High-Touch Coatings with Continuously Active Antimicrobial Functionality

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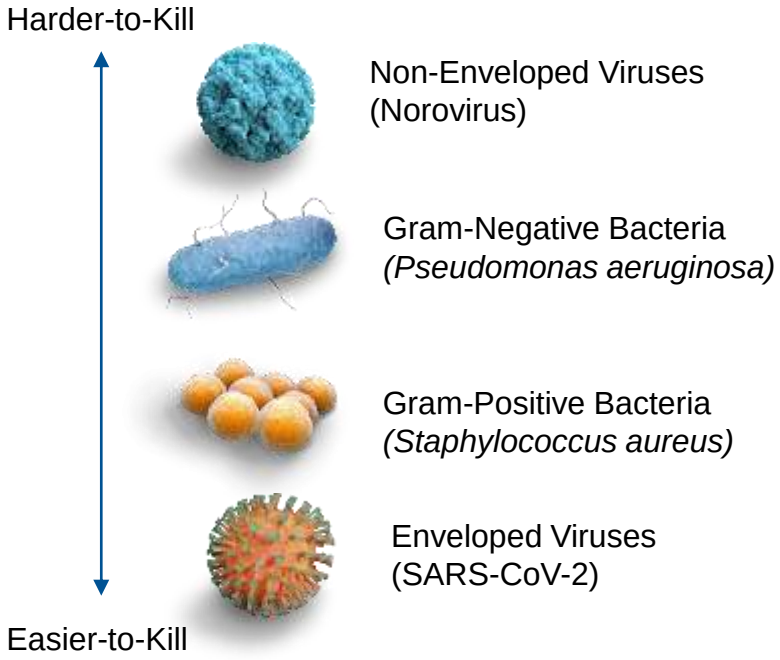
Bactericidal and Virucidal Surface Coatings

- Viruses and other germs are here to stay …and active surfaces are a life-changing innovation to help combat them
- Continuously active coatings
  - Can reduce the level of re-contamination on high touch surfaces
  - Provide antimicrobial efficacy between regular cleaning and disinfection protocols
- Antimicrobial coating technologies have advanced significantly, but there are still challenges…

Performance Requirements for Antimicrobial Surfaces

- Address real-world surface contamination
  - Composed of multiple types of germs
  - Occurs at room temperatures and humidity
  - Dries quickly
- Long-lasting antimicrobial activity
  - Remains active throughout use, including exposure to typical wear and cleaning
- Performance, protection, and aesthetic requirements must also be met



Challenges for High-Touch Coatings

- High-touch surfaces are protected by high-performance coatings
- Factors that enhance coating performance can be detrimental to antimicrobial activity
  - Ion transport, molecular diffusion
- High-performance coatings are finely tuned and sensitive to formulation changes




US EPA Regulates Public Health Claims Against Human Pathogens

- Formalized guidance established in 2022 for products adding residual efficacy claims
- Guidance includes test methods for demonstrating residual bactericidal and virucidal activity
- Example public health claims:
  - Kills 99.9% of viruses and bacteria within two hours of contact on the coated surface
  - Continuously kills viruses and bacteria on the coated surface within 2 hours of exposure for up to 5 years

- Public health claims are <u>not the same</u> as “treated article” claims
  - Claims to protect the article or substance itself can be exempt from registration
  - Example treated article claims:
    - Kills odor and stain causing bacteria
    - Stain and odor-resistant
    - Specially formulated to resist mildew growth on the paint film
    - Article treated to resist deterioration by mold fungus

Understanding Laboratory-Based Antimicrobial Test Methods

Wet Test

- Wet Surface
- 24 Hour Test
- Elevated Temperature and Humidity

Example Test Methods:
ISO 22196, ISO 21702, JIS Z 2801

Typical test method used for substantiating treated article claims

versus

Dry Test

- Dry Surface
- 2 Hour Test
- Room Temperature and Humidity

Example Test Methods:
US EPA MB-41-00 and MB-40-00, OECD Splash Test

Test method required for US EPA-registered public health claims

Dry Test Conditions Simulate Real-World Contamination Events

Dry Test Conditions

Low inoculum volumes (20 µL)

