How to Characterize a Thermal Spray Coating using Electron Microscopy

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Despite all of the advances in metallographic techniques over the past two decades, there are still a number of coatings which cause problems within the metallography lab. Frequently, these coatings will take on different appearances based on the preparation recipe used. From a metallography standpoint, there is no single method which can be relied upon to prove the true structure of the coating. Fortunately, there are simple alternatives to metallography which can be used to characterize a thermal spray coating. This article will discuss one such method, which involves using a scanning electron microscope (SEM) to examine a cryogenic fracture of the coating.

The procedure for creating a cryogenic fracture of a coating is very similar to the procedure used for creating a fracture grain size sample of martensitic steels (per ASTM E 112). A thin section of the sample is submerged in liquid nitrogen until "frozen", removed from the liquid nitrogen, and quickly overloaded to fracture the sample (keeping the coating in tension). Examination of a coating fracture surface often reveals features which may have been masked or exaggerated by metallographic preparation.

A good example of a coating which can be characterized by this technique is tungsten carbide-cobalt (WCCo). WCCo is a coating which is frequently mis-prepared during metallographic preparation. In some cases, carbide particles are fractured and/or "pulled-out" of the coating, artificially increasing the apparent porosity. In other cases, the cobalt phase may be smeared over inherent porosity, therefore decreasing the apparent porosity. As shown in Figure 1, a cryogenic fracture surface of the coating can give the operator a sense of the true porosity present within the coating. Within this fracture surface, pores are readily visible which should correspond to porosity in a mounted and polished sample.

Another application for cryogenic fractures relates to the classification of interfaces between splat particles. Depending on the operator and specification, features such as those shown in Figure 2 may be classified as either porosity or oxides. Analysis of a cryogenic fracture of this sample verifies that these features are in fact porosity. Figure 3 shows a low-magnification view of a nickel-aluminum coating, from which the general structure of the coating can be seen. Figure 4 shows a higher magnification view of what appears to be an individual splat particle. In this case, the smooth appearance suggests a lack of particle bonding. Figure 5 shows another region of the coating at higher magnification, where porosity is again present between particles. The presence of linear porosity, as compared to stringer oxides, can also be verified using a low-viscosity cold mount epoxy containing a colored dye. This procedure was discussed previously in iTSSe (Volume 1, Issue 1).

References

Geary, A.R. Metallographic Evaluation of Thermal Spray Coatings, Technical Meeting of the 24th Annual Convention; International Metallographic Society, July 1991, Monterey, CA. pp 637.

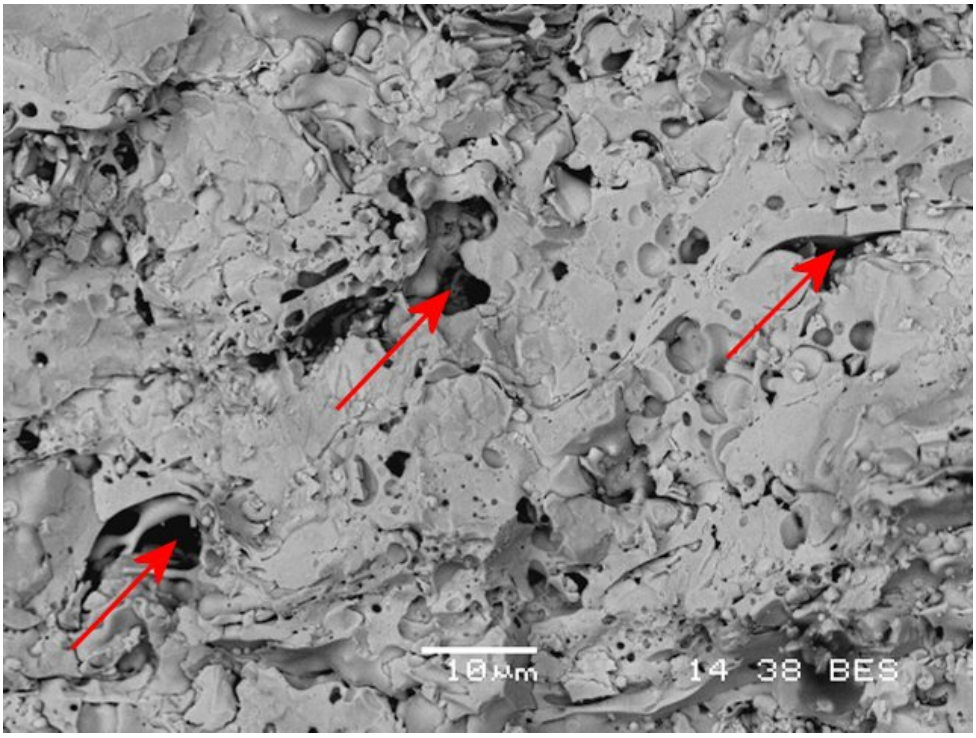

Figure 1. Cryogenic fracture surface of a plasma sprayed WCCo coating. In this case, the fracture surface contains a number of pores and cavities (red arrows) which represent porosity within the coating. Photo courtesy of Pratt & Whitney Quality and Standard Laboratory.

