Functionality of Silanes as Coupling Agents for Coatings

Wayne Powell, CC, CEF

POLYPLEX, Inc.

reinventing your performance coatings

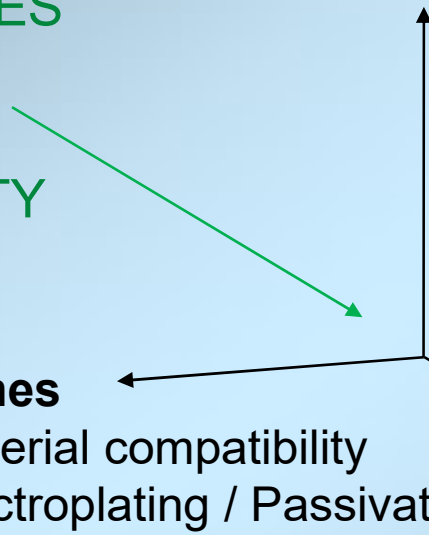
corrosion mitigation – lubricity - release

a veteran owned small business

POLYPLEX, Inc.

Specializing in coatings for corrosion mitigation, lubricity, wear and release

GREEN TECHNOLOGIES and SUSTANIBILITY



Industries

- Department of Defense
- Aerospace / Commercial Airlines
- Medical / Pharmaceutical
- Commercial

customer focus

Disciplines

- Material compatibility
- Electroplating / Passivation
- Ti Anodizing
- Surface Finishing Support
- Polymeric coatings
  - Metals
  - Glass
  - Plastics
  - Textiles

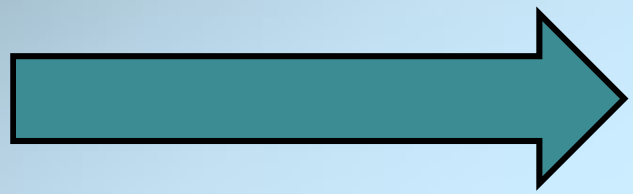
Services

- Consulting
- Prototyping
- Production

Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

Disciplines

- Material compatibility
- Electroplating / Passivation
- Ti Anodizing
- Surface Finishing / Chem Film



- Polymeric coatings
  - Metals
  - Glasses
  - Plastics
  - Textiles

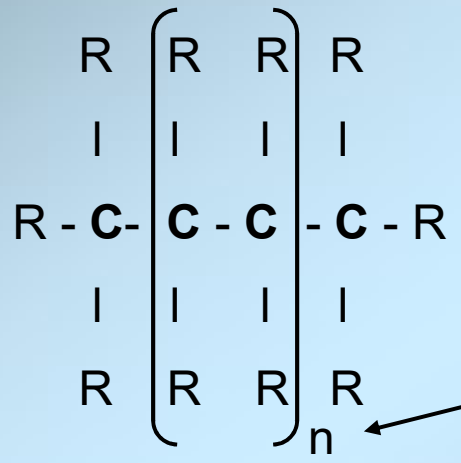
Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

POLYMERS

Organic vs Organosiloxane

Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

Organic Polymers are a combination of organic groups or elements attached to a carbon bond



R represents hydrogen, methyl, ethyl, etc.

