NASA CR-
141693

JSC INTERNAL NOTE EG-74-16
PROJECT SPACE SHUTTLE

ANALYSIS FOR MAR VEL BLACK AND ACETYLENE SOOT LOW REFLECTIVITY SURFACES FOR STAR TRACKER SUNSHADE APPLICATIONS

(NASA-CR-141693) ANALYSIS FOR MAR VEL BLACK AND ACETYLENE SOOT LOW REFLECTIVITY SURFACES FOR STAR TRACKER SUNSHADE APPLICATIONS (Lockheed Electronics Co.) 18 p HC $3.25 CSCL 20F G3/74
N75-19002
Unclas
13521

DISTRIBUTION AND REFERENCING

National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas
June 1974

LEC-3738

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ANALYSIS FOR MAR VEL BLACK AND ACETYLENE SOOT LOW REFLECTIVITY SURFACES FOR STAR TRACKER SUNSHADE APPLICATIONS

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ACKNOWLEDGMENTS

This document was prepared by Lockheed Electronics Company, Inc., Aerospace Systems Division, Houston, Texas, for the Control Systems Development Division at the Johnson Space Center, under Contract NAS 9-12200, Job Order 35-459. It was written by Ed Yung, and approved by James M. Lecher, Acting Supervisor of Guidance Systems Section and by William R. Labby, Manager of Guidance Control and Instrumentation Department, Lockheed Electronics Company, Inc.

CONTENTS

1.0 SUMMARY

Mar Vel Black is a revolutionary new extremely low reflectivity anodized coating developed by Martin Marietta of Denver. It is of great interest in optics in general, and in star trackers specifically because it can reduce extraneous light reflections. A sample of Mar Vel Black was evaluated.

Mar Vel Black looks much like one would expect, a "super black" surface with many small "peaks" and very steep sides so that any light incident upon the surface will tend to reflect many times before exiting that surface. Even a high reflectivity surface would thus appear to have a very low reflectivity under such conditions.

Conversely, acetylene soot does not have the magnified surface appearance which one would predict to be that of a "super black" surface. Its performance is, however, predictable from the surface structure, considering the known configuration of virtually pure carbon.

2.0 INTRODUCTION

Martin Marietta of Denver recently developed a revolutionary "surface" for aluminum which uses a special anodizing technique to achieve an exceptionally low reflectivity.

After various discussions and a formal presentation (by Martin Marietta personnel) regarding the usefulness of Mar Vel Black for sunshade applications, Rockwell International (with the approval of Martin Marietta) gave the Inertial Optics Branch a sample for analysis.

Precision absolute reflectivity measurements were not possible with instruments at our disposal, although it was obvious that Mar Vel Black is indeed very black. There is no reason to doubt Martin Marietta's claim (substantiated by several disinterested agencies) that Mar Vel Black compares closely with acetylene soot in reflectivity. No reflectivity measurements were thus made.

By way of comparison, an acetylene soot coated sunshade was treated (ref. LEC Document No. 1681; dated Jan. 10, 1974, entitled MMOS Scattered Light Test) and found to have an attenuation factor of 10 times the next best coating material tested (3M Black Velvet over black anodized aluminum).

The 4 inch square sample (on ~1/8 in. aluminum) was visually evaluated by use of an optical microscope. Photomicrographs were not made. Since this analysis indicated inconsistencies between surface appearance, known performance, and the laws of reflectivity a higher magnification was desired.

Mr. Frank Baiamonte of the Microelectronics section (ED7, JSC Bldg. 15) agreed to use their Cambridge Stereovision S4 Scanning Electron Microscope, which proved to be an excellent device for evaluating the material in question.

Given the capability of evaluating Mar Vel Black under such a high magnification, it was naturally desirable to compare it with readily attainable acetylene soot. A sample of acetylene soot on aluminum was thus prepared and examined with the S4 system.

3.0 DISCUSSION

3.1 Mar Vel Black

3.1.1 Optical microscope. Analysis of surface configuration by use of an optical microscope proved difficult because of the extremely low reflectivity of Mar Vel Black.

The impression obtained with such a visual analysis was that perhaps 90 percent of the surface was relatively flat (minor irregularities) and medium grey (under the very high-grazing incidence illumination system employed), and that the remaining 10 percent appeared to consist of extremely deep and steep sided "valleys" which trapped virtually all of the light, thus looking totally black. If this were true, the overall reflectivity would be much higher than expected (essentially equal to that of the "grey" area). The fact that the illumination system employed was extremely bright might explain why a very black surface can loo[illegible] [illegible]ey, but the results were still uncertain. Limited dep[illegible] [illegible]cus of the optical microscope may also explain some a[illegible]ies.

