Investigation of Sanded Acrylic Surfaces by Optical Microscopy

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Abstract: Sanded acrylic surfaces have been examined with optical microscopy for evidence of grit embedded by the sanding process. The number of surface imperfections (pits or particles) larger than 5 microns was a factor of two to three times larger in the sanded surface than on a surface that had not been sanded. It was usually possible to distinguish an empty pit from a foreign particle, and the analysis indicated that the larger number of imperfections on the sanded surface was associated with the presence of foreign matter, presumably particles of grit from the sanding. Estimates of the radioactivity that might be associated with such particles are made under various assumptions.

I. Introduction

There is a general concern that abrasive materials used in finishing detector components may introduce radioactivity into surfaces. The most critical case is that of the bonded joints in the acrylic vessel. The bonding procedure includes sanding the surfaces with an abrasive-grit wet-or-dry paper. Although the surfaces are subsequently cleaned by wiping with a solvent solution before the bonding agent is introduced, there is a possibility that grit from the sandpaper remains embedded in the acrylic.

Since it is ultimately uranium and thorium that are of concern, the most direct way to study this question is to measure the amount of uranium or thorium in a thin section of acrylic that has been sanded and compare it to a similar sample that has not been sanded. Such mass spectrometric studies are in progress.[1]

It seemed to us that information could also be obtained by looking directly at the surface with a microscope. If particles were embedded in the surface, we ought to be able to see, size, and count them. Since we were using a microscope to size and count particles

of mine dust deposited on acrylic and other surfaces[2,3], it would be natural for us to apply the same technique to a sanded surface.

Roger Reynolds of RPT arranged to have four samples of acrylic sent to us, each of which had been sanded on one side but not on the other. We analyzed these samples and circulated preliminary results to P. Doe and D. Earle in December 1991. We repeated these measurements in February 1992, this time cleaning and preparing the surfaces in our cleanroom, and obtained similar results. Both these measurements are described here.

II. Preparation of Samples

The samples sent to us by Kevin Dougherty of RPT were 2"x3"x1/4" in size. Before inspecting the surfaces under the microscope, we first cleaned them in a mild soap solution, rinsed them in de-ionized water, and wiped them dry with lens tissue. Then a clean glass microscope slide (2"x3"x 0.040") was used to cover the surfaces to be examined (Fig. 1). The covering of the surfaces with a microscope slide permitted the optical scanning to be done outside the cleanroom. The difference between the first measurement (A) and the second measurement (B) was that for B the cleaning and covering of the surfaces were done in a cleanroom. Also, different areas on the samples were scanned in measurements A and B.

III. Optical Scanning

We examined both sanded and unsanded surfaces (Fig. 2a) and looked underneath the surface both by scanning a comparable area below the surface (Fig. 2b) and by making a series of depth scans (Fig. 2c). Table 1 gives the magnifications used and the areas (or volumes) scanned.

Table 1

Sample	Magnification	Area or Vol.	
		A	B
Sanded surface	200	0.58	0.90 cm^2
Smooth surface	200	1.16	0.90 cm^2
Subsurface area	200	0.58	N/A cm^2
Subsurface vol	100	.0076	.067 cm^3

A sanded surface looks very different than an unsanded surface, and this complicates to some extent a comparison of the two. The grooves left in the surface by the abrasive constitute a background on which one has to look for particles or pits. Figs. 3a (sanded) and 3b (unsanded) illustrate this.

In addition to producing grooves, the sanding process may leave a particle or piece of grit embedded in the surface, or it might tear out a small chunk of acrylic, creating a pit but leaving no residual material. It is possible in most cases to tell whether a pit is empty or contains a particle from the shape of the object as a function of depth and from examining it in both transmitted and oblique light. Examples of what appear to be empty pits and what appear to be particles are shown in Figs. 3a and 3b, and Figs. 4a and 4b, respectively. As shown in Table 2, particles out-numbered empty pits by a factor of three on a sanded surface. On the unsanded surface, empty pits were three times more frequent than particles. Examples where we could not be sure if a particle was present are shown in Figs. 4b and 5. Fig. 6 gives the scale of magnification.

Table 2

	Measurement B		
Surface	Pits	Particles	Unsure
Sanded	24	73	9
Smooth	29	9	2

Particles were counted and binned according to whether their longest dimension was greater than 5, 10, 25, or 50 microns.