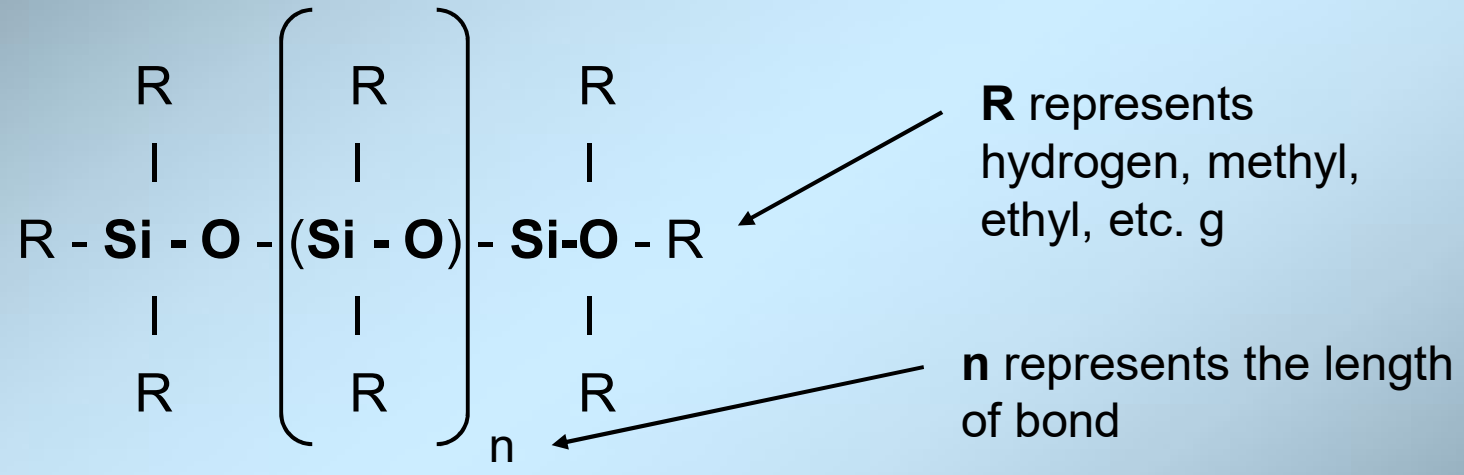
n represents the length of bond

example: polyethylene

- **carbon backbone**: carbon-carbon bond strength around 350 kJ/mol for the organic binders

Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes continued

Organosiloxanes are a combination of organic groups or elements attached to a silicon-oxygen bond



example: polydimethylsiloxane (PDMS)

- **silicon-oxygen backbone**: silicon-oxygen bond strength around 450 kJ/mol for the polysiloxane binders (provides a much stronger bond)

Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

COMPARISON OF PROPERTIES

Organic polymeric **coatings** - "physically" bonded

- •material fused to roughened surface
- •coating thickness typically 0.2 mils to 5.0 mils
- •coating provides primary property over substrate
- •weak C-C bond breaks down in atmospheric/weathering conditions
- •thermally/mechanically stripped, impacting part – low selection of substrates
- •weak adhesion provides limited performance

Organosiloxane **coatings** - covalently bonded

- •monomers chemically attach to active sites and to each other on substrate to form crosslinked polymers
- •coating thickness from 2 nm to 5 microns (0.2 mils)
- •coating aids existing substrate properties
- •strong Si-O-Si-O bond already in oxidized state, provides good atmospheric/weathering properties
- •chemically stripped, not impacting part – high selection of substrates
- •strong adhesion provides superior performance

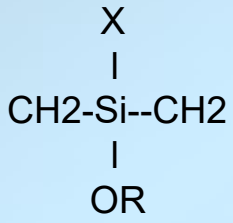
Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes continued

Surface Modification by Converting Silanes to Siloxanes

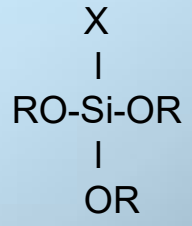
Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes continued

The Oganosilane Molecule

Silanes: a monomeric molecule containing at least one silicon – carbon (Si-C)