Observations were made, of necessity, normal to the sample surface.

3.1.2 Electron microscope.* The S4 Electron Microscope views only from a 45° angle. The appearance would thus be expected to be different than with the optical microscope, even at the same magnification.

*It was first necessary to develop a method and design a fixture which would permit cutting the sample without surface damage or contamination.

Photomicrographs were made at approximately 100, 500, 1000, 2000, and 5000 times magnification as indicated in Figures 1 through 5. It should be noted that the small bar (eg., 10 μm) near the upper left gives the scale of magnification precisely. The magnification value (eg. 100x) quoted is only an approximation.

It should be noted that 100x photomicrographs give approximately the same visual impression as the visual/optical microscope observations (described above).

At 500x the appearance is quite different, as though the entire surface consists of many irregular "peaks" with no relatively flat areas. Closer examination, at higher magnifications, clearly substantiate this impression.

It is apparent that light is trapped by reflection deeper into the cavities so that by the time reversal* is achieved the light has been attenuated by several orders of magnitude as a result of many reflections.

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*Light reflected into an acute cone, such as a reflective axicon, reflects at ever decreasing incidence angles, and eventually reverses direction and exits (after many reflections). Even if the surface has a relatively high reflectivity it will appear "black" after a large number of reflections; eg., $(0.5)^{20} = 4.7 \times 10^{-7}$, so a 50% reflectivity surface will attenuate by a factor of 10^7 in 20 reflections (or a 90% reflectance surface would attenuate by a factor of 90% after 20 reflections). This explains why a low emissivity (and thus high reflectivity) material such as bare copper can be used as an extremely efficient (high emissivity) blackbody by machining very deep, sharp, crested and bottomed, low angle V-grooves into the surface.

It may be noted that the peaks shown in the photomicrographs are extremely deep and sharply pointed, although irregular in shape. Even the edges are quite sharp. The sharp points, which minimize any surface which is parallel with the mean surface plane, combined with the steep sides (nearly perpendicular to the mean surface plane) and great depth of the cavities, works to effectively reduce reflected light to an absolute minimum.

3.2 Acetylene Soot

3.2.1 Optical microscope. Acetylene soot was not examined with an optical microscope. The results of the electron microscope examination indicated that an optical microscope would not have provided significant information on this material because of the small size of the surface structure.

3.2.2 Electron microscope. Photomicrographs of the acetylene soot sample were made at magnifications of 50x, 200x, 500x, 1000x, 2000x, 5000x, and 20,000x as indicated in Figures 6 through 13. The two grooves in Figure 6 indicate that acetylene soot follows the substrate surface irregularities precisely, as in the case of metal deposition. It is assumed that the scattered light spots are impurities, although they may represent surface irregularities instead.

As one progresses through the steps to higher magnifications it is immediately apparent that the size of the surface structure of acetylene soot is much smaller than for Mar Vel Black. Acetylene soot at 2000 to 5000x compares in detail size with 100x Mar Vel Black, so that there is a factor of 20 to 50 times difference in surface structure size.

But even comparing these, little similarity is found. Likewise, the 20,000x acetylene soot photomicrograph bears little resemblance to the 1000x Mar Vel Black. It is possible that acetylene soot functions in the same identical manner as Mar Vel Black, with smaller cavities between small surface projections (carbon crystals). Conversely it may function as an absorber because of interference created by a pattern of irregularities scaled to the wavelength of incident radiation. The method of operation of acetylene soot as an absorber is not immediately obvious from the photomicrographs.

4.0 CONCLUSIONS

The photomicrographs clearly indicate why Mar Vel Black has an exceptionally low reflectivity. They also indicate why it is quite fragile, since the sharp (approx. 5 microns across) peaks would be expected to be delicate.

The acetylene soot photomicrographs were not as readily interpreted, but indicate a much finer surface detail.

APPENDIX

ELECTRON PHCTOMICROGRAPHS

ELECTRON PHOTOMICROGRAPHS

Note that the dimentioned limit bar gives the exact scale of the photographs; eg., in figure 1 the length of the bar is 100 microns or approximately 0.004 inches. The magnification quoted with the captions is only approximately that produced on the CRT of the Scanning Electron Microscope; the actual magnification exhibited in the printed reproductions of the photomicrographs is approximately 0.6x the quoted magnification.

