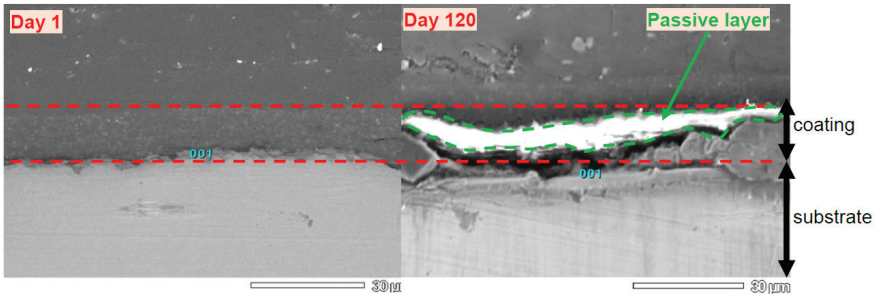

FIGURE 4 SEM figures of physical barrier 1; left figure represents day 1, and right figure represents day 120.

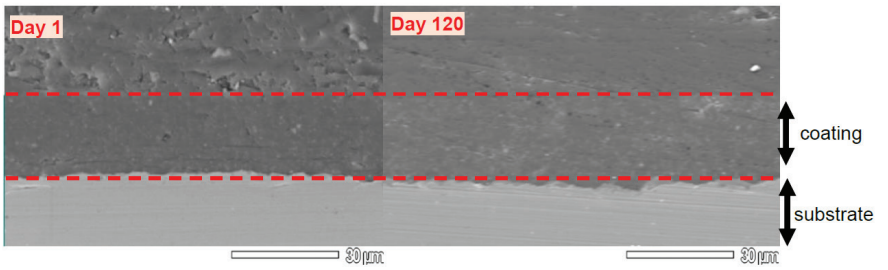

FIGURE 5 SEM figures of physical barrier 2; left figure represents day 1, and right figure represents day 120.

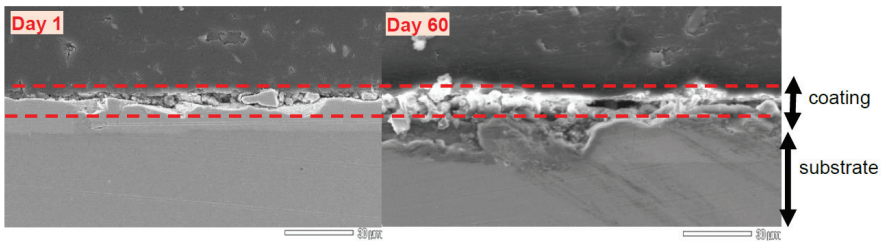

FIGURE 6 SEM figures of sacrificial barrier; left figure represents day 1, and right figure represents day 60.

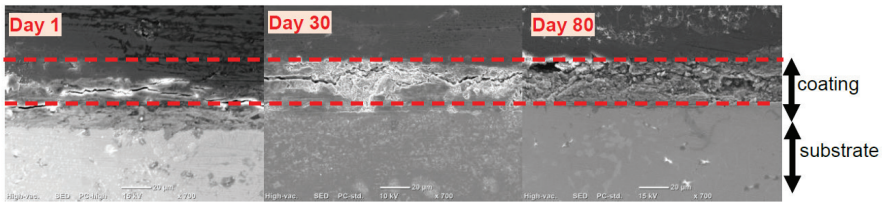

FIGURE 7 SEM figures of hybrid barrier; left figure represents day 1, and right figure represents day 80.

vides greater protection, but at a cost.

"The barrier coating is a material that prevents the interaction from the environment with the metal we call the substrate," says Castaneda, who has a Ph.D. in materials science and engineering from Penn State University.

"That physical barrier not only prevents the interaction, but also the potential damage because of that interaction."

The researchers observed that as time passed, water slowly penetrated the coating. Initially, the coating did a good job of keeping water out, but eventually, the water reached the metal underneath. The thicker the coating, the better it performed. The ANN model (Figure 1) predicted that after about 120 days of lab time, the water would start to react with the metal, forming a protective oxide layer that would stabilize the system.

Sacrificial Coating

A sacrificial coating is made from a metal that corrodes before the underlying metal does, thus protecting it.

"Sacrificial means that you would rather damage or deteriorate that coating instead of the substrate, so you put another coating that protects by reacting with that coating, so it sacrifices itself to prevent the interaction from the environment to the substrate."

When exposed to the salt solution, the sacrificial metal in the coating started to corrode first, forming a protective layer over the underlying metal. This process happened over about 80 days of simulated real-world conditions in the lab, after which the sacrificial layer was mostly used up, leaving behind a stable protective oxide layer. Their model (Figure 2) successfully predicted this progression, showing that the sacrificial coating would offer protection for around 100 days of accelerated conditions before substrate activation is observed.

Hybrid Coating

The hybrid coating is a combination of the first two types, offering both a physical barrier and sacrificial protection.

"Here we have a material that is not that thick, but is thick enough to have a polymer base material, but also you have another material embedded in the polymer that is sacrificial," Castaneda says.

It combines the benefits of both physical barrier and sacrificial coatings and shows the most complex behavior. Initially, it acted like a physical barrier, but as time went on, the sacrificial metal within the coating started to corrode, providing an extra layer of protection. The team's predictions (Figure 3) indicated that this coating could offer

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