Consumer Coatings in the Home: Fact and Fiction

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Why do we need Paints and Coatings?

PRODUCTS OF THE PAINT AND COATINGS INDUSTRY

Enamels
Primers
Undercoats
Stains
Varnishes
Clears
Powder
UV/EB Cures
Hi-Solids
Waterborne
Solventborne
Electrodeposition
Aerosol

ADD VALUE BY

PROTECTING
PRESEIVING
BEAUTIFYING

Homes
Buildings
Factories
Bridges
Ships
Cars
Buses
Furniture
Appliances
Machinery
Metal Food Cans
Highway Safety Markings
Aircraft

Source: American Coatings Association (www.paint.org)
Global Coatings Market

- Global market was $128 billion in 2014
  - US market was $24 billion
- Product Segments
  - Architectural/Decorative coatings
  - Industrial/OEM Coatings
  - Special Purpose Coatings
    o Auto Refinish
    o Industrial Maintenance
    o Marine
    o Traffic marking paint
- Trends – low VOC, higher quality

Source: P&S Market Research; American Coatings Association
Global Coatings Industry

- Major players:
  - PPG Industries
  - Sherwin-Williams Company
  - Valspar Corporation
  - Akzo Nobel
  - Axalta Coating Systems
  - Kansai Paint Co.
  - Henkel AG & Co.
  - Asian Paints Limited
  - RPM International
Sources of Materials used in the Coatings Market

SOURCE FOR MATERIALS USED TO MAKE PAINTS AND COATINGS

MINES
- Ore
- Clays

WELLS
- Crude Oil
- Natural Gas

FARMS
- Seeds
- Beans

METALS
- MINERALS
- PROCESSING

PAINT COLORS
- ALUMINUM PIGMENTS
- TITANIUM DIOXIDE WHITE
- IRON OXIDE YELLOW
- EXTENDER PIGMENTS
- INORGANIC COLORS

PAINT SOLVENTS / LIQUIDS
- ALCOHOLS
- ESTERS
- KETONES
- OTHER HYDROCARBONS
- GLYCOLS
- WATER

PAINT RESINS
- ALKYDS
- ACRYLICS
- EPOXYS
- POLYESTERS
- POLYURETHANES
- VINYL
- DRYING OILS

Source: American Coatings Association (www.paint.org)
## Consumer Coatings in the Home

<table>
<thead>
<tr>
<th>Type of Coating</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural – exterior, interior paints</td>
<td>Beauty</td>
</tr>
<tr>
<td>Furniture – wood, metal finishes</td>
<td>Protection</td>
</tr>
<tr>
<td>Automotive – paint, corrosion</td>
<td>Increased value</td>
</tr>
<tr>
<td>Packaging – can interiors, labels, printed packages</td>
<td>Insulation</td>
</tr>
<tr>
<td>Electronics – wire coatings</td>
<td>Anti-stain/non-stick</td>
</tr>
<tr>
<td>Appliance</td>
<td>Easy clean</td>
</tr>
<tr>
<td>Glass - eyewear</td>
<td>Thermal Stable</td>
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<td></td>
<td>Anti-reflective</td>
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</tbody>
</table>

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Appliance Coatings

• Appliance coating market
  – Refrigeration
  – Cooking appliance (stoves, cookware, bakeware, rice cookers, grills)
  – Laundry (washer/dryers)
  – Miscellaneous kitchen appliances (dishwasher, microwave, and others)

• Coatings mainly epoxy-based exterior coatings to protect metal and provide color

• Interior coatings provide metal protection and easy clean benefits
Cookware and Bakeware Coatings

- Main benefit is non-stick surface which provides easy clean up
- Best coatings are oleophobic and acid-resistant
- Sold as branded coatings (i.e. Teflon® Platinum) or unbranded
- Ingredients used in cookware/bakeware coatings have to be compliant with FDA regulations (21 CFR 175.300)
- Many choices for the consumer depending on how they cook
Bakeware

