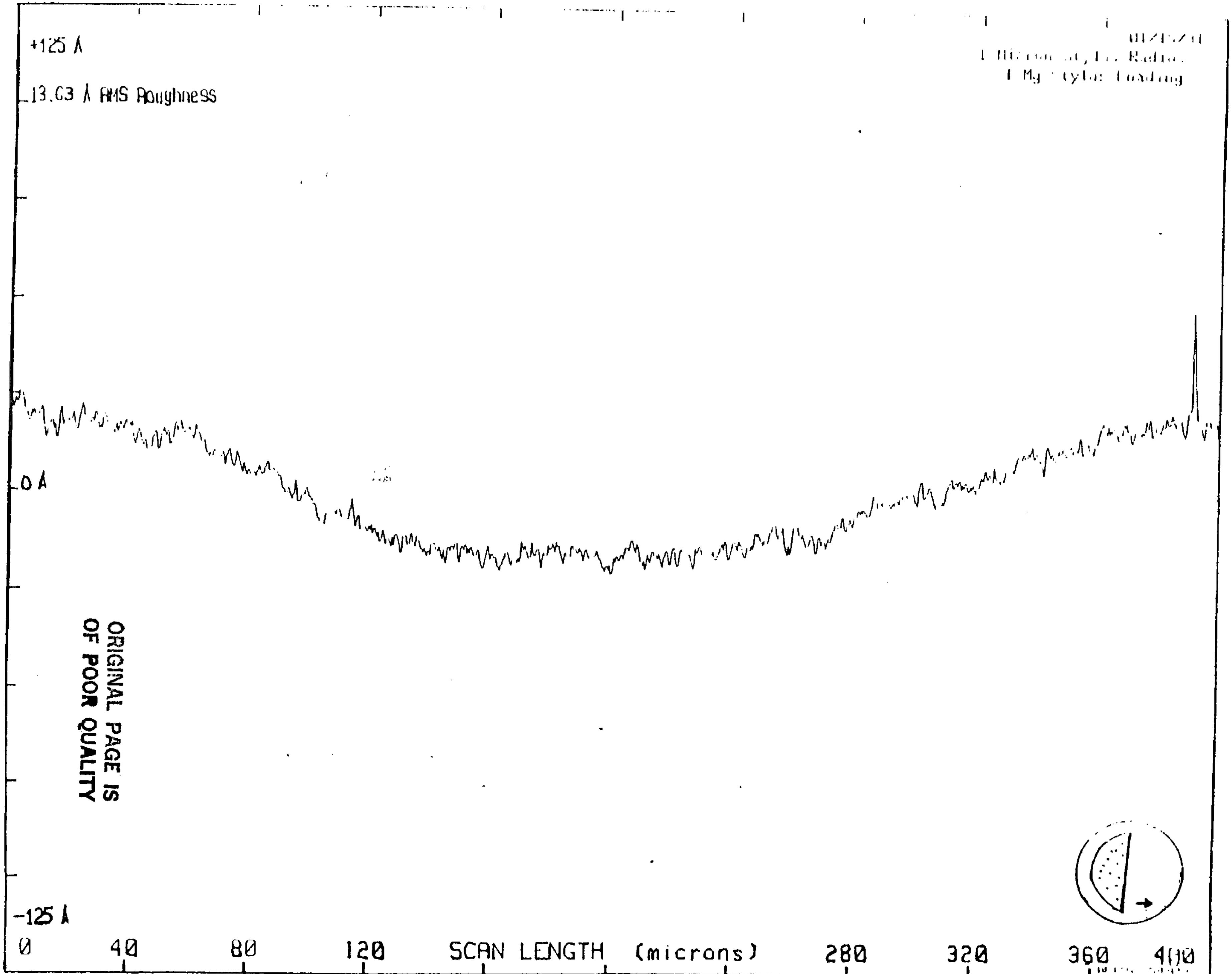