alkoxysilane

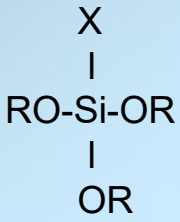


trialkoxysilane

Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes continued

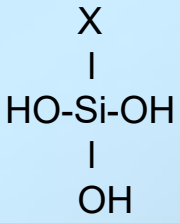
Silane Coupling Agents

functional groups that bond
to both organic and inorganic



OR: hydrolyzable groups

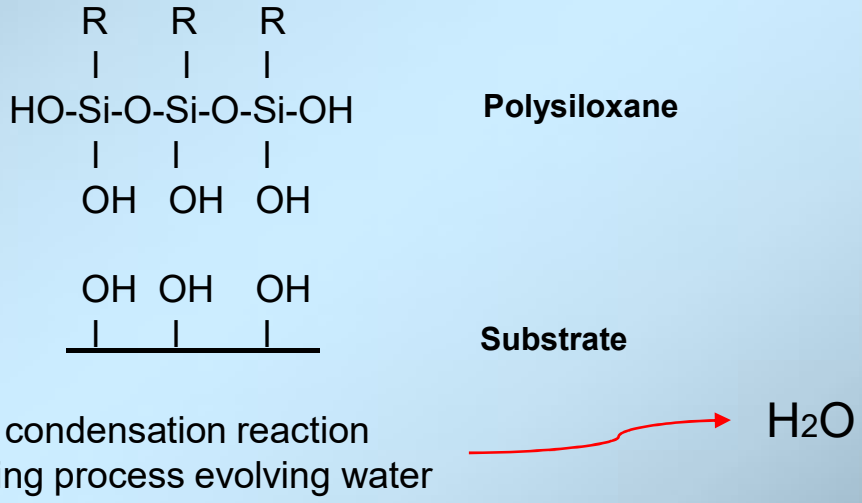
X: non-hydrolyzable groups

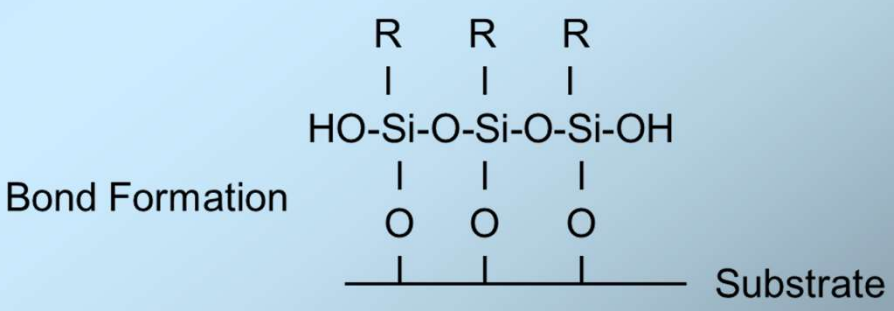


Hydrolyzable groups react with
water to form silanol groups

Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

- Organosiloxane Bonding Process





Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Titanium Nitride on Stainless Steel

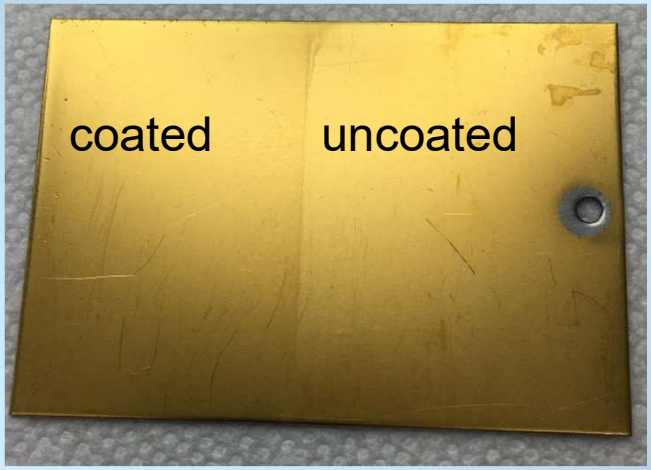
Request:

add polysiloxane properties while maintaining TiN properties

Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Increased lubricity using polysiloxanes on coated TiN/SS

Test Method: ASTM D1894, measuring kinetic CoF



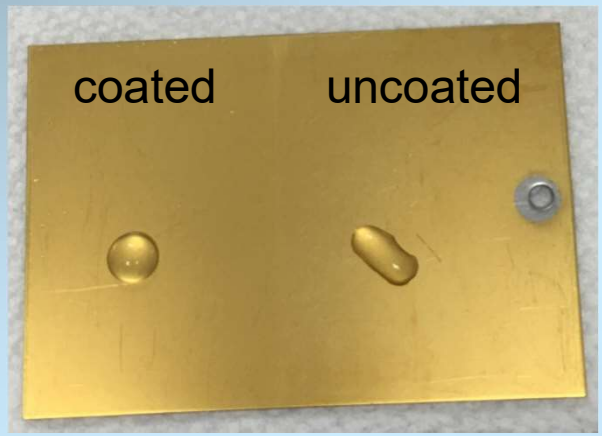
Titanium Nitride Coated Stainless Steel Coupon