Scanning below the (smooth) surface (Fig. 2b) was easier in the sense that all surface imperfections were out of focus and therefore less visible. Inclusions or voids showed up clearly and quickly in a scan made with oblique light and a dark background.

IV. Results

The results for measurements A and B are presented in Table 3. It is immediately apparent that there are significantly more particles or pits per unit area on the sanded surface than on the unsanded surface. Since the appearance of the surface imperfections

suggests mostly particles in the sanded surface and mostly empty pits in the unsanded surface, it is reasonable to assume that the embedded particles originate with the sanding process.

We can also show that the imperfections on both the smooth and sanded surfaces cannot be ascribed to imperfections in the bulk material that are exposed when the surface is sanded. This is immediately apparent by noting in Table 3 the number of particles/cm^2 observed in a subsurface scan. There are only 1/4 to 1/10 as many imperfections per unit area below the surface as at the surface.

Table 3

Sample	Particles or Pits, ≥ 5μ		
	A	B	
Sanded surface	120±14	117±12	/cm^2
Smooth surface	74±8	44±7	/cm^2
Subsurface area	12±5	N/A	/cm^2
Subsurface vol	1400±400	1250±100	/cm^3

The relative number of pits in the sanded surface and in the bulk can be estimated by considering the volume of material (area x depth) defined by a sanded surface. From a measurement with the microscope we found that the grooves formed by sanding have a mean depth of about 23 microns. The pits (or particles)/volume in the scanned sanded surface was thus $120/(23\times10^{-4}\ cm^3) = 5\times10^4/cm^3$. The number of imperfections, or inclusions, per unit volume in the bulk material, however, was only $1.3\times10^3/cm^3$ (Table 3). We obtain a similar result by comparing a subsurface scan with the surface scan (see Table 3) where we note that ten times as many imperfections are found in the sanded surface, and four to six times as many in the unsanded surface, compared to a plane of equal area below the surface

An attempt to size the particles was made in order to obtain a crude number/size distribution. Fitting these distributions with a power law of the form $N(\geq D)/cm^2 = kD^{(-m)}$ gave the following results (see Table 4).

Table 4

Surface	A $kD^{(-m)}$	B $kD^{(-m)}$
Sanded	$670xD^{-0.97}$	$890xD^{-1.3}$
Smooth	$487xD^{-0.89}$	$136xD^{-0.85}$

V. Interpretation

The optical analysis of the sanded surface indicates that foreign matter is introduced into the surface by the sanding process. Therefore we need to know how much radioactivity is associated with it. To estimate this we have to make assumptions about the foreign matter. (These are strong assumptions and, indeed make the following interpretation speculative.) We will interpret the results under the arbitrary assumption that the foreign matter has the characteristics (U/Th content and number-size distribution) of norite dust that we made by grinding a norite core sample. This is done in the following way: One of the samples of norite dust we had prepared (Table 4 in ref. 3) had a number/size distribution given by $N(\geq D) = 6550xD^{-0.98}$. An XRF analysis of this same sample indicated a mass of 22 $\mu g/cm^2$. Comparison with Table 4 above indicates that the number/size distribution of particles on the sanded surfaces would correspond to about 2 $\mu g/cm^2$ of mine dust. At 5 ppm of Th, this would indicate 10^{-11} g/cm^2 of Th. Multiplying this by the total area of machined and sanded surfaces in the bond joints gives a total amount of Th equal to $3x10^{-6}$ g. The total amount of Th in the bulk acrylic making up the entire acrylic vessel (at 1ppt Th) is $30x10^{-6}$ g. Therefore, under our assumptions, the grit in the sanded surfaces would contribute 10% of the total radioactivity in the acrylic vessel.

V. Conclusions

Optical analysis of acrylic surfaces that have been sanded in preparation for bonding indicates that the sanding process embeds grit in the surface that is not removed by cleaning. Estimating the amount or radioactivity that is associated with this embedded grit is difficult at present and requires making strong assumptions. Under

the assumption that the embedded grit has the characteristics of ground norite (number/size distribution and 5 ppm Th) we estimate that this grit could contribute 10% of the total Th activity in the acrylic vessel, assuming the latter to contain Th at 1 ppt. The machined surfaces to be bonded are not the only surfaces that are sanded with wet-or-dry paper, however. The edges of the bonded joints on the interior and exterior surfaces of the acrylic vessel are finished by sanding with a progression of grits. This could double or triple the surface area of the acrylic in which grit becomes embedded.