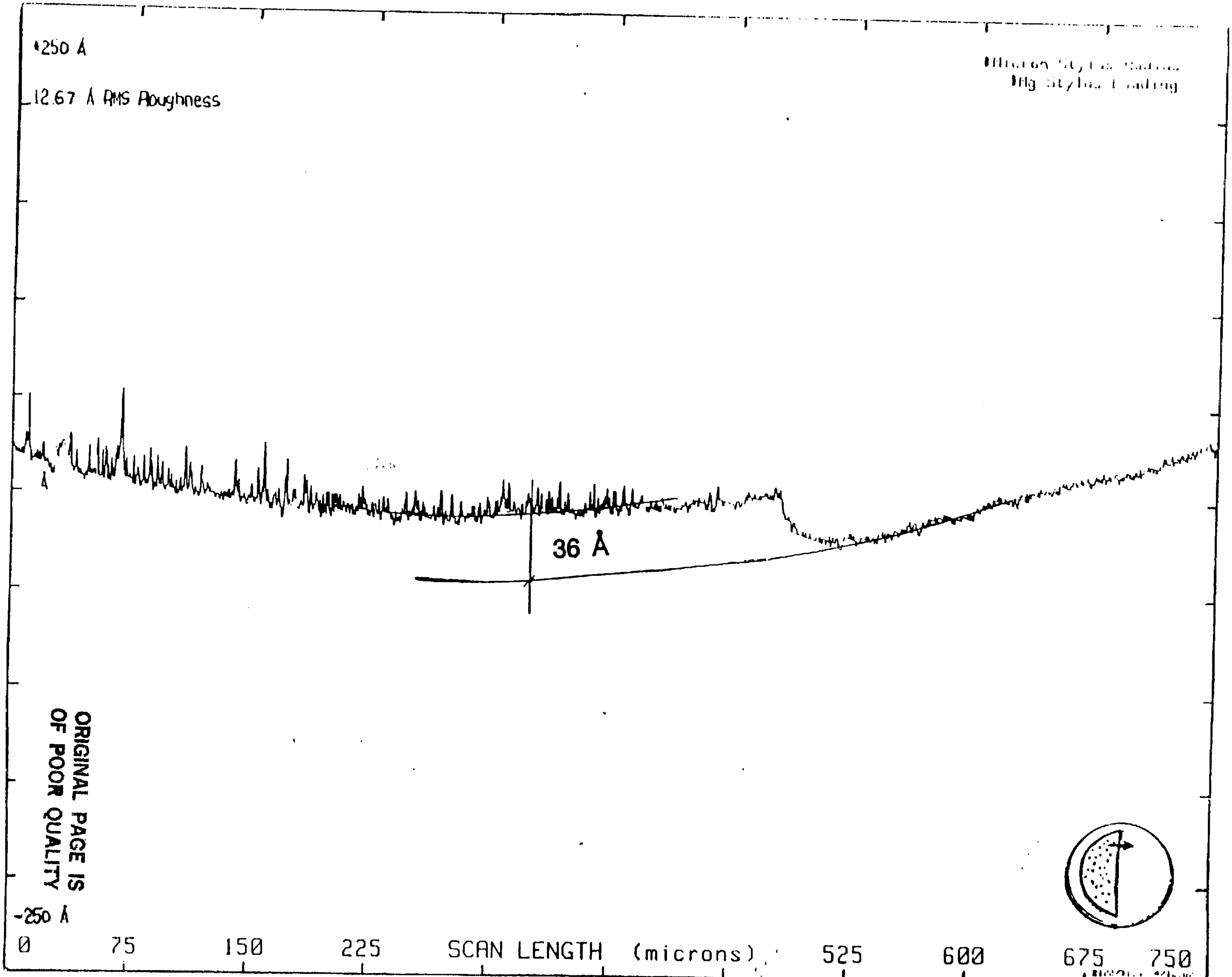