SAMPLE TYPE		TiN	TiN / Type 3	TiN / Type 4
Plastic	kinetic CoF	0.3	0.05	0.04
Chrome plated steel	kinetic CoF	0.5	0.08	0.07

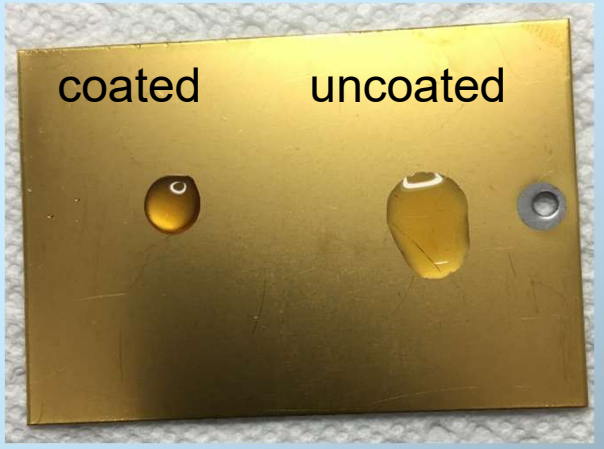
Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

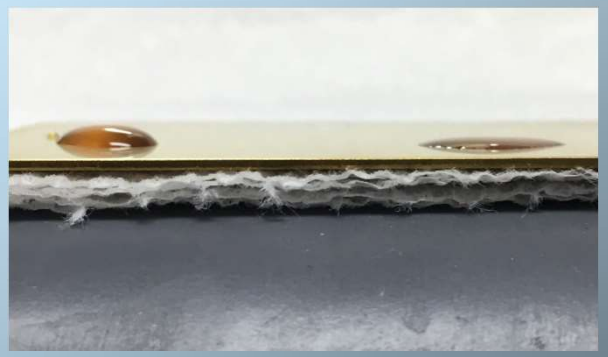
Increased contact angle using polysiloxanes promoting change in surface energy