• Made of carbon steel, aluminum, glass or silicone elastomer
• Consumer bakeware coated with non-stick silicone
• Industrial bakeware coated with non-stick fluoropolymer
• Glass bakeware is usually uncoated
Top of Range (TOR) Cookware

• Made of aluminum, hard-anodized aluminum, stainless steel or clad (Al core/SS cladding)
• Stainless steel and clad tends to be uncoated
• Aluminum is always coated with a non-stick interior coating
• Hard-anodized can be uncoated or coated
• Exterior can have an optional coating for scratch-resistance or color
Types of Cookware coatings

• Seasoned metal
  – Cast iron skillets, carbon steel woks

• Porcelain
  – Old ceramic coatings, TOR exteriors, broilers and grills

• Silicone
  – Most consumer bakeware, some TOR cookware, rice cookers

• Fluoropolymer
  – TOR cookware, industrial bakeware and high-end rice cookers

• Ceramic/Sol-gel
  – TOR cookware marketed as “green” alternative to PTFE-based coatings
Materials Used in Cookware/Bakeware Coatings

• Materials used in coatings must have high use temperatures
  – Silicone, fluoropolymer, polyimide, ceramic, pigments

• Maximum oven temperature 500˚F (250˚C)

• Maximum stove top temperatures
  – Gas: 428˚F (220˚C)
  – Induction: 666˚F (352˚C)
  – Electric: 742˚F (394˚C)

• Food/water in the pan reduces temperature of cookware and the cookware coating
Cookware and Bakeware Coating Systems

- Formulated as solvent or water-based paint
- Usually 2-coat or 3-coat systems
- Primers typically are silicone or polyamide imides
- Topcoats are typically fluoropolymer and silicone
- Pigments and fillers added to primers and midcoats for scratch and abrasion resistance
- Applied between 1-1.5 mil (25-38 μm) and baked at high temperatures
  - 500-550°F for silicone coatings
  - 800°F for PTFE/fluoropolymer coatings
Application of Coatings

• Non-stick coatings are applied using printing and spray processes
• Coil coating process is mainly used for bakeware

Types of Testing Used in Cookware Coatings

• Adhesion

• Durability
  – Abrasion and scratch resistance
  – Dishwasher cycles

• Real time cooking and baking
  – Egg release
  – Cake/cookie release

• Accelerated failure testing
Seasoned Metal

- Probably discovered 2000 years ago with cast iron use in China
- Used now in cast iron skillets and carbon steel woks
- Provides a great easy clean, non-stick coating
- Non-stick surface is thought to be formed by oxidation and degradation of cooking oil and fats
- Seasoning must be reapplied to keep surface non-stick
  - Little consensus on best oil and temperatures for seasoning
- High acidic foods and the dishwasher can strip the seasoning
Porcelain

- True ceramic coating
- Used on aluminum and steel
- Very high temperature resistance
  - Ceramic is fired at 1200 – 1400 °C
- Benefit – high temperature resistance
- Has poor non-stick properties
- Color palette limited to high temperature pigments
- Mainly used in frying pan exteriors and on grill grates
Silicone Coatings

• First use was as baking mats in France in the 1980’s by Silpat
• Used mainly on bakeware due to high temperature resistance of silicone 675°F (360°C)
• Coatings use methyl phenyl siloxane
• Silicone rubber used in flexible bakeware
• Benefit – good non-stick for baking goods but will lose non-stick over time
  – Silicones are hydrophobic but not oleophobic
• Clear, colorless coatings allow wide array of colors

Structure of a silicone resin (Tego)
Fluoropolymer Coatings

• Developed by DuPont in 1951 for industrial bakeware
• Tefal developed use on TOR cookware in 1954
• Coatings use PTFE (polytetrafluoroethylene) dispersion
  – PFOA (C8) was a surfactant/soap used in the manufacture of PTFE
• Benefit – coating is oleophobic, hydrophobic and chemically inert
• Excellent non-stick and easy-clean properties
• Limited colors due to primer and bake temperature
Perfluorooctoate (PFOA)