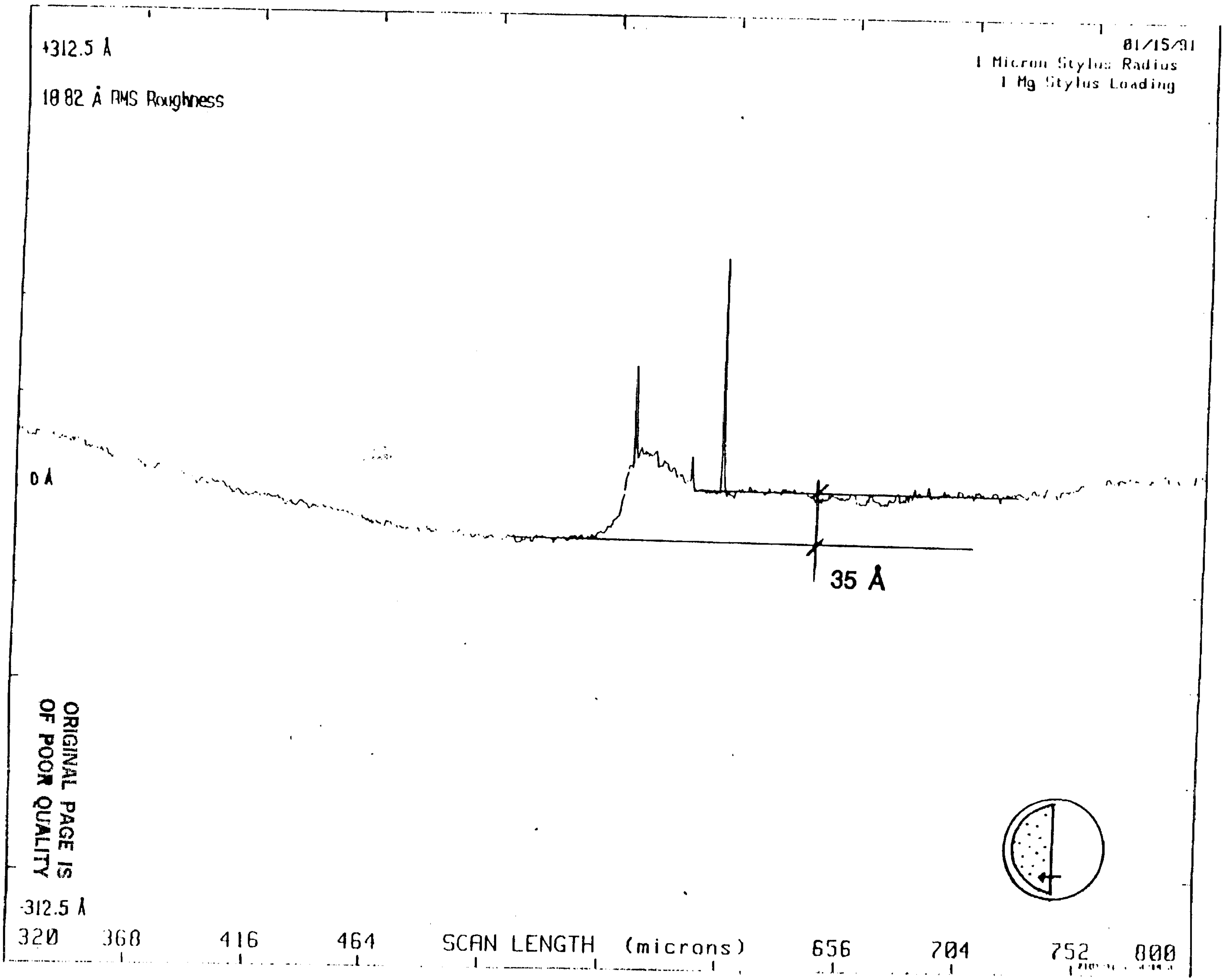