hydrophobic property



olieophobic property

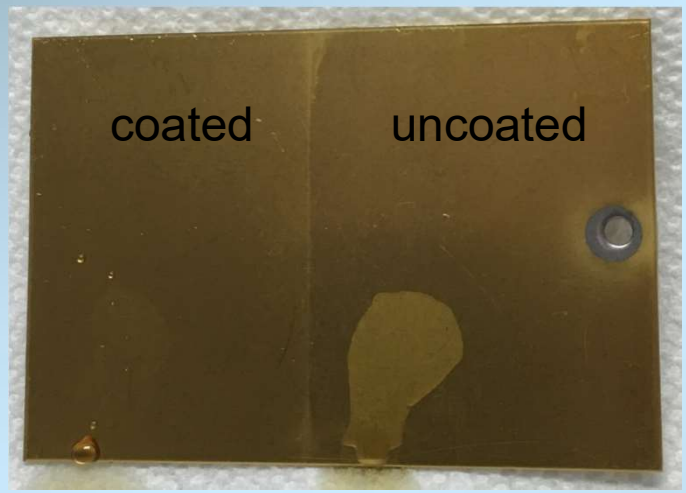




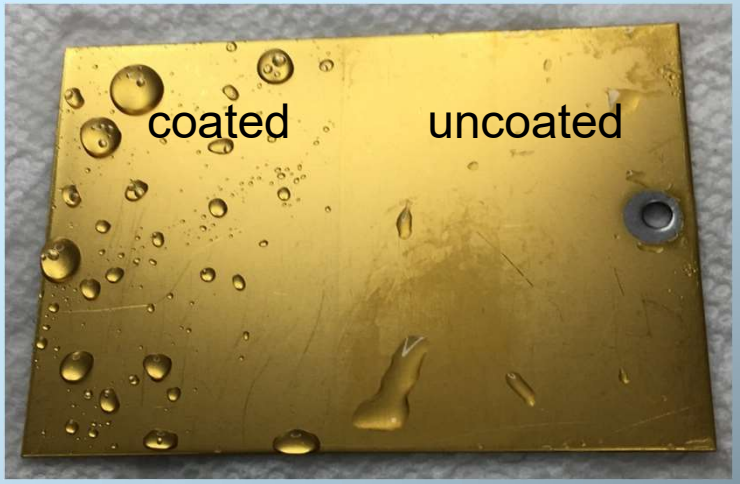
Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Increased repellency and easy cleaning using polysiloxanes

oil draining from TiN coating



Spray rinse on TiN coating



Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Chrome Nitride on Steel

Request:

add polysiloxane properties while maintaining CrN properties

Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Increase corrosion protection using polysiloxanes

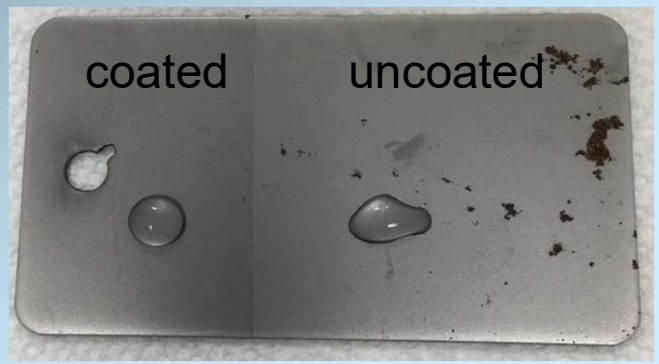
ASTM B-117 Salt Spray Test

180 hour salt spray test
coated vs uncoated

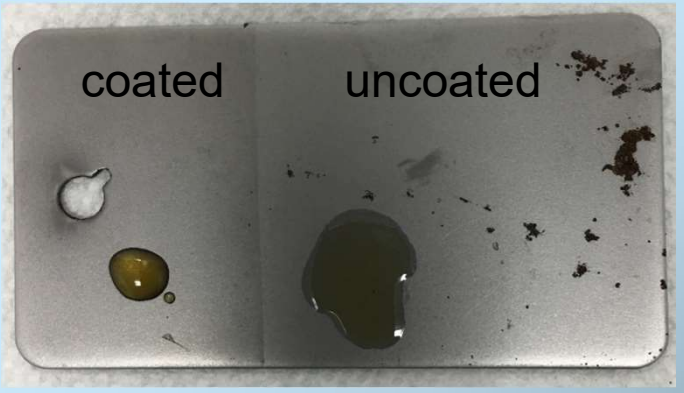
Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