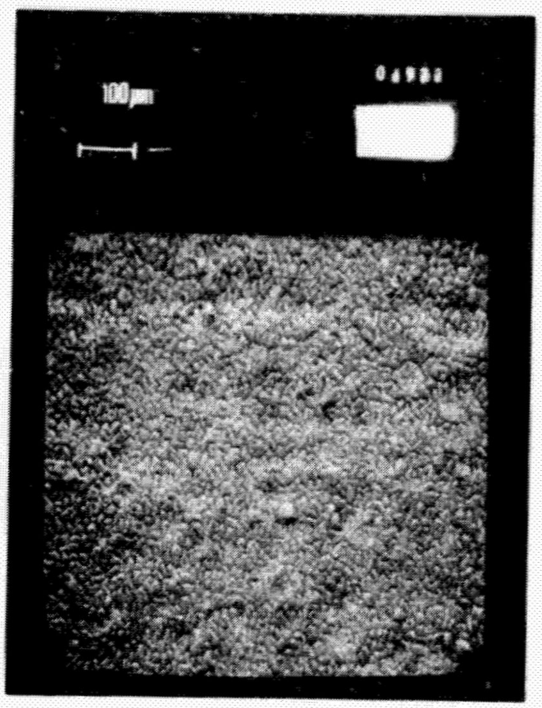

Figure 1. — Mar Vel Black at 100x magnification (x0.6).

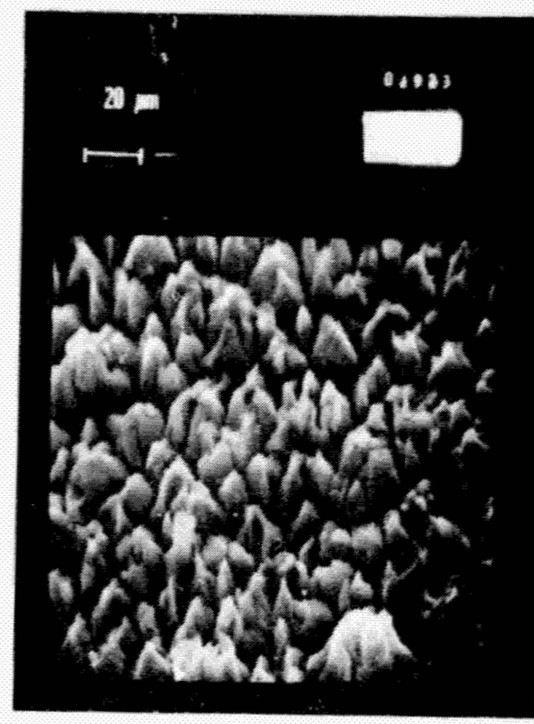

Figure 2. — Mar Vel Black at 500X magnification (x0.6).

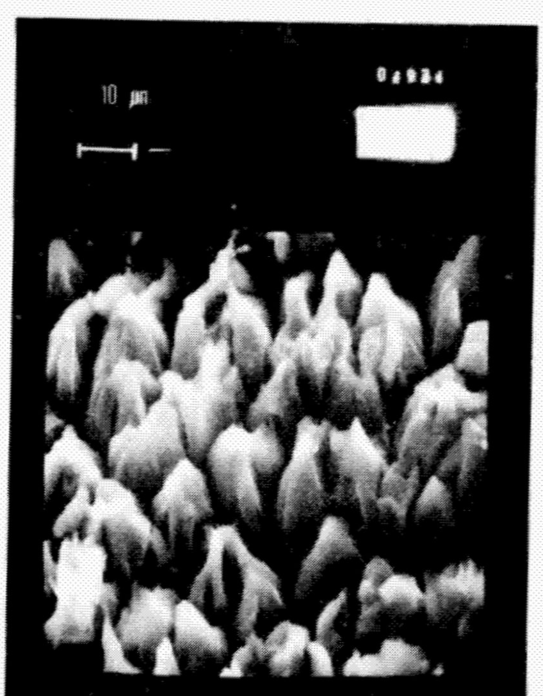

Figure 3. — Mar Vel Black at 1,000x magnification (x0.6).

