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ABSTRACT

The structure of materials prepared using thermal spray methods is difficult to determine using conventional microscopy or porosimetry methods. The difficulties inherent in these approaches can be circumvented using synchrotron computed microtomography (CMT). An example of the use of CMT to produce a high resolution non-destructive image of a thermal-spray coating is described here to illustrate the power of this technique.

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INTRODUCTION

Thermal spray technology is used to fabricate coatings of different types of materials that will improve the thermal properties or wear resistance of the substrate material. The quality of the coating is affected by its homogeneity, porosity, adhesion to the substrate, etc. The determination of these quantities is often attempted using conventional optical microscopy methods. This necessitates sectioning and polishing the coating which can produce artifacts that obscure the true nature of the section. Use of conventional porosimetry methods is also hazardous since the pores may not be connected.

Synchrotron CMT is an alternative technique which can be used to generate images of the morphology in transverse planes in a sample non-destructively. The limited x-ray brilliance from conventional x-ray tubes, however, generally makes the spatial resolution in CMT much worse than 20 micrometers, which is around the maximum size of pores observed by optical microscopy of thermal sprayed deposits. Synchrotron x-ray sources have orders of magnitude higher brilliance than x-ray tubes, and have made possible CMT with much higher spatial resolution (1,2). The construction of third generation synchrotron x-ray sources now taking place makes CMT with submicrometer spatial resolution conceivable, although it still has yet to be implemented.

EXPERIMENTAL APPROACH

A CMT instrument which can be used for non-destructive microscopy down to a volume resolution of 5 micrometers^3 has been developed at the X26 Microscopy Beam Line of the National Synchrotron Light Source (3). This instrument is ideally suited to detect voids in small (one mm or less) samples of thermal sprayed coatings. It has been used for a study of voids and material homogeneity in a whole series of thermal sprayed deposits, produced at different temperatures and using different feedstock materials. The imaged quantity was the linear attenuation coefficient averaged over the energy spectrum of the synchrotron x-rays. The linear attenuation coefficient depends on both the material composition as well as the density in the samples. For elements having a photoelectric absorption edge at an appropriate energy in relation to the sample size, it is possible to map the two-dimensional distribution for a selected element by making a subtraction image from images generated using two different x-ray energies straddling the edge energy (4).

EXPERIMENTAL RESULTS

To illustrate the application of CMT a thermal-spray coating of Cr_3C_2/NiCr was prepared. The conditions were chosen to produce a coating with high porosity so that the ability of the CMT method to differentiate between the material and voids would be most evident. The tomographic section that was produced is shown in Fig. 1. The pixel size for this image is about 5 μm × 5 μm with a slice thickness also of 5 μm. The grey scale used to produce the image shows regions of high linear attenuation coefficients as lighter gray than regions of low attenuation coefficients (voids).

The relative quality of the specimen can be shown by constructing a histogram giving the frequency of occurrence of the linear attenuation coefficients within the specimen. The results obtained for the section shown in Fig. 1 are shown in Fig. 2. The area under the two peaks, the one for void space not being very distinct, can be used to estimate the porosities of the sample.

CONCLUSIONS

The results shown in Figs. 1 and 2 demonstrate the usefulness of synchrotron CMT for investigation of the thermal spray coatings. A systematic application of the method to investigation of thermal spray materials should give new insights into the quality of coatings produced under different conditions. This will make possible a correlation between quality and preparation conditions which has not been previously possible and should thus lead to improved coating methods.

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FIGURE CAPTIONS

Figure 1. Tomographic section through a specimen of Cr_3C_2/NiCr produced using thermal spray technology under non-optimal conditions.

Figure 2. Histogram showing relative distribution of linear attenuation coefficients in the specimen. The coefficient for air is centered around zero attenuation coefficient.