Increased contact angle using polysiloxanes promoting change in surface energy

hydrophobic property



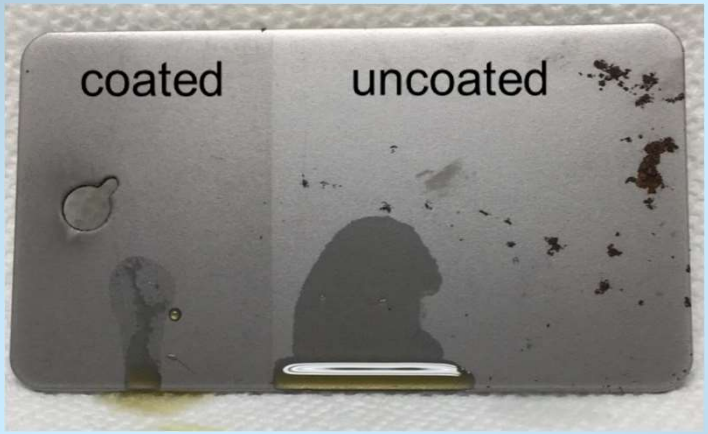
olieophobic property



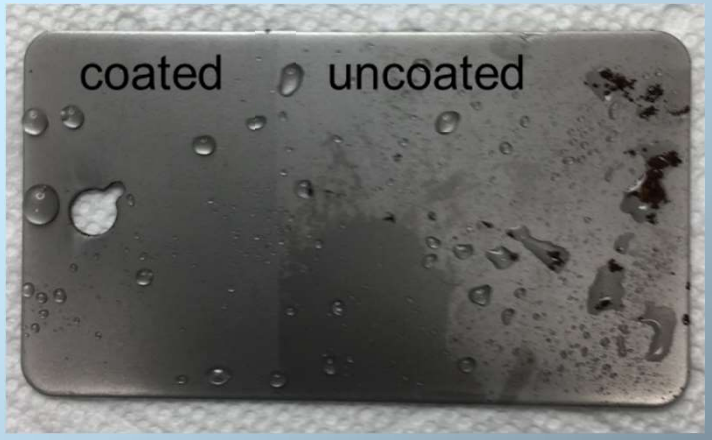
Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Increased repellency and easy cleaning using polysiloxanes

oil draining from CrN coating



spray rinse on CrN coating



Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Coating Organosiloxanes over Organic Polymers

Enhance Hydrophobic and Olieophobic Properties
Over Organic Coatings and Plastics

- Provide environmental corrosion protection
- Provide UV protection
- Provide antimicrobial protection
- Increase product life cycle

Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Organic Polymeric Coating on Steel

Water runoff after 30 minute soak in 2 molar NaOH at 125 F

Video one

Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

Organosiloxane Polymeric Coating Over Organic Coating

Polysiloxane bonded to organic polymeric coating

Water runoff after 30 minute soak in 2 molar NaOH at 125 F

Video two

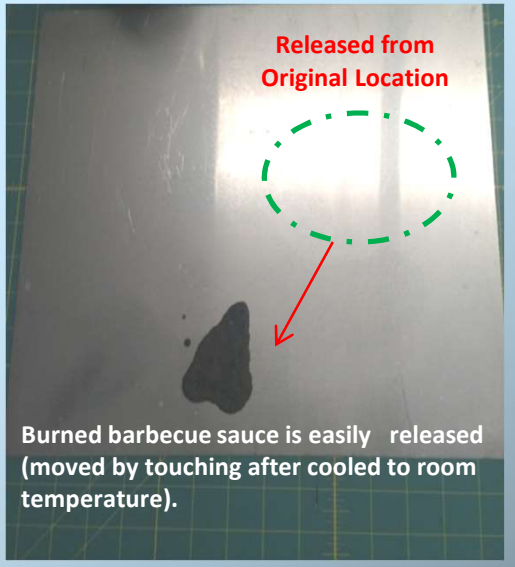
Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

More Examples of Organosiloxane Polymers Solving Stringent Customer Requirements

Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

MILITARY FOOD SERVICE – advanced coatings for cookware



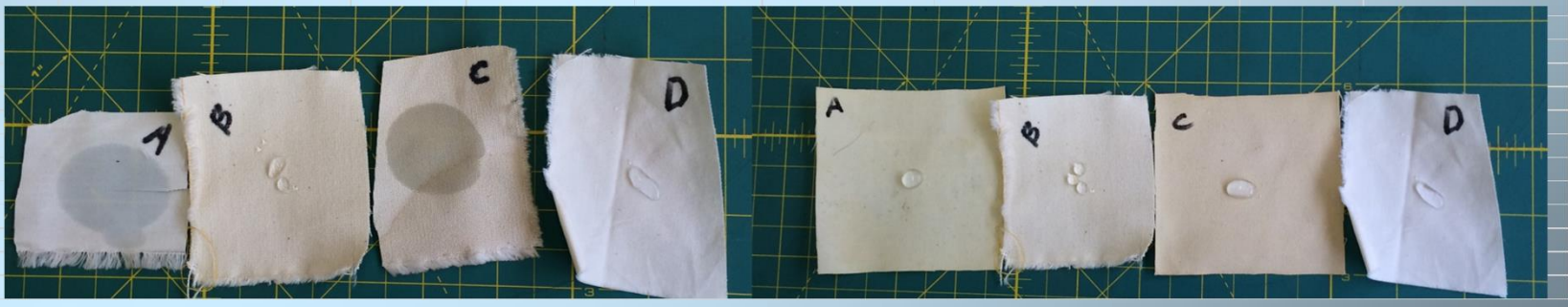
- Requirements:
  - Non-PTFE, non-stick coating surface
  - Meet FDA 21CFR for contact with food and NSF certification
  - High temperature release (600F)
  - Meet environmental impact restrictions - reduce detergent and oil usage
  - Reduce labor – easy clean
  - Pan coating is not to peal or flake
  - Increase useful life from 3-4 months to + 4 years (24/7 usage)
  - Maintain the look of stainless steel

Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

Coatings on Commercial and Military Textiles

- Antimicrobial protection
- Ultraviolet protection
- Water repellency

Sample ID	Brand	Item No	Item Name	Precoat wetting	Sample Size	Uncoated Wt (g)	Coated Wt (g)	% Wt Takeup	% Cu Equiv	Post coat wetting
A	T/C fabric	Pre-Treated	1.5M	wet	3in X 3in	1.12	1.37	22.32%	0.27%	not wet
B	100% organic cotton	Greige fabric	1.5M	not wet	X	X	X	X	X	X
C	100% organic cotton	Pre-Treated	1.5M	wet	3in X 3in	1.38	1.72	24.64%	0.30%	not wet
D	T/C fabric	Greige fabric	0.8M	not wet	X	X	X	X	X	X

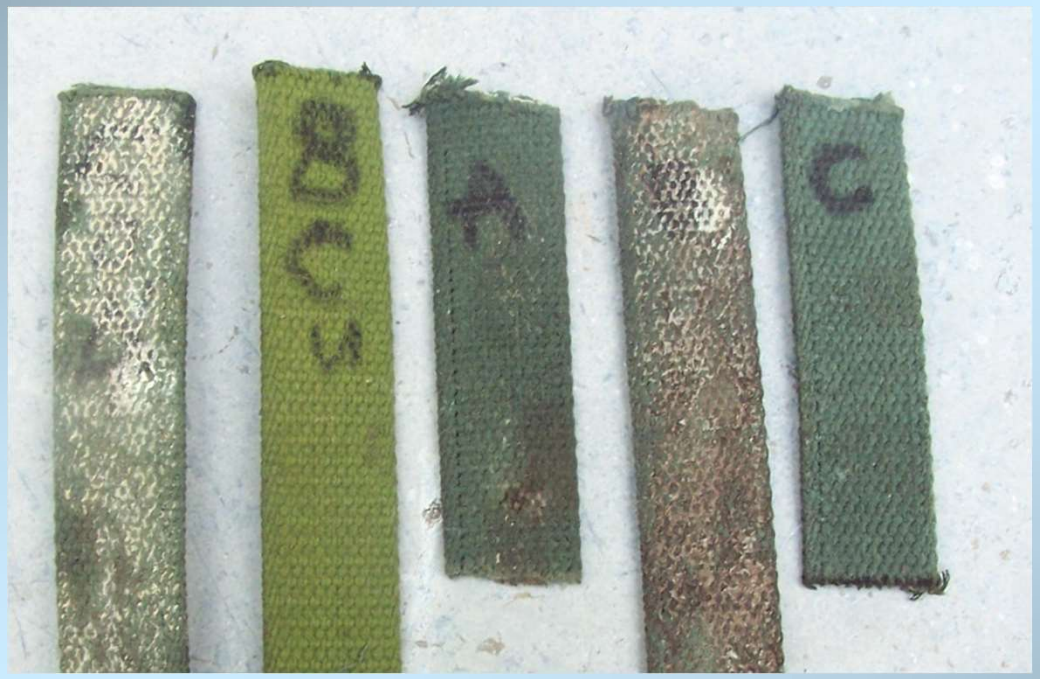


as received water test

post coating water test

Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Testing for Antimicrobial Protection and Water Repellency