- 2000: 3M announced removal of PFOS (perfluorosulfonate) products and phased out PFOA production
  - PFOS found to have adverse effects in animal studies and elevated levels in worker’s blood (C&EN May 29, 2000)
- 2006: PFOA Stewardship Program formed at request of EPA to provide baseline tox testing and eliminate use by 2015
- Human heath effects from PFOA (from EPA 2014 draft report)
  - Positive association in high exposure populations with testicular, kidney, ovarian and prostate cancer and non-Hodgkin’s lymphoma
  - Neutral or negative association for other exposure categories

References: EPA and American Cancer Society
Fluoropolymer Cookware Concerns

• Teflon is toxic
  – PTFE coating is inert but can decompose at high temperatures
    • Some deterioration above 500°F (260°C)
    • Significant decomposition above 660°F (349°C)
  – Typical cooking temperatures are less due to oil, water and food in pan
    – PTFE cookware should not be overheated

<table>
<thead>
<tr>
<th>Oil</th>
<th>Smoke Point</th>
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</thead>
<tbody>
<tr>
<td>EV Olive Oil and Butter</td>
<td>320°F</td>
</tr>
<tr>
<td>Canola Oil</td>
<td>400°F</td>
</tr>
<tr>
<td>Peanut Oil</td>
<td>450°F</td>
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</table>
Fluoropolymer Cookware Concerns

• Coating has come off of my cookware, should I throw it away?
  – PTFE is chemically inert. Primers, pigments and filler are FDA compliant
  – Replace cookware when non-stick benefit is lost

• The non-stick pans may expose my family to PFOA
  – Ammonium PFOA sublimes at 266°F (130°C)
  – PTFE cookware is typically baked at 800°F (427°C)
  – DuPont tested commercial Teflon-branded cookware
    • No PFOA observed at detection limits of 0.1 ppb
  – 2014 EPA Progress Report shows most PTFE manufactures have reduced or eliminated use of PFOA

Ceramic/Sol-Gel Coatings

- Developed due to consumer concerns of PFOA and PTFE
- Coating is mainly organosilica/silicone formed using sol-gel
- Silicone oil is added to surface to provide non-stick feel
- Benefit - coating is very scratch-resistant
- Non-stick surface similar to silicone bakeware
- Does not provide long-term easy-clean, non-stick properties
- Same color palette as in silicone bakeware
Sol-Gel Process and Chemistry

- Developed as a process to make metal oxides at low temperatures
- In cookware coatings, blends of Si(OEt)$_4$ and MeSi(OMe)$_3$ are used to increase durability and provide non-stick


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Performance of Ceramic Coatings vs. Teflon®

- Results of a 2008 DuPont study on simulated equivalent nonstick cooking life
- One pan made with Teflon® nonstick lasts longer than 9 pans coated with sol-gel ceramic or silicone

Ref: DuPont Media Center
New Coatings Innovations

- Superhydrophobic coatings
- Smart Materials
- Green solvents
- Optical coatings
Superhydrophobic Surfaces

- Rough surface causes water to bead – “Lotus effect”
- Benefit is never wet and self cleaning
- Ongoing research on superoleophobic surfaces to repel oil
- Durability is critical issue for commercial applications
- Self cleaning challenge is to repel environmental grime

How to Purchase Quality Cookware

• Decide on your use and what benefit is important
  – *Non-stick coating or non-coated metal*

• Stick with a reputable cookware and coating brand

• Heavy is better than light
  – *Thicker metal is better (~ 1/8” or 10 gauge)*
  – “A proper sauté pan should cause serious head injury if brought down hard against someone’s skull” Anthony Bourdain

• Riveted handles with silicone grip
“A nonstick sauté pan is a thing of beauty”
Anthony Bourdain