Given the uncertainties in our assumptions, the conceivable amounts of Th embedded in the surface begins to be of concern and suggests that additional measurements be made. Clearly, it would be of interest to measure the Th content of the grit used in sanding the surfaces. Accordingly, we have requested RPT to send us packages of the sandpaper they use for direct counting of Th activity. Mass spectrometric measurements[1] of the Th in the sanded surfaces should be definitive.

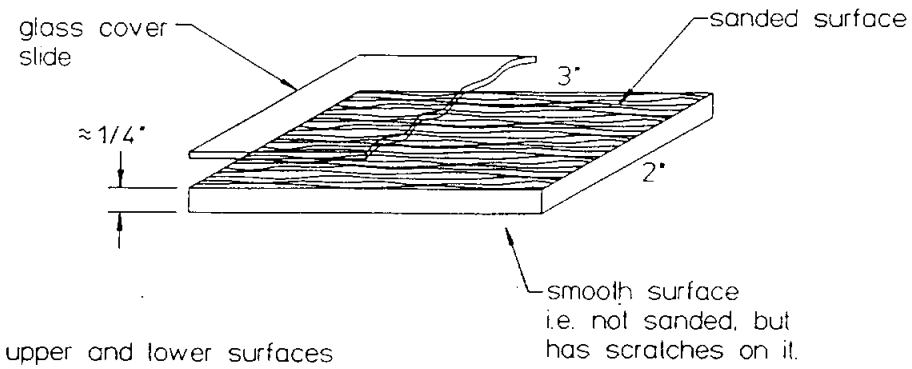
References

1. D. Earle, private communication.

2. "Measurement of Surface Contamination," R.G. Stokstad and E. Kong, SNO-STR-92-48.

3. "Contamination Control Study on Mine Dust," E. Kong, SNO-STR-92-49.

Fig.1



upper and lower surfaces covered with microscope glass slide during scanning

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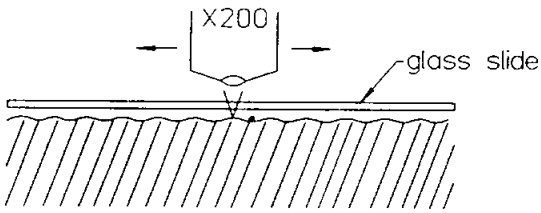
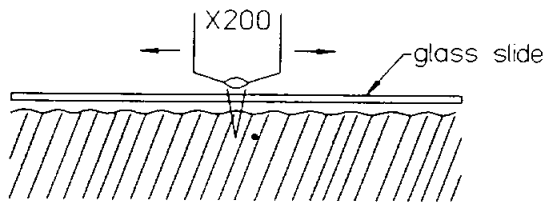
Fig.2

a)



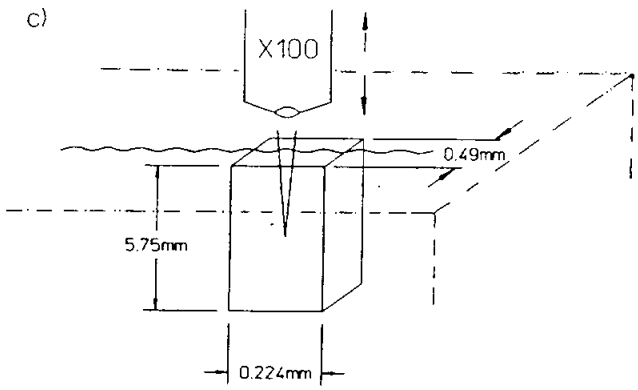
Surface Scan

b)



Subsurface Scan

c)