Cotton textile samples after 11 weeks in test chamber

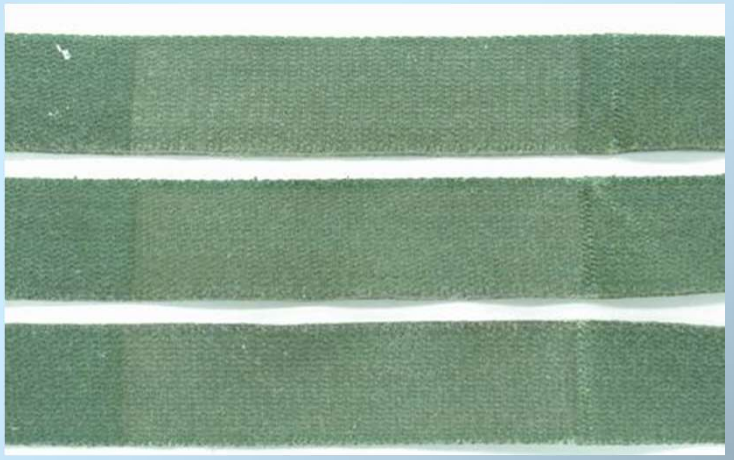
Left to right: control, metalorganic, A,B,C are various concentrations of polysiloxane formulation

Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Testing for Ultra Violet Protection

AATCC 186 – Test Method for UV Exposure and Strength for Cotton Webbing

1008 Hours UV exposure
Metalorganic impregnation



1008 Hours UV exposure
polysiloxane coating

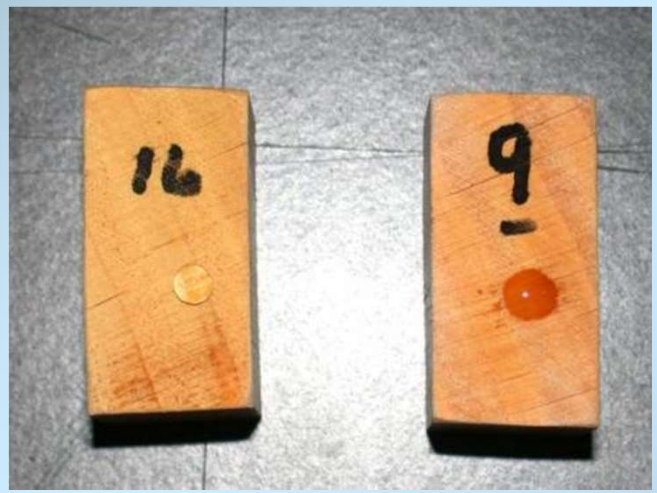
Added Performance Properties for Coatings and Substrates Using Topical Organosiloxanes-continued

Polysiloxane Coating of Textiles

- EPA compliant
- Provides antimicrobial protection
- Provides water repellency
- Provides UV protection
- Extends product life

Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Commercial and Military Coatings on Wood



Water bead comparison of treated (16) and untreated (9) samples after 336 hours of room temperature exposure

- Hydrophobic protection
- Antimicrobial protection
- UV protection

Added Performance Properties for Coatings and Substrates
Using Topical Organosiloxanes-continued

Conclusion:

Organosiloxanes

- thickness – nano to low micron scale
- green coating technology – water base and VLVOC formulations
- chemically bonds to the substrate
- bonds to many types of substrates
  (metals, PVD, thermal sprayed and plated parts, glasses, plastics)
- enhances hydrophobic and olieophobic properties
- provides lubricity, wear, corrosion protection, release
- maintains substrate properties while adding polymeric properties
- completely coats parts while maintaining critical dimensions
- extends product life

… Thank you

contact: Wayne Powell, CEF

POLYPLEX, Inc.

reinventing your performance coatings

corrosion mitigation – lubricity - release

a veteran owned small business

wpowell@polyplexinc.com