How porous are our coatings?

Technical Insight

Author

Jesse Bischof,
R&D Scientist

SilcoTek® Corporation

Synopsis

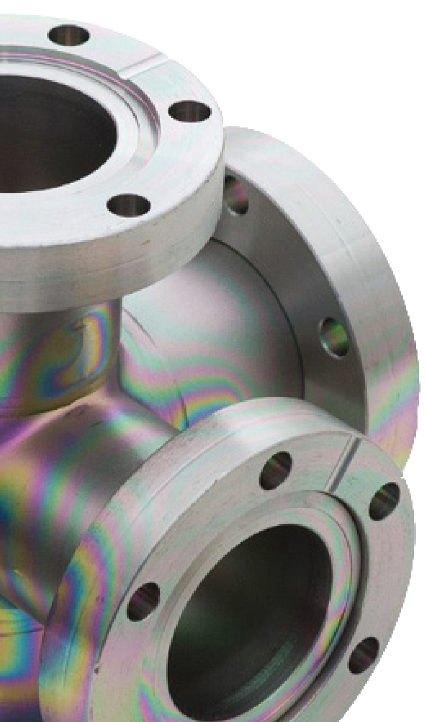
SilcoTek provides thin film coatings deposited via CVD. Customers often ask for the porosity of our coatings. This TI will discuss porosity and provide information regarding the various coatings that we offer.

Background

SilcoTek offers coatings for a variety of industries and an even wider variety of applications. We often are asked “how porous are your coatings?” The short answer is “they are not porous”, but the long answer will be described here.

Data and Discussion

When measuring roughness, there are size domains, each with their own unit of measurement. For instance: which is rougher? The Rocky Mountains or the Appalachian Mountains, a piece of paper or a piece of sandpaper, a glass slide or a mirror polished metal sample? Each pair of comparisons would be measured in a different way and on a different scale. The same is true for porosity. Figure 1 shows various scales of porosity. They are sorted into 3 size domains: macroscopic, microscopic, and atomic. Examples of porosity are shown at each level. For instance, a sponge is obviously porous at the macroscopic level. This can be witnessed with the naked eye. A sintered metal disc does not appear to be porous until you examine it at the microscopic level. Finally, silica-like coatings, such as our Dursox coating or a 2D silica coating on graphene as shown in the image, are not porous until you reach atomic levels.[1] The 5 Å sized pores in glass may allow small molecules such as hydrogen (2.9 Å kinetic diameter) to permeate through easily, but a molecule such as oxygen (3.5 Å kinetic diameter) would diffuse much slower, and a molecule like carbon tetrachloride (5.9 Å kinetic diameter) would struggle to penetrate at all.



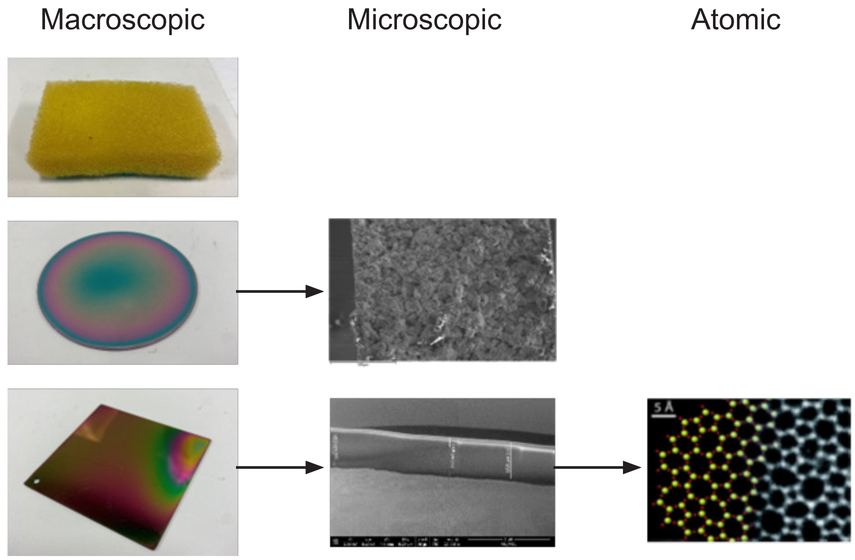


Figure 1: Various domains of porosity and examples of each.

Most customers when asking about the porosity of our coatings are inquiring about the microscopic domain, which is why SilcoTek says our coatings are non-porous. Figure 2 shows an electron image of a typical plasma spray coating along with commonly found defects in such a coating.2 Figure 3 shows a focused ion beam cross section of two of our coatings (Dursox and Silcolloy) on stainless steel. Note that there is a porous carbon layer deposited onto the Silcolloy to protect it from ion milling performed during sample preparation, and is not a part of the SilcoTek coating. This coating is not a SilcoTek coating. Also note that Figure 3 was taken under a much higher magnification (12,500x) than Figure 2 (2,000x), yet no visible pores or other defects could be detected in the Dursox or Silcolloy coating.