Volume Scan

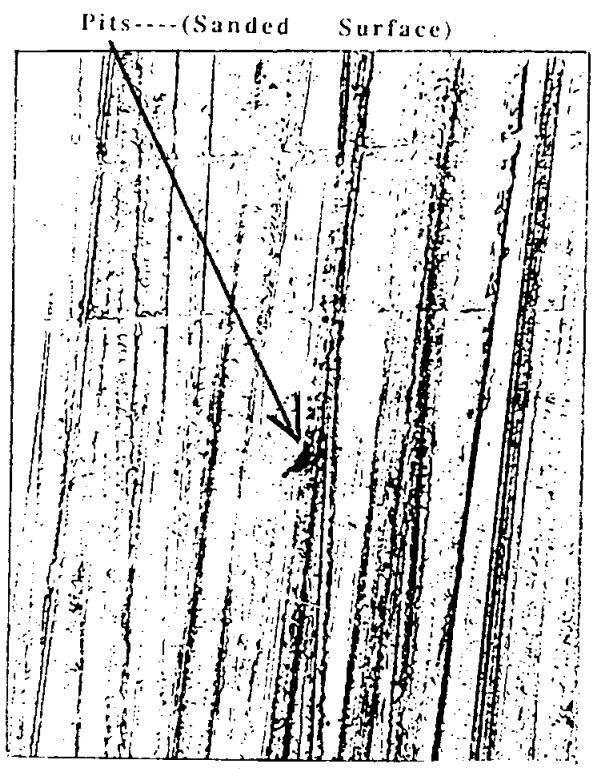


Fig 3a

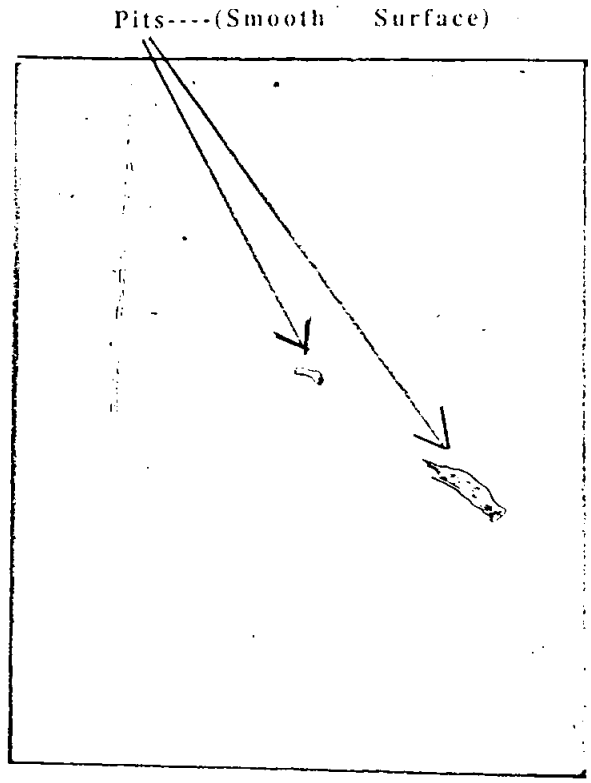


Fig. 3b

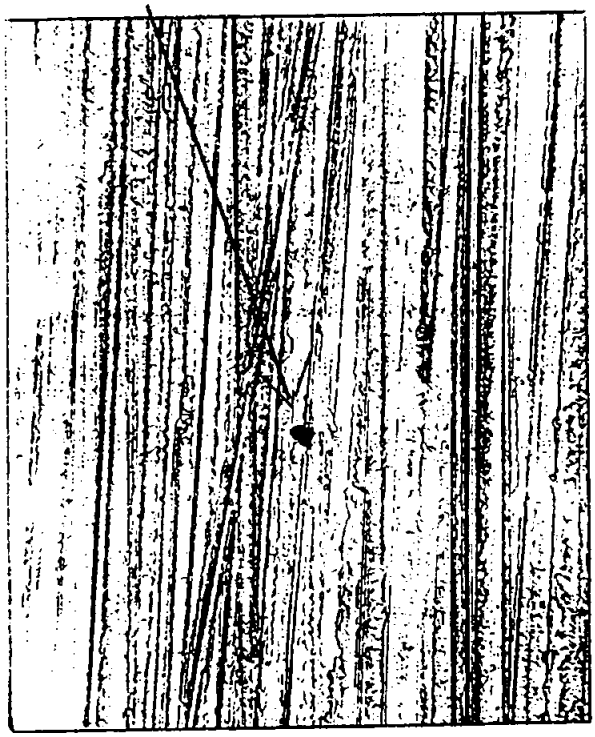

Particles----(Sanded Surface)