Spread over surface

Inoculum left undisturbed

Inoculum dries within 5-10 minutes

2 Hour Test

Room Temperature and Humidity

Wet Test Conditions

Higher inoculum volumes (120 µL)

Cover slip applied

Cover slip promotes uniform coverage

Surface remains wet for duration of test

24 Hour Test

Elevated Temperature and Humidity

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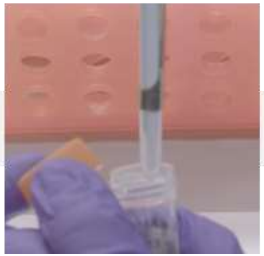
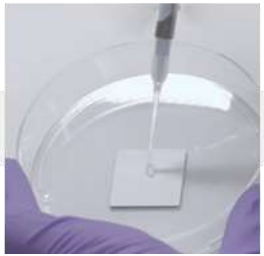
Bactericidal Efficacy Testing

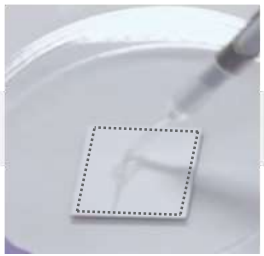
Bacteria prepared with soil load



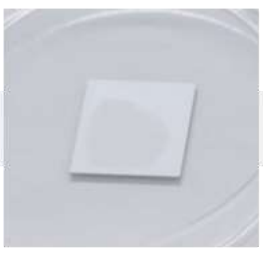
'Dry' test volumes of bacteria applied to coupon



