Illustrating Coating Thickness

Technical Insight

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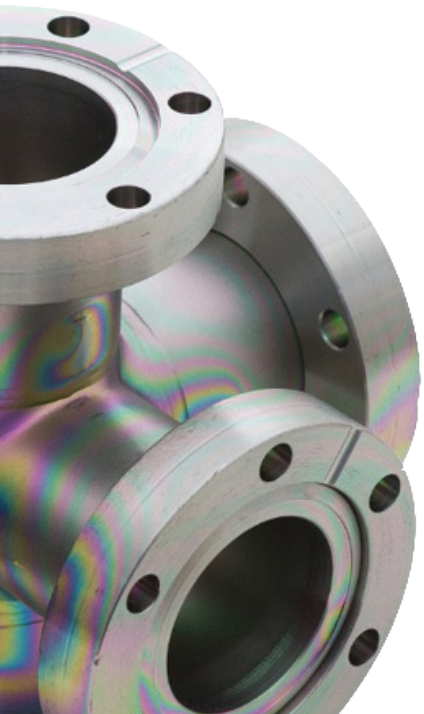

Synopsis

"How thick is Notak?" is a fair question that does not have an easy answer. Typical coatings sold by SilcoTek have a deposition thickness that can be measured with spectroscopic and microscopic techniques and generally have a thickness range from 100nm to 1.5um. Notak is different. Instead of atoms attaching to and building up on the surface of a substrate as they bond to each other to form a growing layer, Notak binds whole molecules (groups of bound-atoms) to the substrate surface. Those molecules form a "forest" upon the surface that is only one molecule thick, which requires very specialized instruments to measure. This TI will help illustrate the thickness differences of Notak and other SilcoTek coatings.

Background

When SilcoTek was first founded in January 2009, it offered 5 different CVD coating options for its customers: SilcoNert 1000, SilcoNert 2000, Silcolloy, SilcoKlean, and SilcoGuard. All 5 options deposit coatings, and two of them (SilcoNert 2000 and SilcoKlean) have an additional functionalization to the surface of the base coating. Since then, SilcoTek has continued to expand its offerings to include multilayered coatings, coatings with primer layers, and a process that involves attaching molecules to the substrate surface without building a substantial thickness beyond the molecular layer.

Data and Discussion

For SilcoNert 1000, silane gas (SiH_4) is brought into a chamber under vacuum at a high temperature. The bonds between silicon and hydrogen break. Hydrogen atoms (H) like to be bound to only one other atom, particularly another unbound hydrogen atom to form hydrogen gas (H_2). Silicon atoms (Si) also combine with each other, but they like to be bound to four other atoms. During this reorganization and bonding, the silicon atoms form a 3-dimensional matrix of bound silicon atoms that also bind to the surfaces of the substrates within the vessel (Figure 1). This process of bond-breaking and reforming in the gas phase to eventually form a solid surface coating is generally referred to as chemical vapor deposition, or CVD.

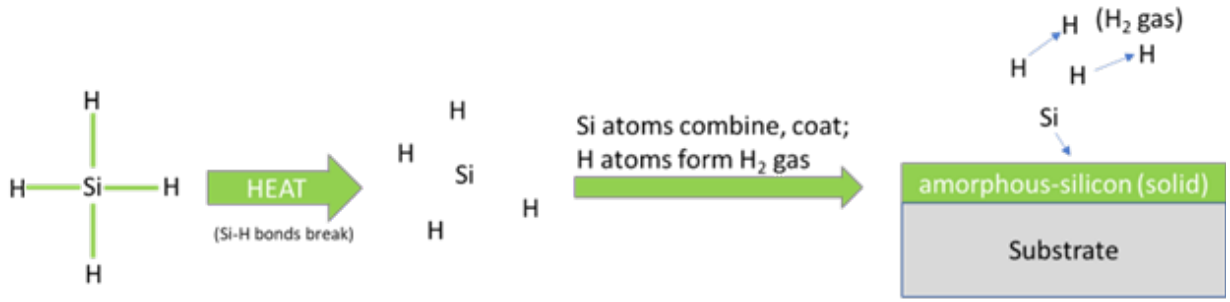

Figure 1. Illustration of silane (SiH_4) gas decomposition to form a silicon coating and hydrogen gas.

As the process of bond-breaking and bond-making continues, more and more hydrogen gas forms and a thicker layer of silicon builds up on all the surfaces of the substrates within the vessel (and the vessel walls too). Eventually, the coating is thick enough for us to see with our eyes, and with a spectrometer (a Filmetrics F20 or F40) we can easily measure the thickness, which is typically 200-1,500 nanometers (nm). Sometimes the thickness is discussed in microns (um), where 1,500nm is the same as 1.5um.

The Notak process is a bit different than the one described above. Instead of using heat to break all the silicon-hydrogen bonds of a precursor molecule (like silane), with Notak, heat is used to drive a reaction between a precursor molecule and the surface of a substrate. Heat energy forces the precursor to bond to the surface of the substrate without breaking the rest of the bonds throughout the precursor. Figure 2 illustrates this process using a carbon molecule (with 4 carbon atoms) as the example precursor molecule (for proprietary reasons, the Notak precursor will not be described here), and shows how the end of the precursor molecule bonds to the surface of the substrate.