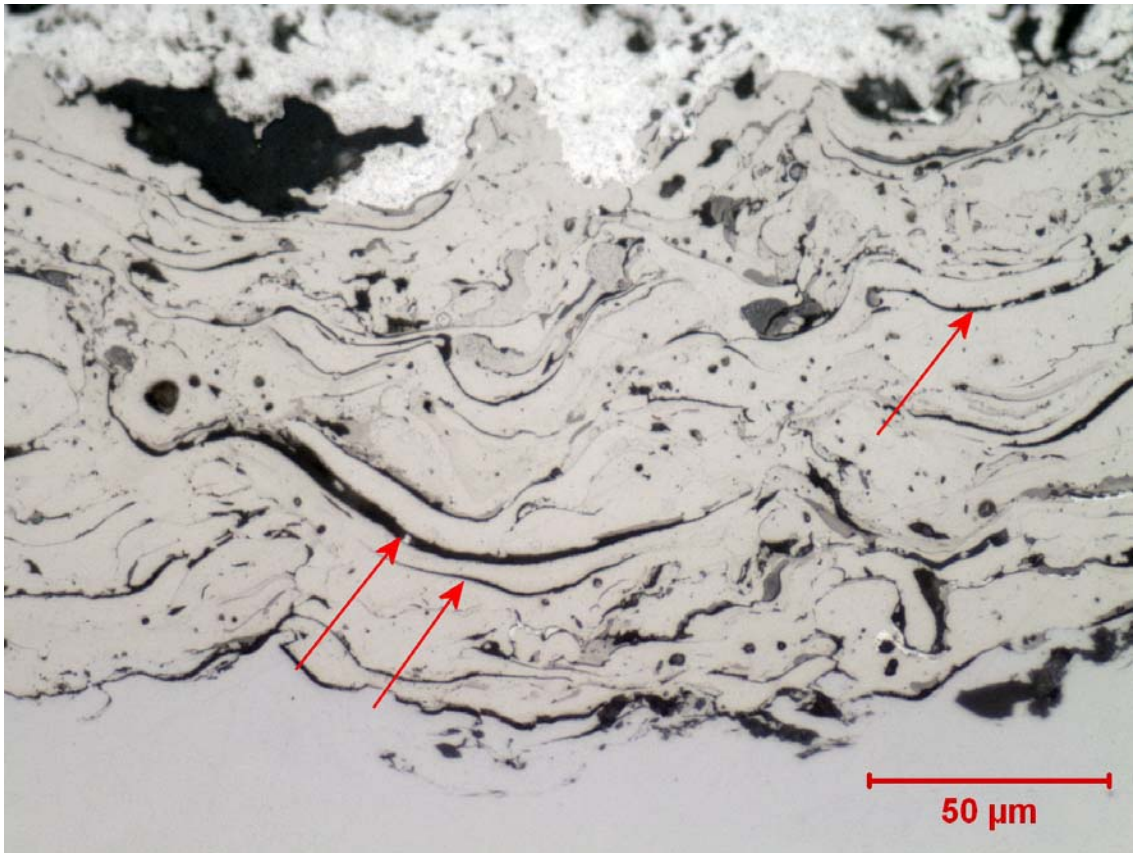

Figure 2. Cross-sectional view of a nickel-aluminum bond coat. The red arrows in this image are used to identify porosity between the splat particles.