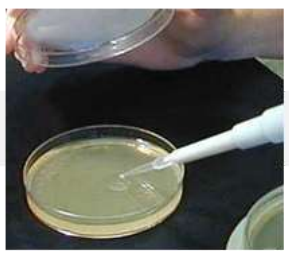
Bacteria spread evenly across coupon



Drying of inoculum occurs during a 2-hour exposure



Bacteria collected and incubated on agar

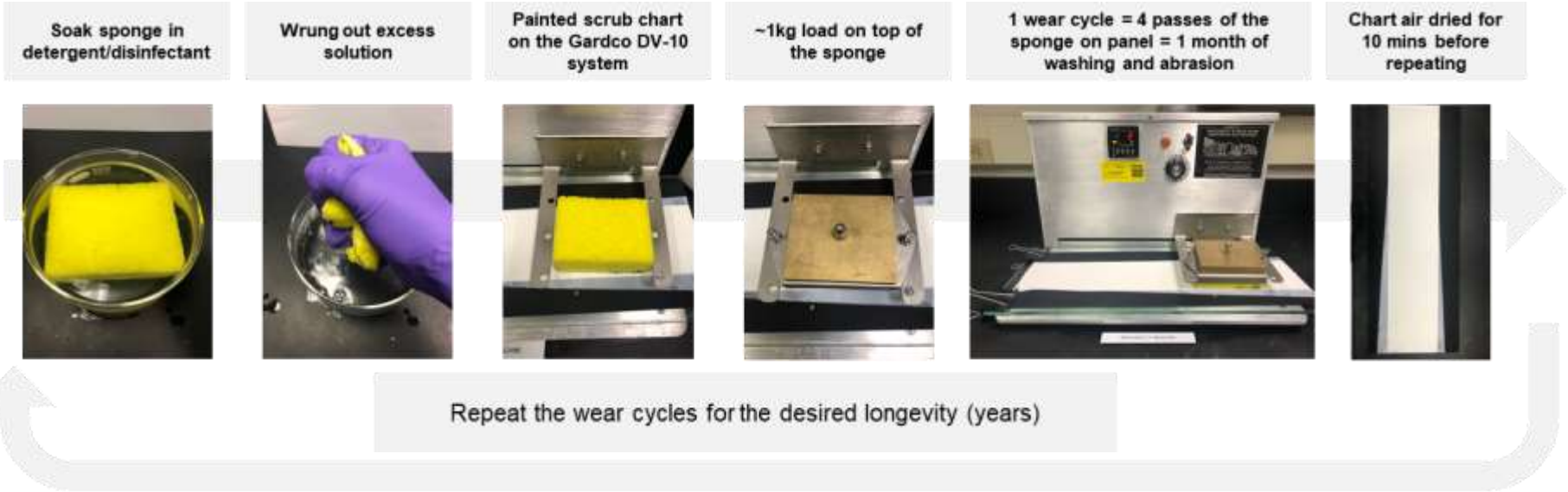


Colonies counted after 48 hours

Results are reported as a log-scale reduction of organisms on a test sample versus a control

5 log kill → 99.999% reduction
4 log kill → 99.99% reduction
3 log kill → 99.9% reduction (Required performance for US EPA registration)
2 log kill → 99% reduction
1 log kill → 90% reduction

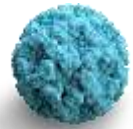
Residual Efficacy Testing – Simulated Wear Procedure



1 Wear cycle = 4 Passes of sponge over coating = 1 Month of cleaning

Bactericidal or virucidal efficacy testing is repeated on coatings subjected to simulated wear.

Literature Search Indicates Few Technologies Pass Dry Test Conditions Against A Broad Spectrum of Microbes

	Inorganics				Organics	
	Silver	Zinc	Copper	Titanium Dioxide	Quaternary Ammonium Compounds	Isothiazolinones
 Non-Enveloped Viruses	✗	✗	✓	✗	✗	✗
 Gram-Negative Bacteria	✗	✗	✓	✗	✓	✗
 Gram-Positive Bacteria	✗	✗	✓	✗	✓	✗
 Enveloped Viruses	✓	✓	✓	✗	✓	✗

SOURCE:
Ikner, L. A., Gerba, C. P., 2021, 'Antiviral Coatings as Continuously Active Disinfectants', in D. R. Nims, D. M. Khalid (eds.), *Disinfection of Viruses,* IntechOpen, London. 10.5772/intechopen.101752
Williams, Terry M. "The Mechanism of Action of Isothiazolone Biocide." Paper presented at the *CORROSION 2006*, San Diego, California (March 2006)
Michels H.T. "Effects of temperature and humidity o the efficacy of methicillin-resistant Staphylococcus aureus challanged antimicrobial materials containing silver and copper. *Letters in Applied Microbiology* (2009)

Copper is A Powerful, Natural Antimicrobial

Benefits

Cu^{+1}

- Kills >99.9% bacteria (*Staph, E.coli, MRSA*)*
- Kills >99.9% viruses (Flu & cold viruses, Norovirus, Sars-CoV-2)
- Favorable animal toxicity
- Enable long-term antimicrobial potency
- No off-gassing
- AMR — Reduced risk of leading to antimicrobial resistance

*Gross, T.M., Lahiri, J., Golas, A. *et al. Nat Commun* **10,** 1979 (2019). https://doi.org/10.1038/s41467-019-09946-9