Figure 2. Surface profile of unexposed Iridium film


+250 Å
12.67 Å RMS Roughness
36 Å
-250 Å
0
75
150
225
SCAN LENGTH (microns)
525
600
675
750



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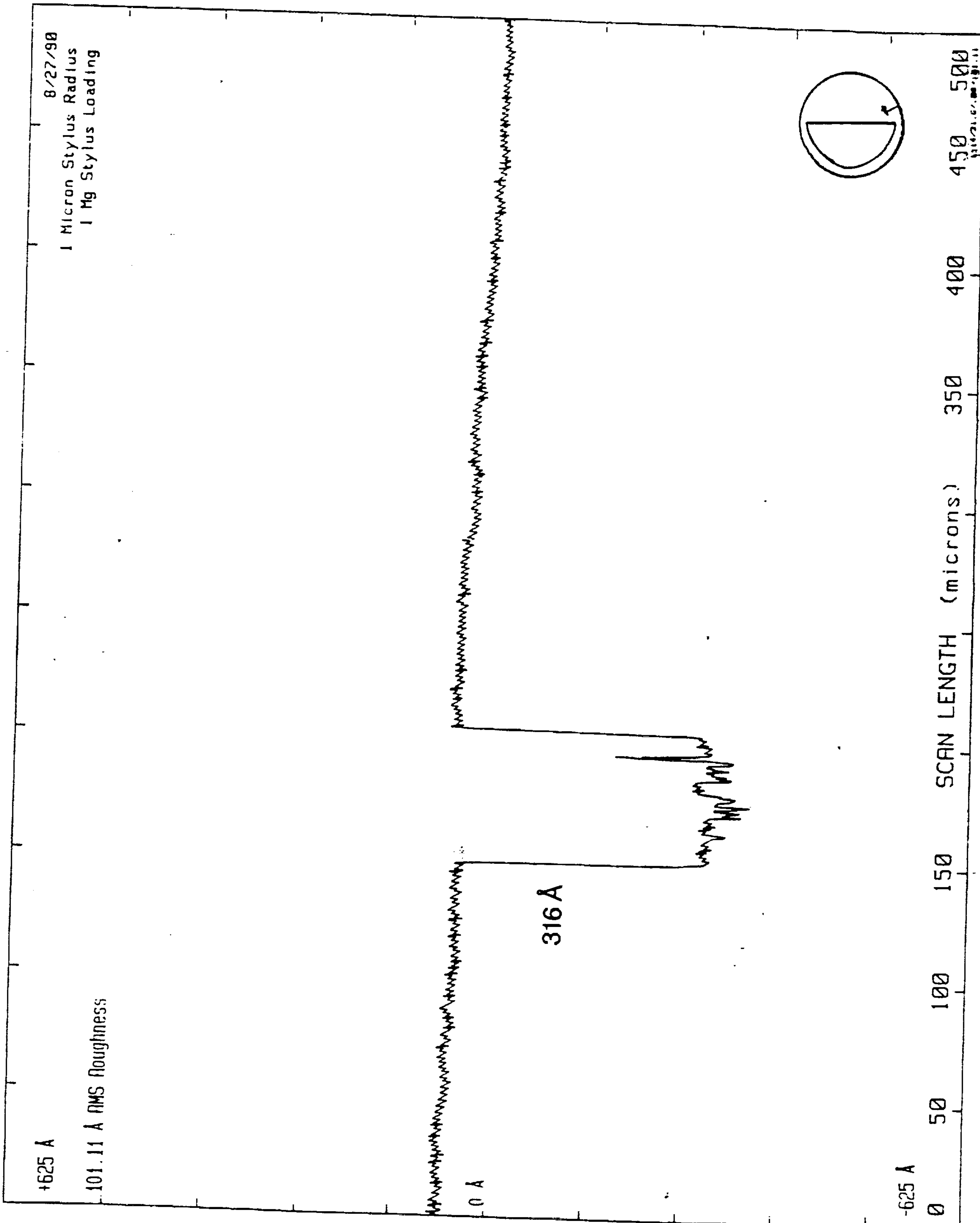

8/27/90
1 Micron Stylus Radius
1 Mg Stylus Loading
+625 Å
101.11 Å RMS Roughness
0 Å
-625 Å
316 Å
0
50
100
150
350
400
450
500
SCAN LENGTH (microns)