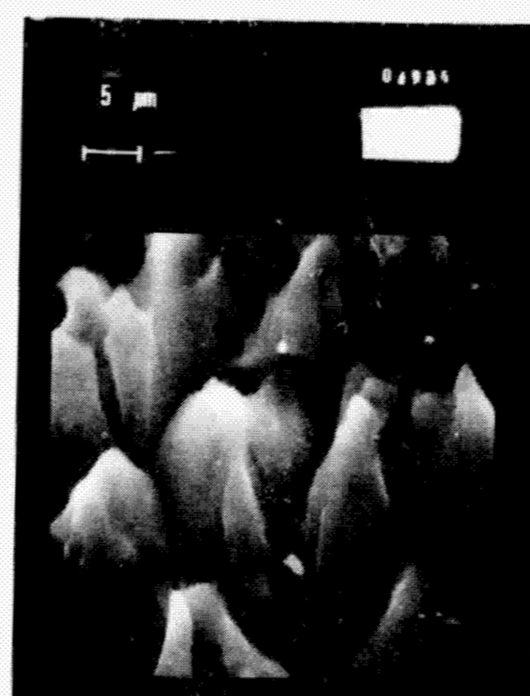

Figure 4. — Mar Vel Black at 2,000x magnification (x0.6).

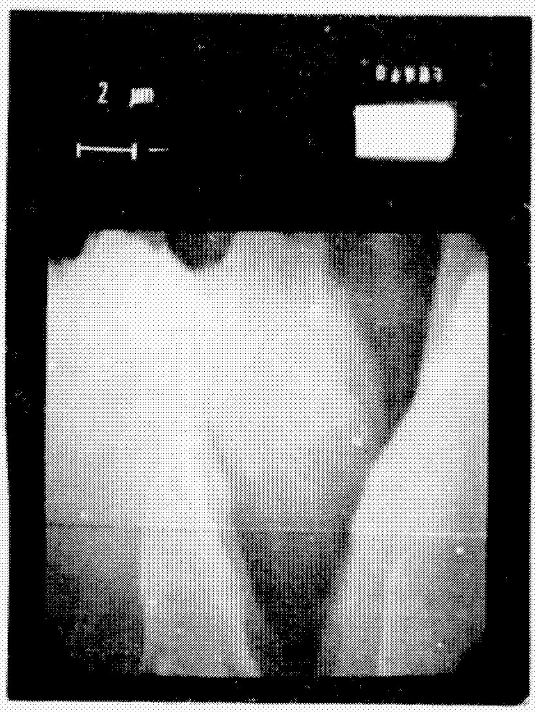

Figure 5. – Mar Vel Black at 5,000x magnification (x0.6).

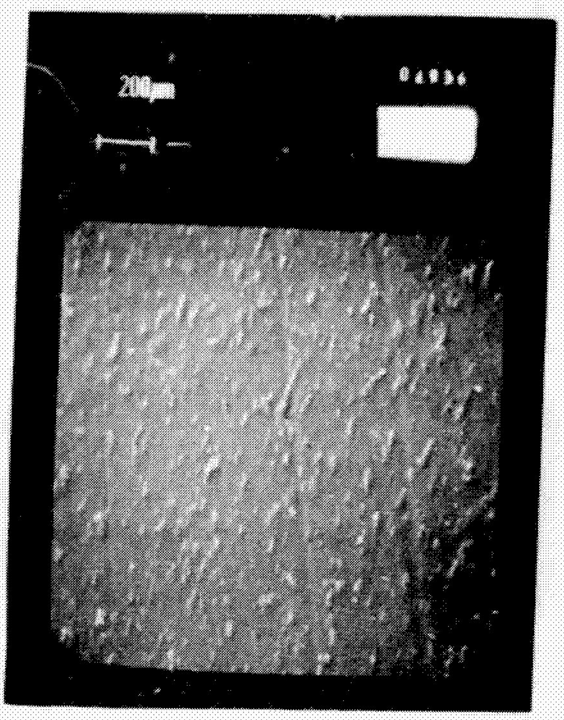

Figure 6. – Acetylene Soot at 50x magnification (x0.6).