A Copper-Glass Antimicrobial Additive

Aluminoborosilicate Glass

+

Copper Source

Melting and glass forming

Copper-Glass

Milling

4-micron average particle size

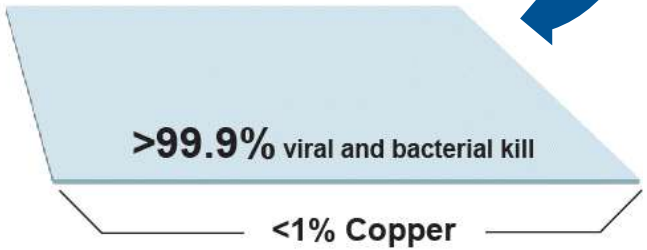
Copper-Glass Additive

Comparison

Copper Metal

Can Be Formulated Into a Large Variety of Colors

Coating Formulated with a Copper-Glass Additive



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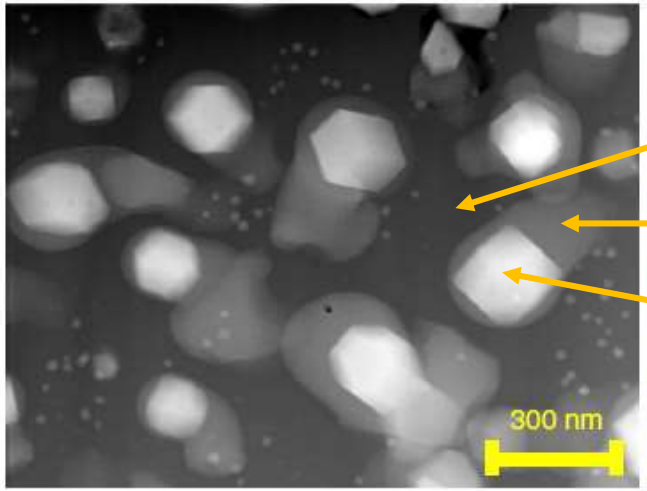
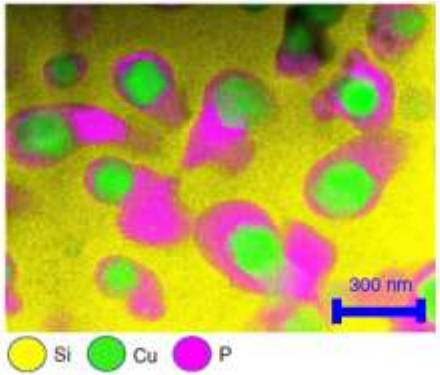
The Copper-Glass Stabilizes Cu^{1+}

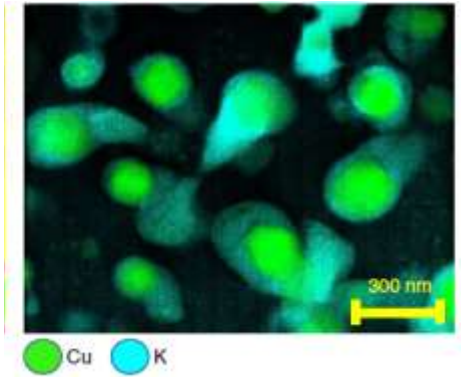


Continuous Phase

Discontinuous Phase

Copper(I) Oxide Crystals



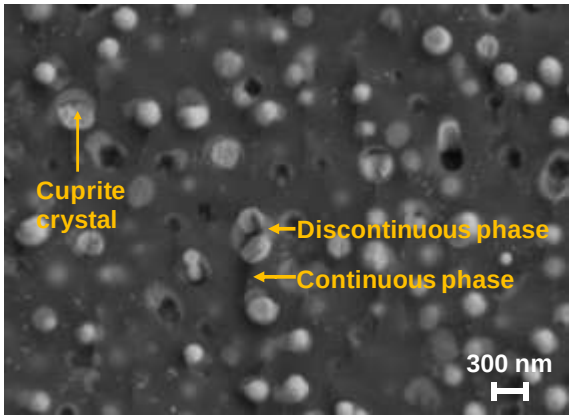


Cu —Remove First Electron→ Cu^{1+} —Remove Second Electron→ Cu^{2+}

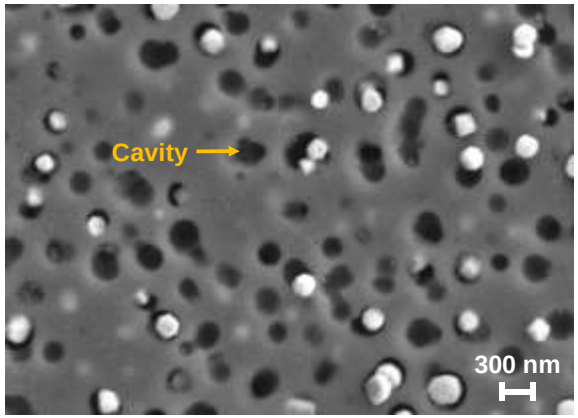
Most Bioactive
Least Stable, but Effectively Stabilized in the Copper-Glass