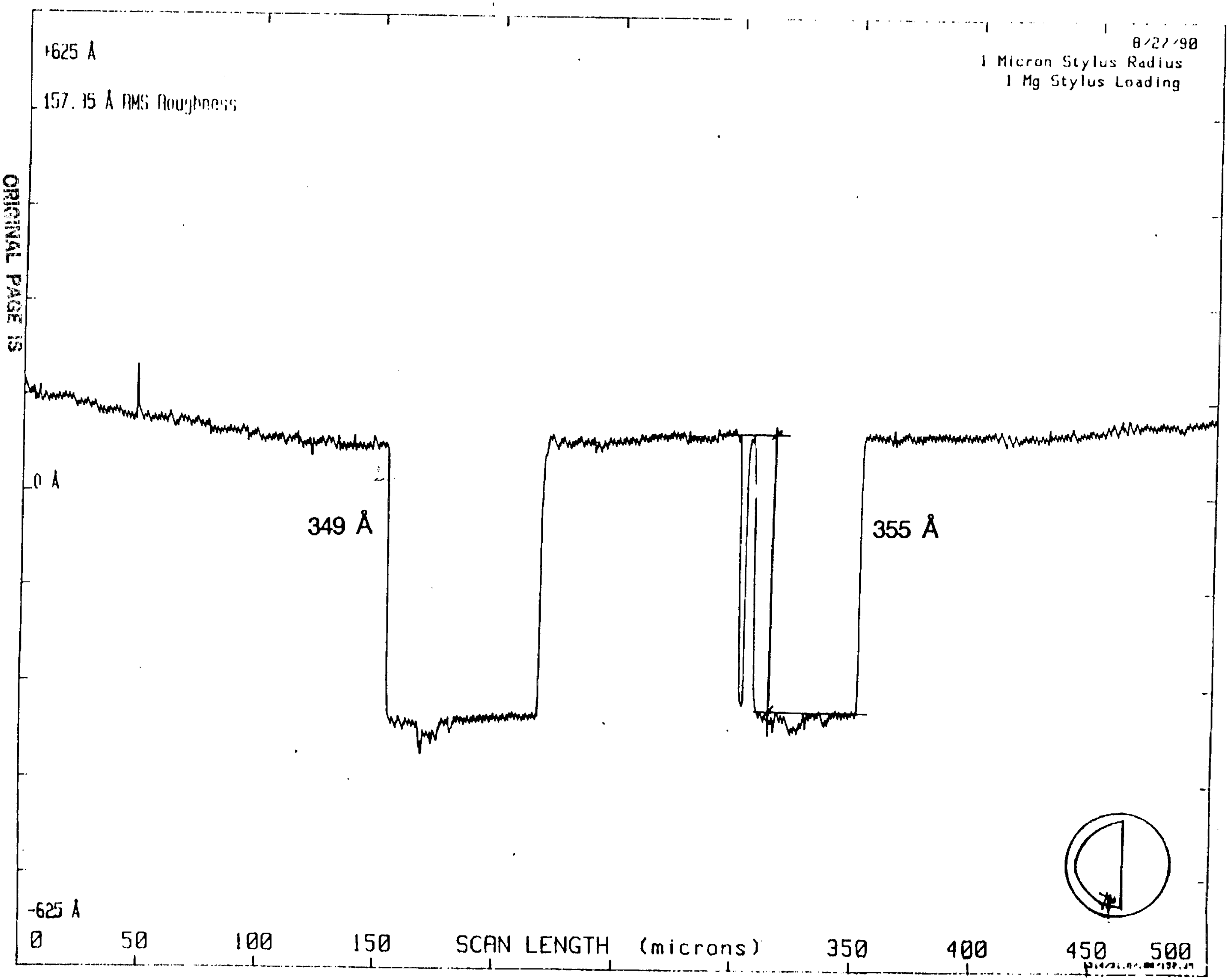