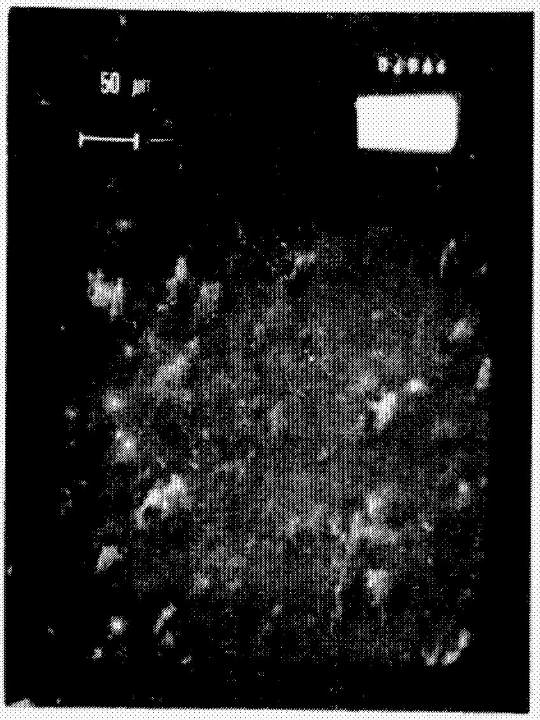

Figure 7. – Acetylene Soot at 200x magnification (x0.6).

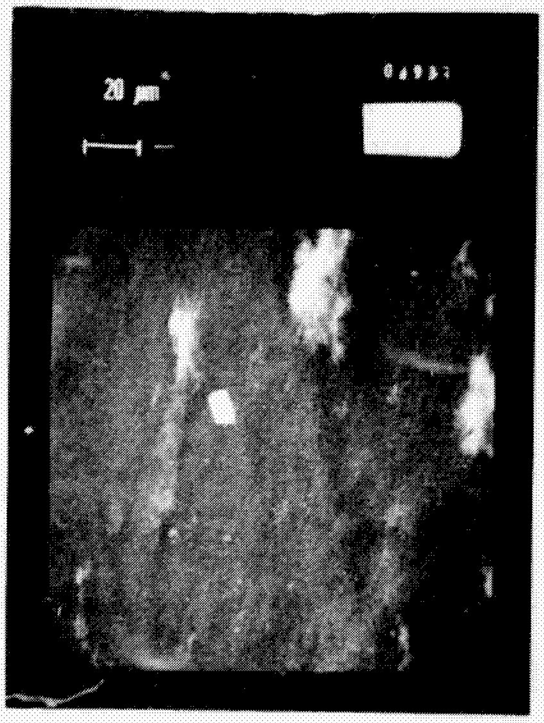

Figure 8. – Acetylene Soot at 500x magnification (x0.6).

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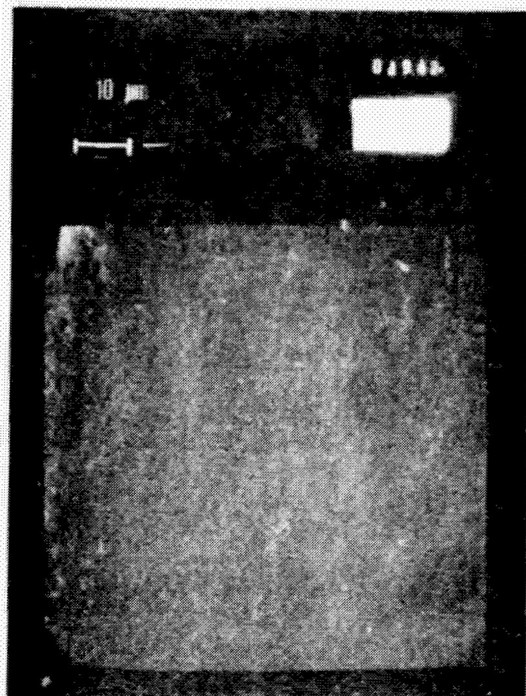

Figure 9. – Acetylene Soot at 1,000x magnification (x0.6).

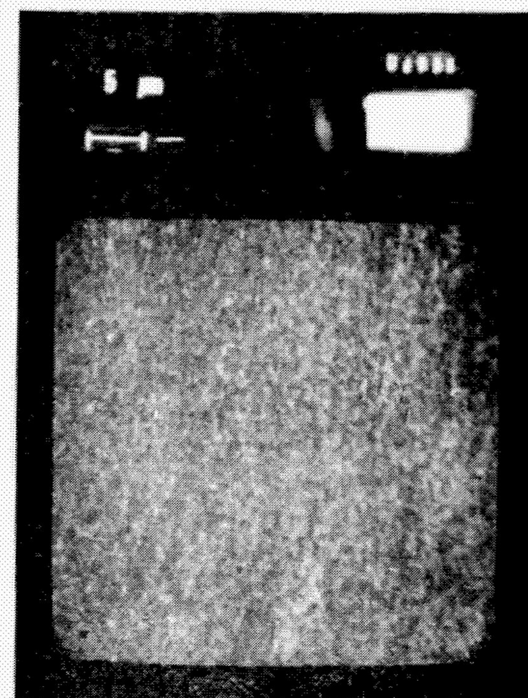

Figure 10. – Acetylene Soot at 2,000x magnification (x0.6).