Copper-Glass Morphology is Critical to Antimicrobial Efficacy

Before Exposure to Water



After Exposure to Water



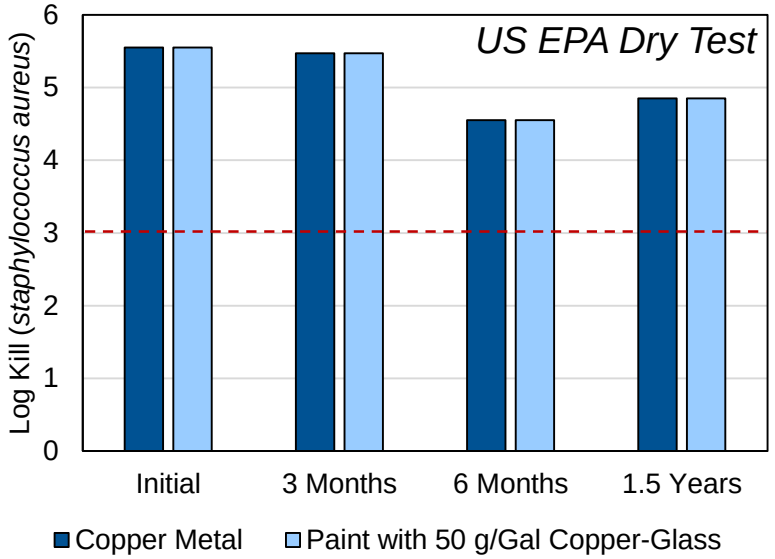
- Discontinuous phase dissolves in water
- Cu^{1+} enables bactericidal and virucidal properties of the material that the copper-glass is incorporated into
- Use rates of 1% copper-glass by weight on total formulation are typical (~ 50 grams of copper-glass per gallon of coating)

Achieving Long-Lasting Antimicrobial Activity in Coatings

Performance requirements:

- Cu^{1+} must retain antimicrobial activity
  - Inhibit oxidation to Cu^{2+}
  - Inhibit reactivity with other materials
- Cu^{1+} must be available at the coating surface
  - In sufficient quantity
  - Sufficiently stable to provide long-lasting antimicrobial efficacy, even through cycles of washing and cleaning

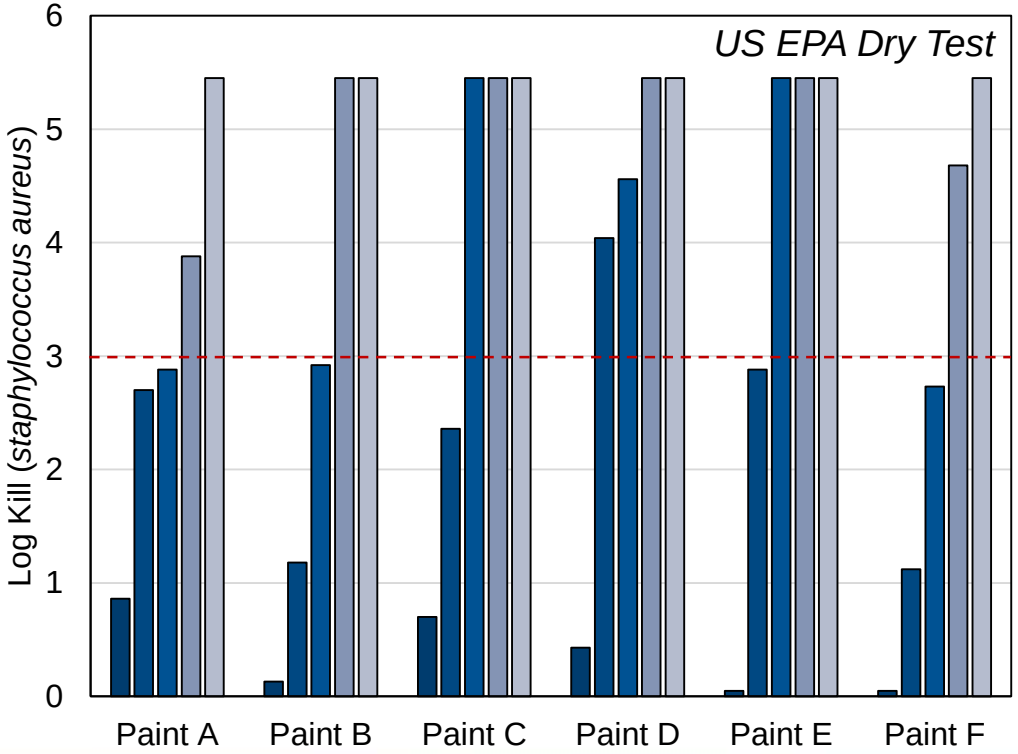
Real-Time Aging of Copper-Glass Coatings