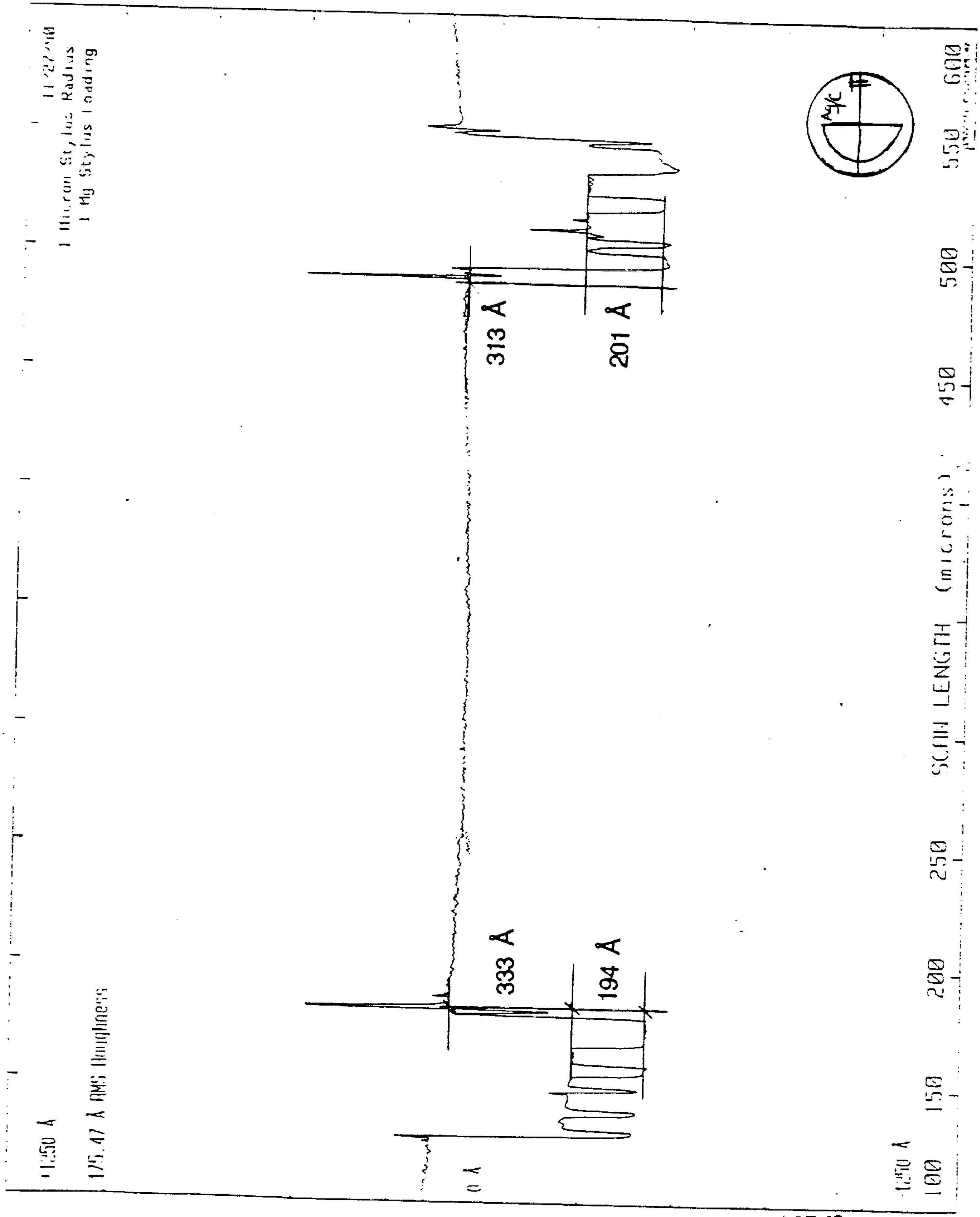