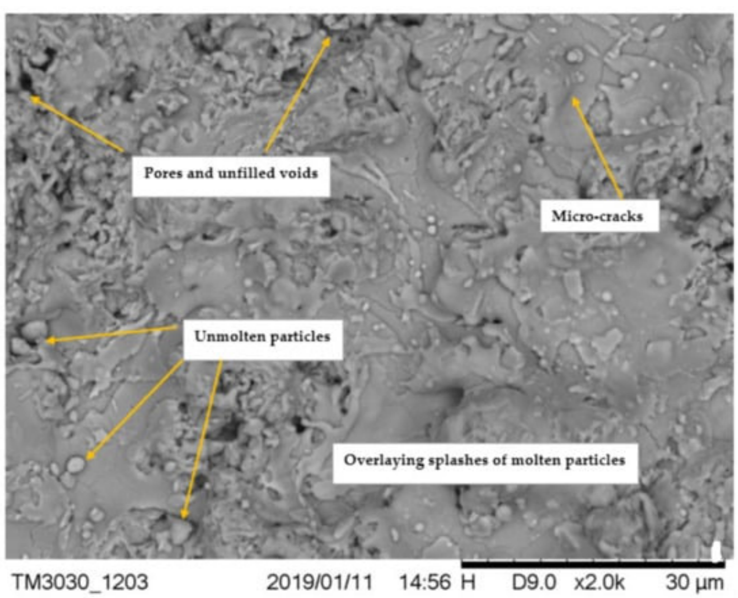


Figure 2: Example of a “typical” atmospheric plasma-sprayed coating of chromium oxide onto Q235 steel. Many anomalies in the coating are highlighted.

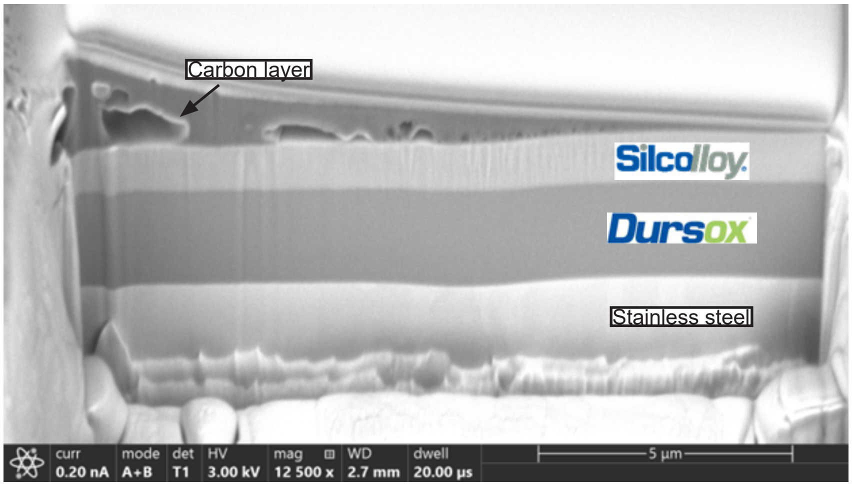


Figure 3: Cross sectional FIB-SEM of a stainless steel coupon coated with Dursox and then Silcolloy. There is no visible porosity in either coating. There is some "curtaining" which is a result of the milling process to expose the coated steel coupon.

Conclusion

SilcoTek's coatings can be considered "non-porous" in comparison to similar protective technologies such as thermal or plasma spray coatings. A previous study using polarization resistance scan in 5% HCl solution has shown that the coatings are also pin-hole free providing complete protection to the base substrate.

References:

1. Huang PY, Kurasch S, Srivastava A, Skakalova V, Kotakoski J, Krasheninnikov AV, Hovden R, Mao Q, Meyer JC, Smet J, Muller DA, Kaiser U. Direct imaging of a two-dimensional silica glass on graphene. Nano Lett. 2012 Feb 8;12(2):1081-6. doi: 10.1021/nl204423x.
2. Odhiambo, J.G.; Li, W.; Zhao, Y.; Li, C. Porosity and Its Significance in Plasma-Sprayed Coatings. Coatings 2019, 9, 460. https://doi.org/10.3390/coatings9070460

SilcoTek® Corporation. All rights reserved. Printed in the USA. See www.silcotek.com/company-patents-trademarks for our patents and trademarks. TI-4.10.23