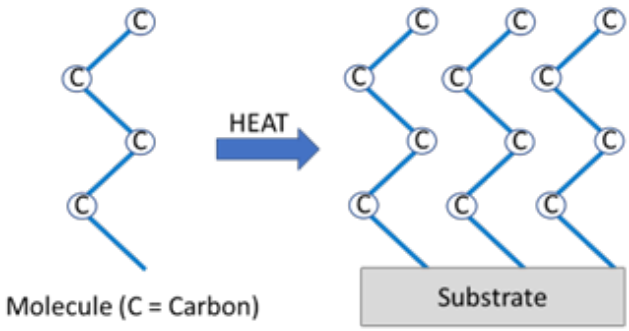

Figure 2. Surface bonding of a precursor to a substrate.

As drawn in Figure 2, there seems to be a significant and potentially measurable thickness, but the drawings in Figures 1 and 2 are not to scale with each other. The length of the molecule bound to the substrate (Figure 2) is significantly less than the measured thickness of a CVD deposition (Figure 1). To illustrate this further, Figure 3 attempts to differentiate between the relative thicknesses of these two processes, and relate them to a tangible yet thin example, the human hair.

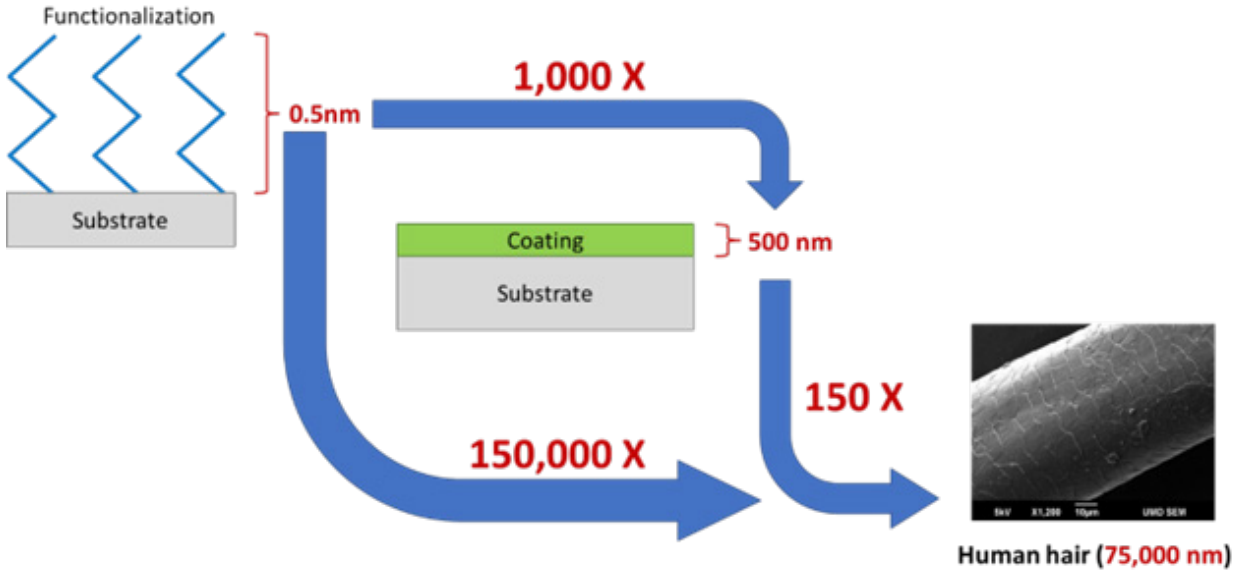

Figure 3. Thickness difference illustration of surface bonding, a CVD coating, and a human hair.

In Figure 3, a 4-carbon-length molecule attached to the surface of a substrate may be around 0.5nm long. As mentioned earlier, an amorphous silicon deposition from SilcoNert 1000 may be around 500nm thick. That coating is therefore 1,000 times as thick as a molecule bound to the surface (as would be with Notak). To further illustrate, a human hair is typically 75 microns thick (or 0.075mm), which is 150 times as thick as the CVD coating, or 150,000 times as thick as the molecule bound to the surface.

Conclusion

The purpose of this TI was to illustrate the differences in how Notak achieves its surface modification through bonding molecules of a nearly immeasurable thickness to substrate surfaces vs. other SilcoTek processes that use chemical vapor deposition to build a measurable coating thickness. Both processes will impart unique properties that are beneficial to our customers' needs but are accomplished through different surface-treatment strategies. It is therefore helpful to understand these differences in processes and thickness and visualize them by comparison to something very thin and relatable (a human hair). With Notak, it is somewhat amazing to think that such a small amount of material bound to the surface (something that can only be seen with the most sensitive of electron microscopes) can have a dramatic effect on the properties of that surface, such as high hydrophobicity and oleophobicity. Also remarkable is how other SilcoTek coatings that are 1000 times thinner than a human hair will take a customer part from failure to success, allowing it to perform in conditions never before imagined. Major changes in performance and physical characteristics with such thin/small modifications is one of the things about surface science that makes it so intriguing and powerful.