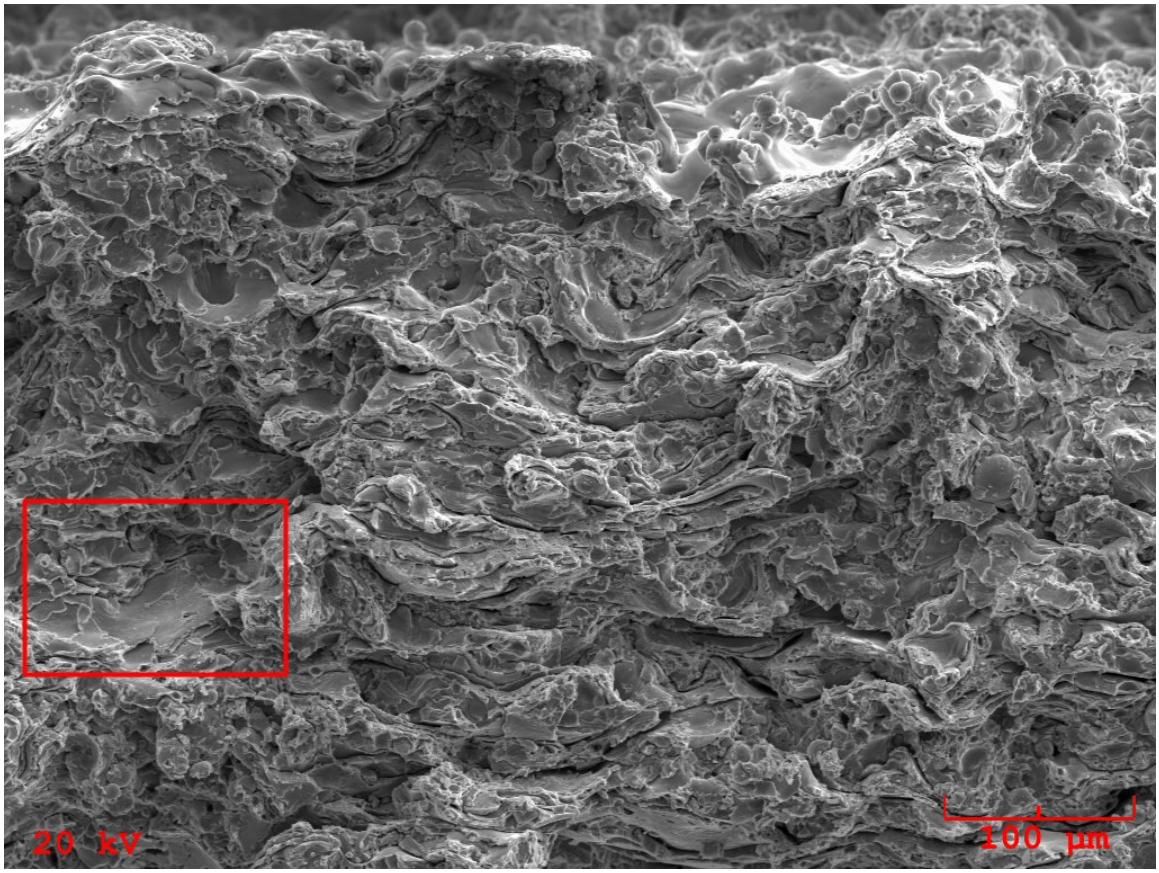

Figure 3. SEM micrograph of a cryogenic fracture surface of a nickel-aluminum coating. The area within the red box is shown in greater detail in Figure 4.