Copper Metal

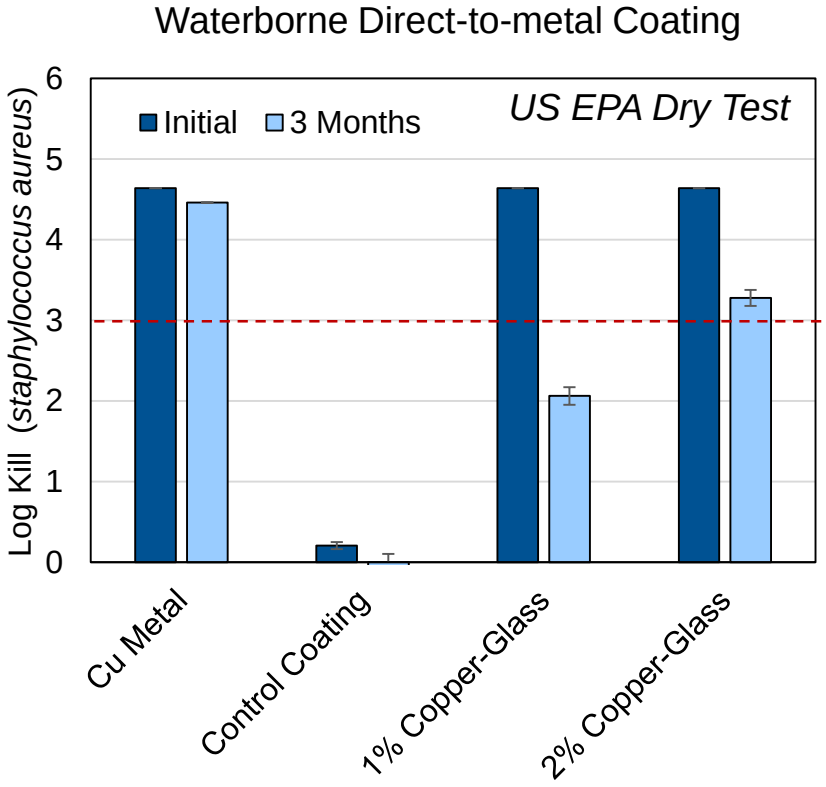
Paint with 50 g/Gal Copper-Glass

Formulation Ingredients Can Influence Antimicrobial Activity



- Commercial coatings dosed with copper-glass can show variable dose-dependent antimicrobial activity
- It can be difficult to identify which raw materials may be detrimental to antimicrobial efficacy