Figure 6. Surface profile of exposed Gold film


1 Micron Stylus Radius
1 Mg Stylus Loading
1250 Å
175.47 Å RMS Roughness
0 Å
333 Å
194 Å
313 Å
201 Å
1250 Å
100
150
200
250
SCAN LENGTH (microns)
450
500
550
600

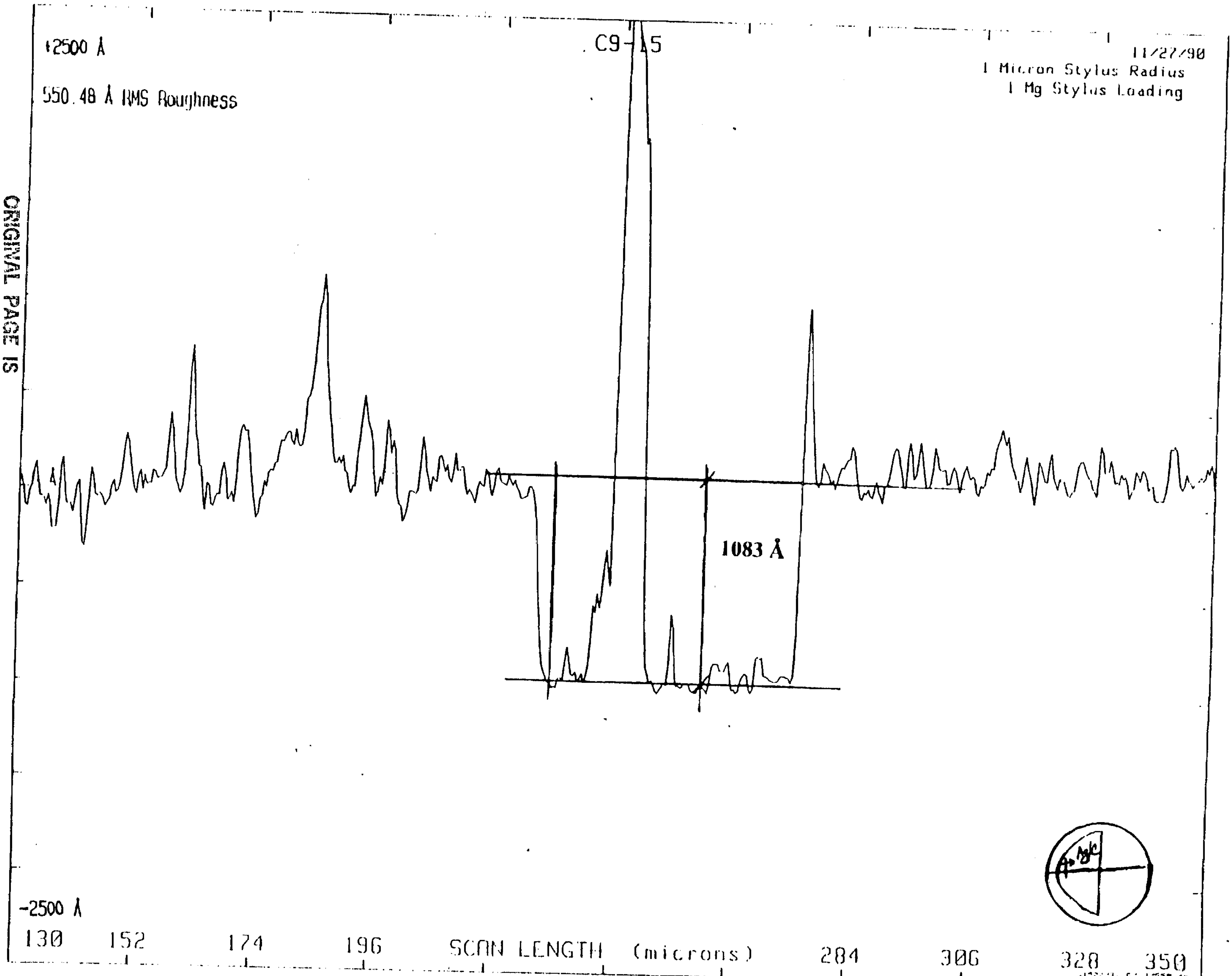
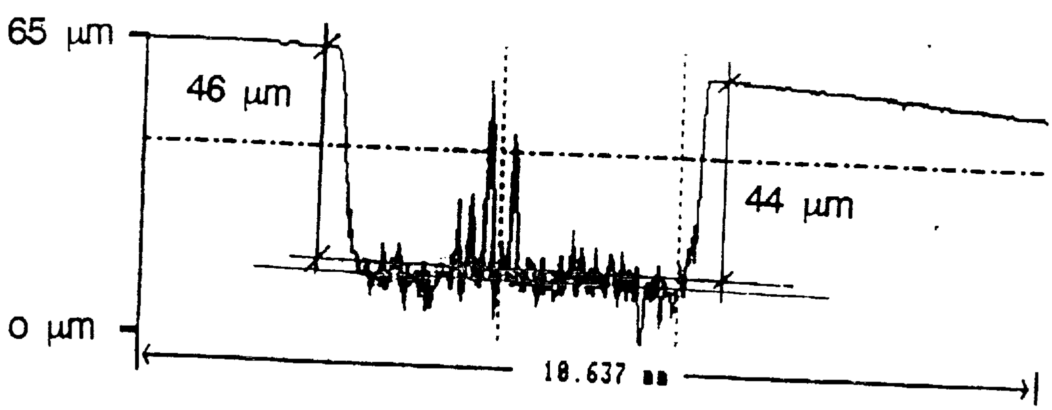


Figure 8. Surface profile of exposed Silver over Carbon film

Polycrystalline Carbon (C9-05)



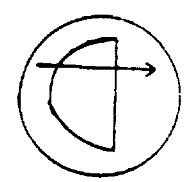


Figure 9. Surface profile of Polycristalline Carbon

PMMA (C9-31)