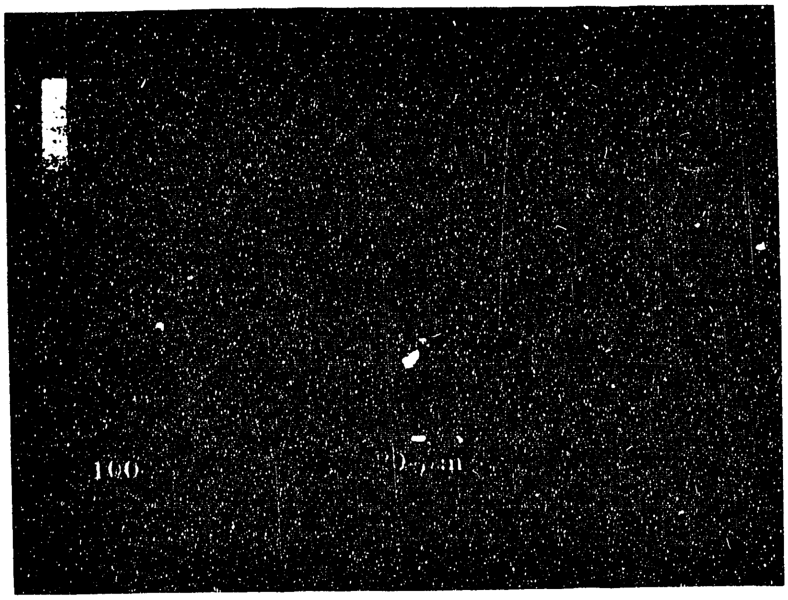

Figure 1

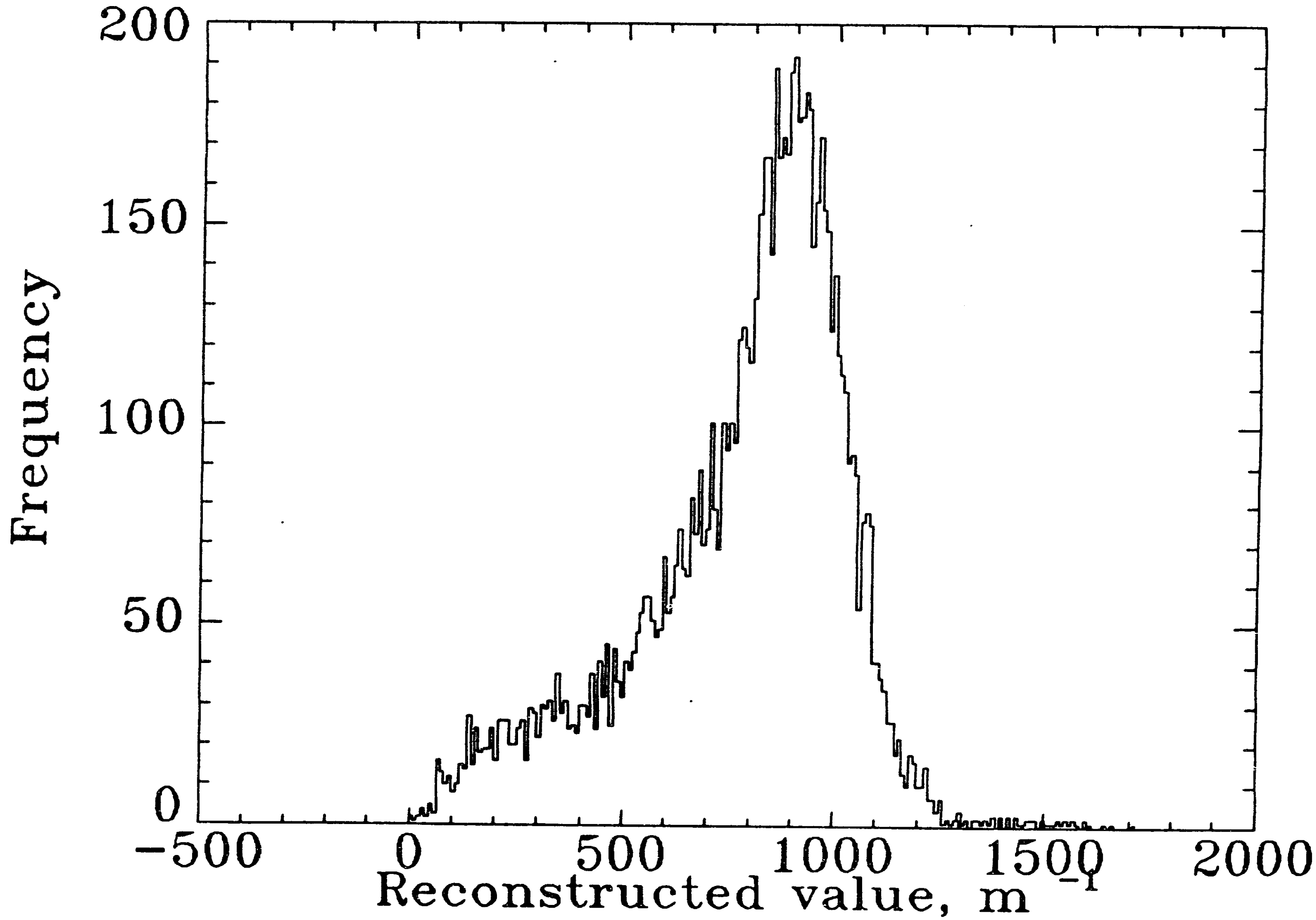
200
150
100
50
0
Frequency
−500
0
500
1000
1500
2000
Reconstructed value, m⁻¹

Figure 2

END

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