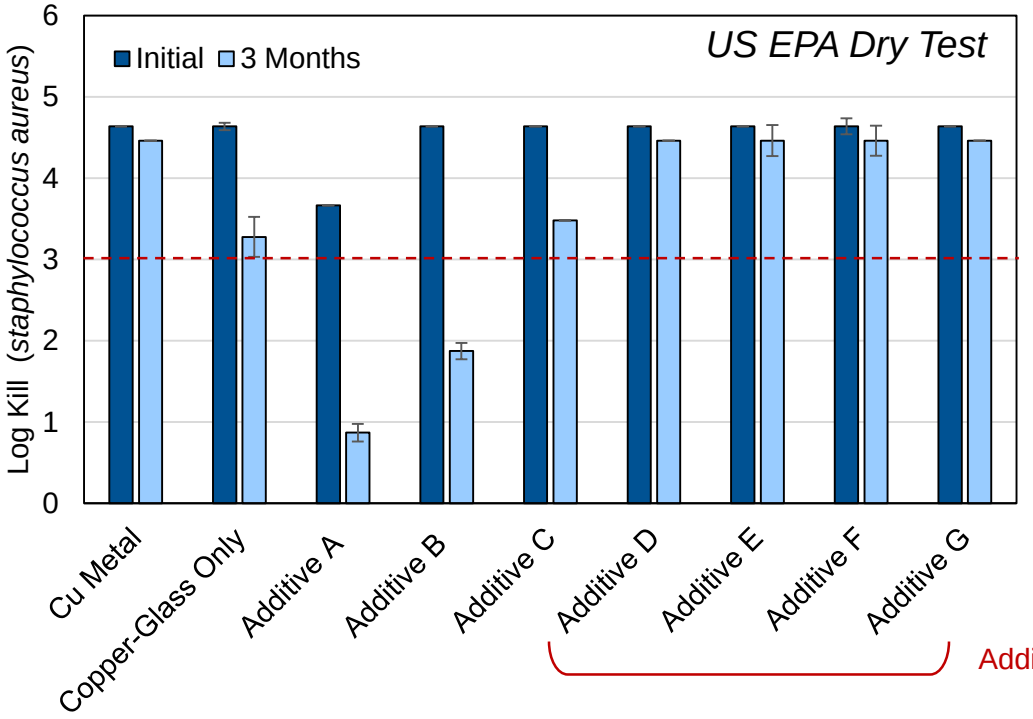
Challenges for High-Touch, High-Performance Coatings



- Antimicrobial efficacy can be more challenged for some high-performance coatings, such as waterborne direct-to-metal (DTM) coatings
- Challenges can arise for initial or long-term antimicrobial efficacy, depending on the formulation
- Polymer-rich, high gloss, and low porosity coatings may prevent adequate accessibility of Cu^{1+} to organisms on the surface of the coating

A New Approach: Formulating Copper-Glass With Additives

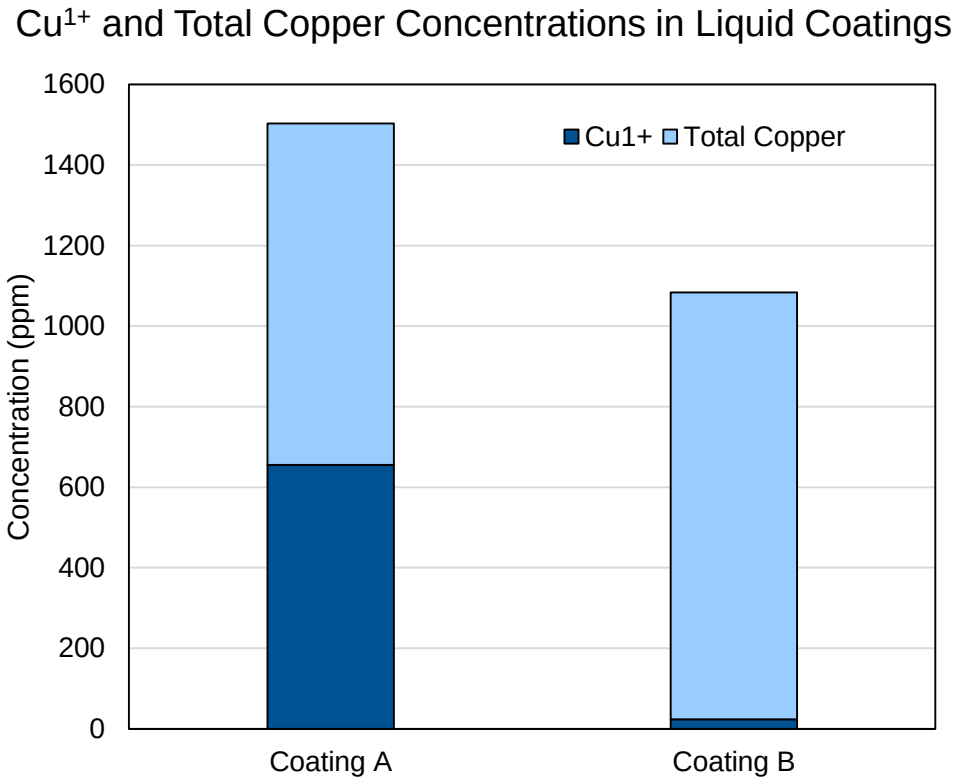
DTM Coating with 2% Copper-Glass and Various Additives