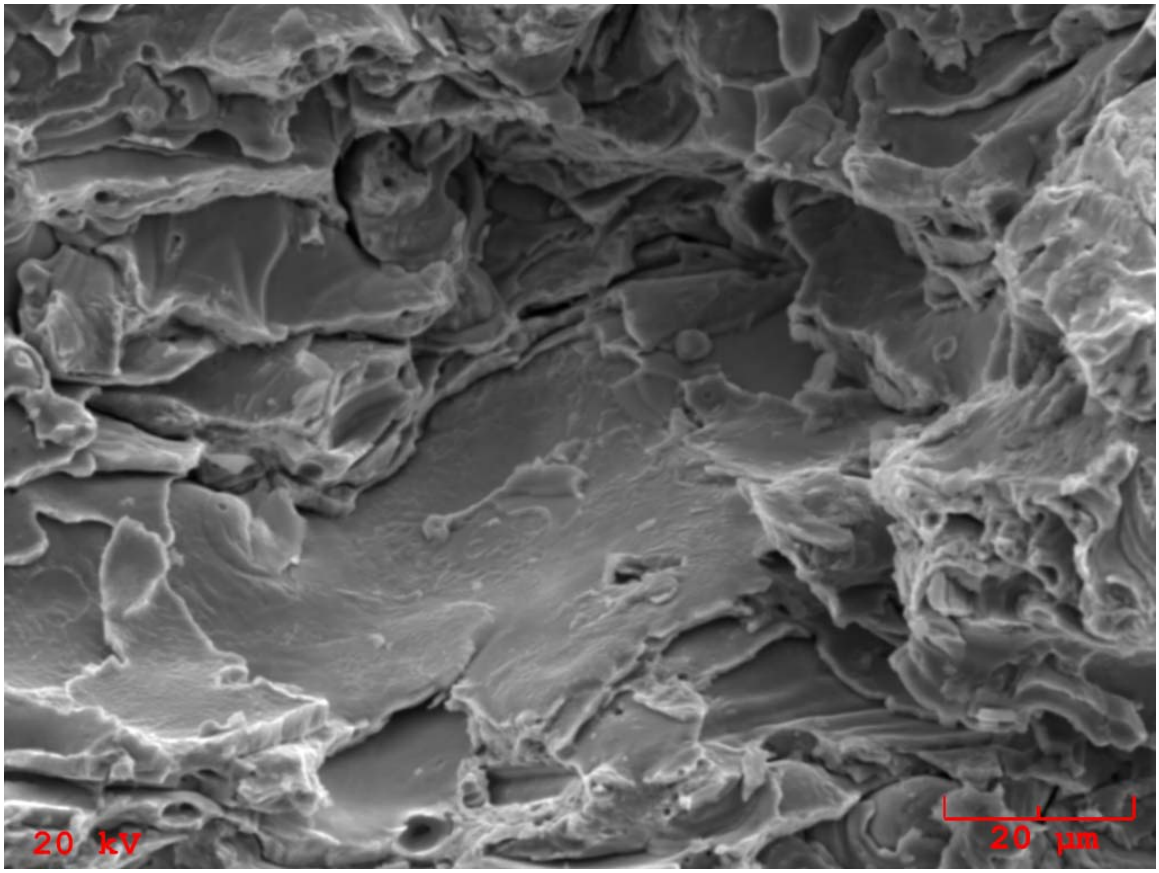

Figure 4. SEM micrograph showing one surface of a splat particle. The smooth appearance of this surface suggests that this particle was not originally bonded to its neighboring particle.

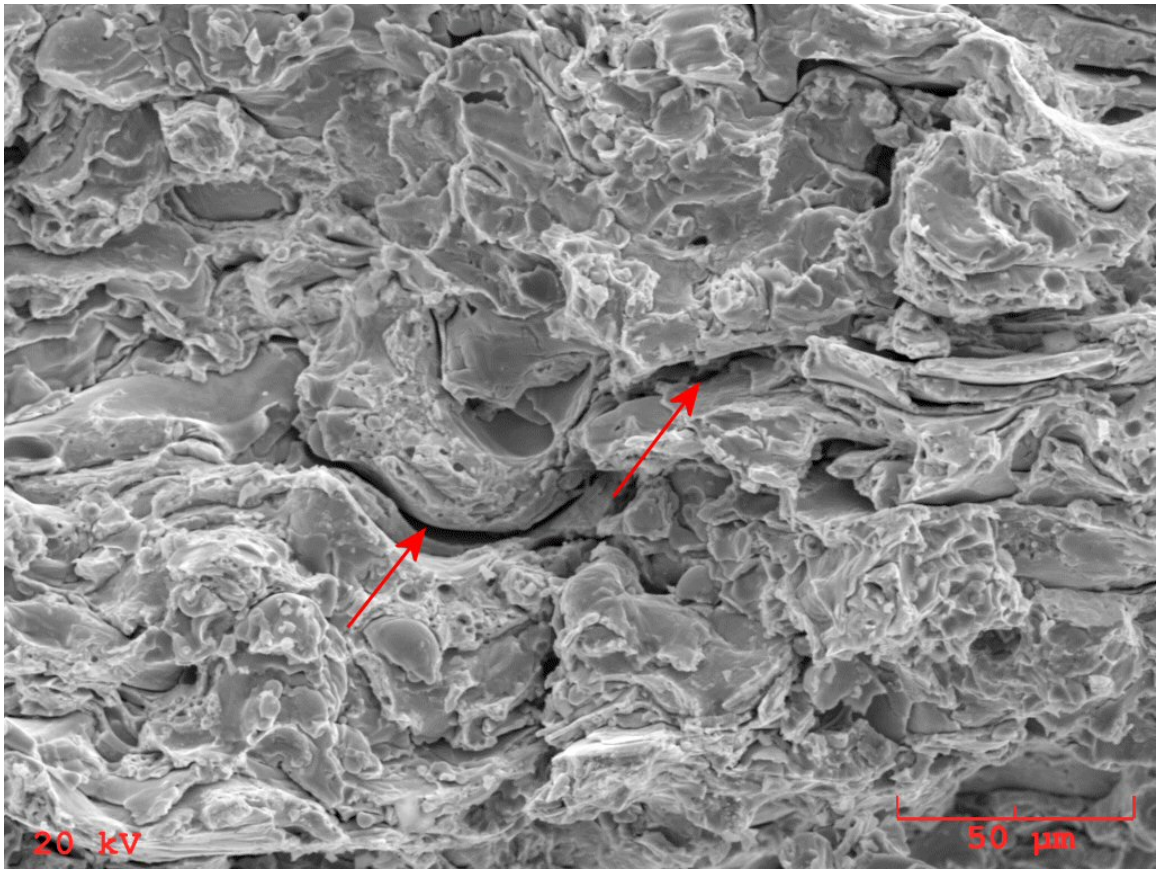

Figure 5. SEM micrograph showing another region of the nickel-aluminum coating. Porosity (red arrows) can be seen between the splat particles.