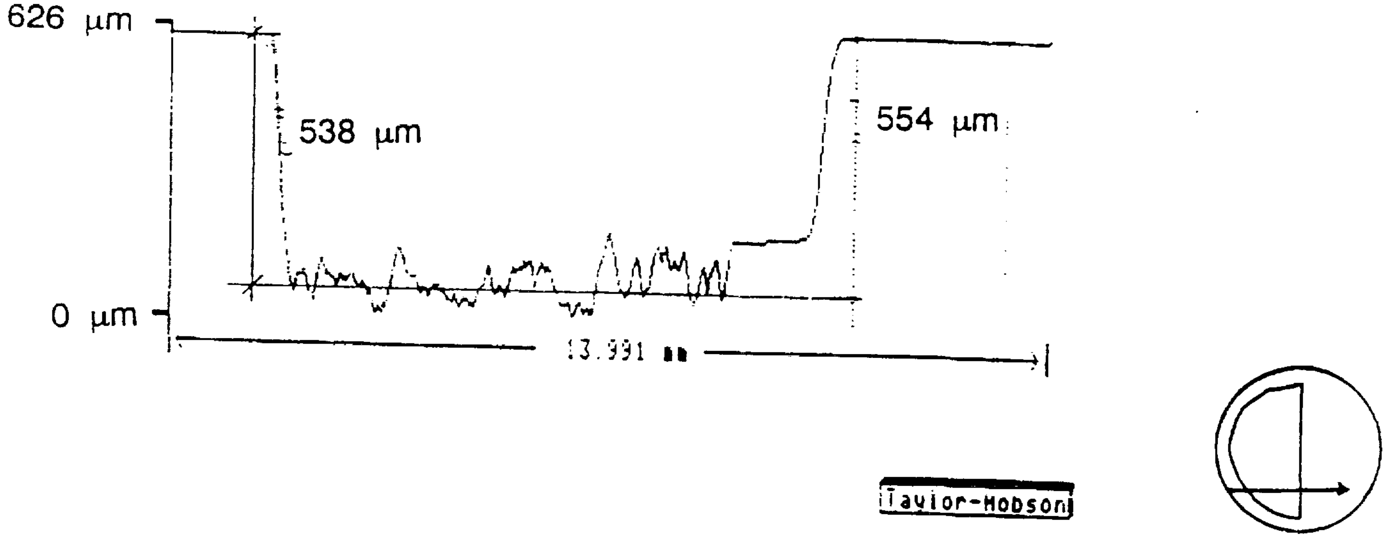


Figure 10. Surface profile of Polymethylmethacrylate at ambient temperature

PMMA (C9H-03)

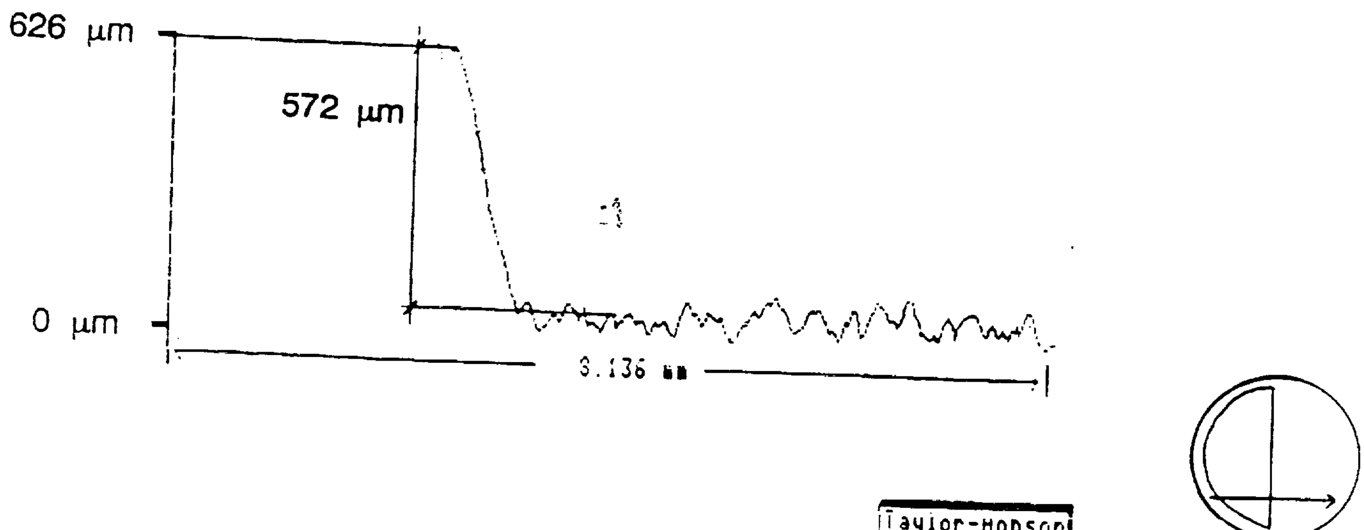


Figure 11. Surface profile of Polymethylmethacrylate at 10^0 C above the ambient temperature