- Rather than focusing on reformulating coatings to remove incompatible materials, we focused on identifying additives to assist in controlling the stability and availability of the copper-glass
- Additive chemistries have been identified that enable long-term antimicrobial performance in high-touch coatings

Analytical Tools to Guide Development Work

- Analytical tools were developed to quantify Cu^{1+} and total copper concentrations (Cu^{1+} + Cu^{2+}) in coating formulations
- Copper quantification assists in diagnosing mechanisms leading to poor antimicrobial performance and drives additive selection

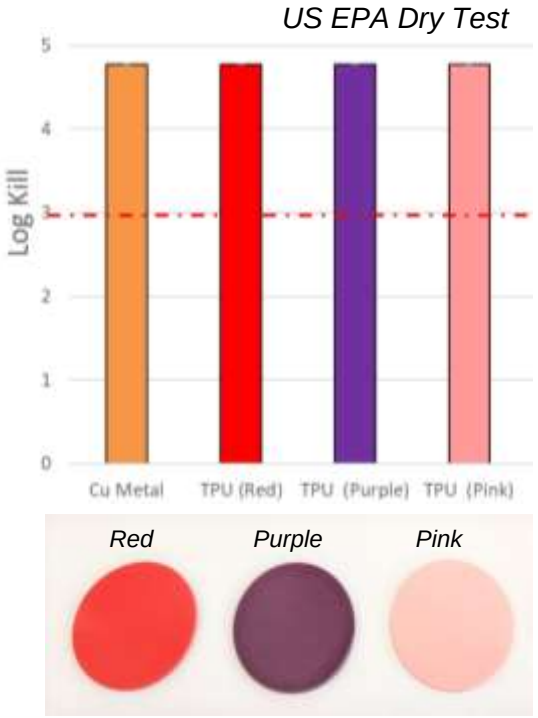


Copper-Glass Also Enables Antimicrobial Efficacy in Other High-Touch Materials, Including Plastics

- Copper-glass can enable long-term antimicrobial efficacy in a variety of plastics
- Antimicrobial efficacy can be maintained in pigmented formulations
- Evaluations of additional plastic chemistries in progress

Thermoplastic	Copper-Glass Concentration	Additive Concentration	Full Kill Efficacy*
Polyurethane Elastomer (Polyether)	1%	1%	12+ months
Nylon (PA6)	2%	2%	12+ months
PVC	3%	3%	6+ months

* Last data point collected



Summary

- Viruses and other germs are here to stay …and active surfaces are a life-changing innovation to help combat them
- Public health claims against human pathogens are regulated by the US EPA and require bactericidal and virucidal testing under ‘dry’ conditions
- Copper is one of the few technologies that can pass dry test protocols against a broad spectrum of microbes
- The use of additives in combination with a copper-glass antimicrobial can enable many high-touch, high-performance coatings, like DTM coatings, to achieve long-lasting antimicrobial efficacy
- Additives formulated with copper-glass antimicrobials can eliminate the need for making significant formulation changes and more easily enables current commercial formulations to add antimicrobial functionality

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Thank You!

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