Fig 4a

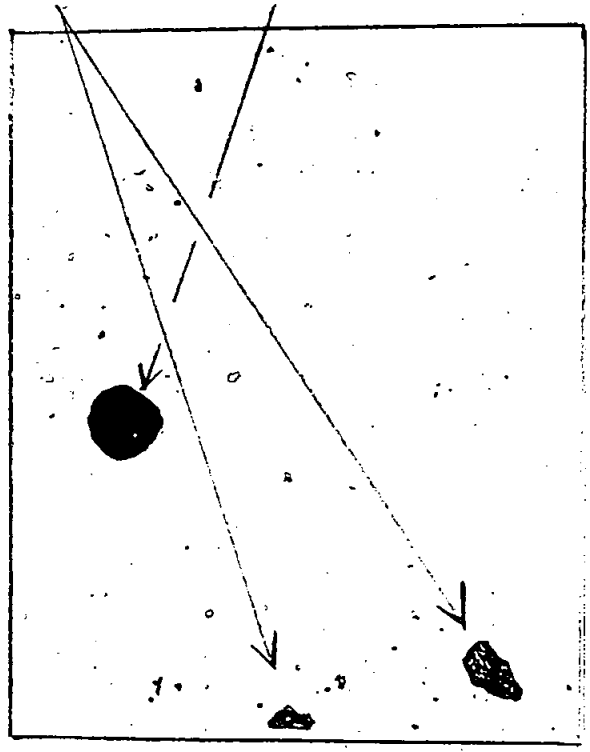

Particles and Unsure----(Smooth Surface)

Fig 4b

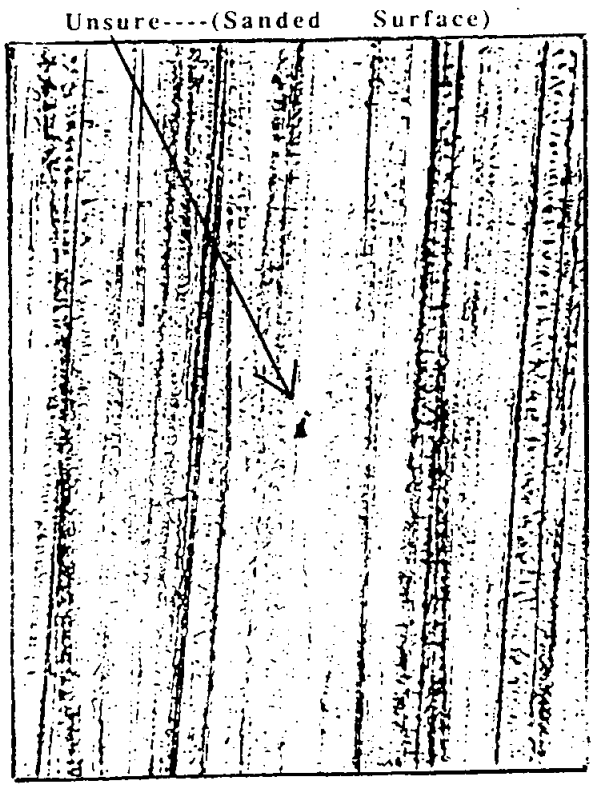


Fig. 5

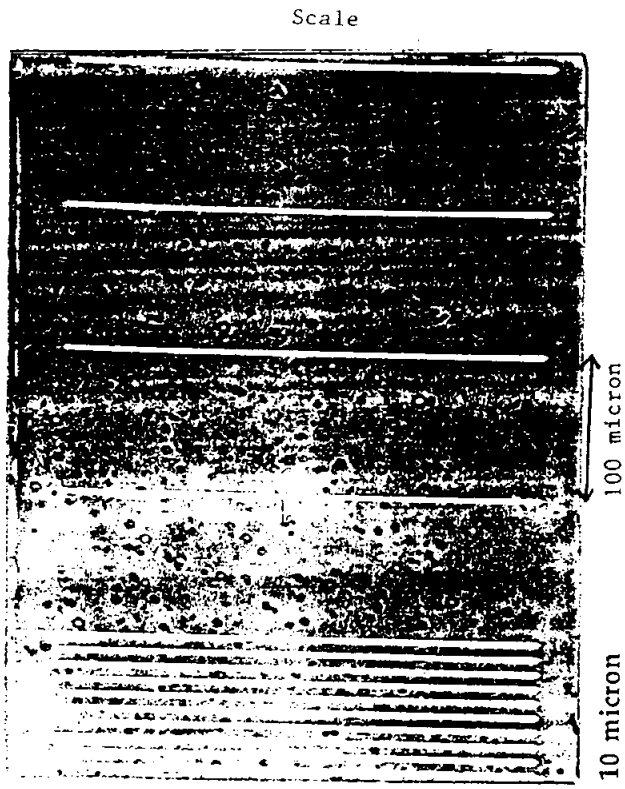


Fig 6