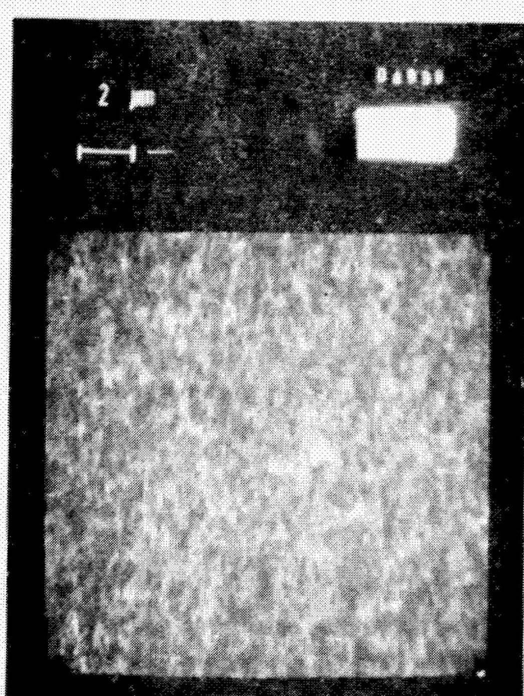

Figure 11. – Acetylene Soot at 5,000x magnification (x0.6).

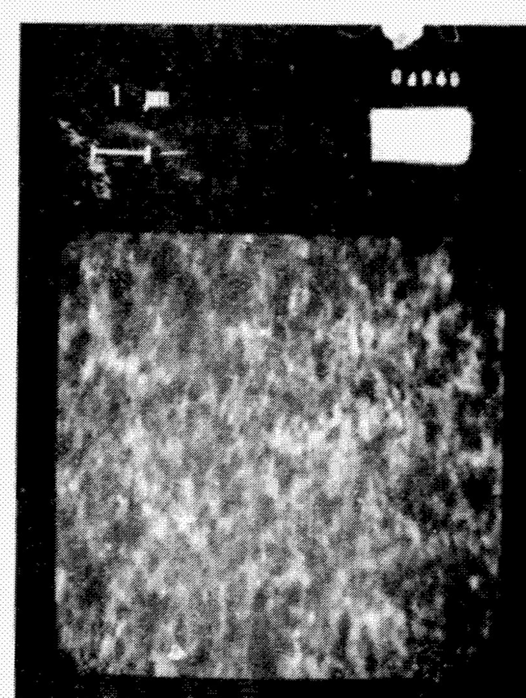

Figure 12. – Acetylene Soot at 10,000x magnification (x0.6).

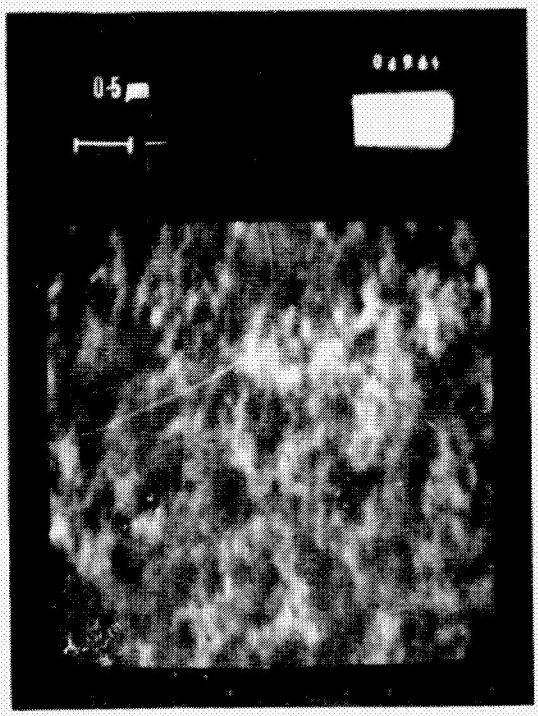

Figure 13. - Acetylene Soot at 20,000x magnification (x0.6).