Anticipating Change in the Future of Coatings and Materials

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Summary

- Drivers for change
  - Cost
  - Performance
  - Environmental
- The future of regulations
- The future of coatings
- From headache to opportunity
Drivers for new materials and coatings

- Performance
- Cost
- Compliance
Driver – Performance

- Fuel/energy efficiency
  - In automotive, more efficient engines, lower weight
    - Hybrids, electrics, ignition control
    - More use of plastics, Al, Mg
  - In aerospace, more efficient engines, lower weight
    - Geared turbofans, composite fan blades
    - More use of C–fiber composites, Ti, composite connectors
  - In electrical, more power in a small space
    - More use of high–power flux rare earth magnets for motors and generators
    - Electronic controls
Driver – Cost

Cost

- All industries (including aerospace and defense) looking for reduced cost
  - Up-front purchase cost
    - Governed by material, labor, transportation, etc.
    - Favors lower cost materials, but also lower weight (less materials usage)
  - Lifetime cost of ownership
    - Often governed by fuel efficiency
    - Maintenance cost

The real cost of an aircraft is not its billion-dollar purchase price, but its fuel efficiency and maintenance cost per passenger mile; which is why airlines park MD-80s in the desert, and buy B-787s
Driver – Regulatory Compliance

- Recently regulatory compliance has become
  - A major up-front driver for design/redesign
  - An increasingly serious materials cost
  - A major compliance cost, for both manufacturing and sales
    - Compliance cost may continue throughout life, even to disposal
- Customer demand for compliance
  - Customers increasingly demand compliance with local regulations
  - Ease of compliance throughout product life, primarily by avoiding problem materials
The future of regulations on Materials and Coatings
Regulations

There are two basic types of regulation that affect your choice of materials for products:

- Regulation of emissions to the workplace or the environment – impacts production by country
  - Chemicals in the workplace
  - Air emissions, solid/liquid waste to the environment
- Regulation of materials – impacts products worldwide
  - In the final product
  - In the manufacturing process
  - Permitted for import or use
Regulations adopted in one country tend to be adopted in others, usually with local flavor
  - The “California effect”
  - Often little regard for feasibility or economic impact
    - Regulators/legislators seldom understand industrial production and supply chains
    - Lower permitted limits often driven by lower detection limits rather than by actual health risk
      - If you can detect it, it must be bad, e.g. Cr6+ in drinking water

Regulations increasingly based on Precautionary Principle
  - Explicitly in Europe, implicitly in US
  - Manufacturer must prove safe before use, not government prove unsafe once in market
  - Mere presence of a substance is bad, whether in products or processes – no link to science or risk
Regulations are going global, but there are no Global Regulations. So your local regulations control air emissions, worker safety, allowed materials; but the regulations on materials in your markets control what you are allowed to export, while the regulations in your supply chain countries determine what you are able to import. And they are probably all different.
International impact of regulations

- Even without diffusion, regs in one country affect others
  - Determine what can be made or imported (eg ELV)
  - Requirement in one major market can enforce compliance in all markets (e.g. RoHS led to non-lead solder)
    - Eliminating in one market reduces market size, leading to loss of materials in all markets (e.g. REACH)
    - Restricting substance in EU increases liability risk in US
Example: Impact of European regulations

- We have all become very painfully aware of European regulations
  - Earlier ELV, WEEE; more recently RoHS, REACH
  - RoHS (and recent RoHS recast)
    - Restricts Cd, Cr\(^6\), Pb, Hg, fluorinated flame retardants
    - Major impact in solder, Zn plate finishing, PCBs
  - REACH
    - All substances must be registered
    - SVHCs ultimately subject to restriction or authorization
    - Far less severe requirements for substances in articles (materials and coatings on imports)
    - Leading to loss of chemicals from market
    - Will reduce innovation because of market entry cost and requirement for registration (effectively government permission) for new materials (e.g. nanomaterials)
Classifying more and more chemicals as SVHCs

- Chemicals drop from market as soon as put forward as SVHCs
- Many chemicals will no longer be sold as not worth the cost/risk of registration, even at 1,000 tonne/yr level
  - Many more will be lost as go to one tonne level

<table>
<thead>
<tr>
<th>Chemical</th>
<th>%</th>
<th>Brian Norton, SUR/FIN 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy Resin</td>
<td>31.30</td>
<td></td>
</tr>
<tr>
<td>Strontium Chromate Pigment</td>
<td>20.00</td>
<td>At Risk: SVHC Listing</td>
</tr>
<tr>
<td>Other Colour Pigments</td>
<td>3.38</td>
<td></td>
</tr>
<tr>
<td>Anti-Settlement Agent</td>
<td>1.17</td>
<td>At Risk: Volume/Cost</td>
</tr>
<tr>
<td>Dispersing Agent</td>
<td>0.50</td>
<td>At Risk: Volume/Cost</td>
</tr>
<tr>
<td>Extender</td>
<td>17.30</td>
<td></td>
</tr>
<tr>
<td>Aromatic Hydrocarbon</td>
<td>15.85</td>
<td>At Risk: Solvent Emissions</td>
</tr>
<tr>
<td>Esters</td>
<td>10.50</td>
<td>At Risk: Solvent Emissions</td>
</tr>
</tbody>
</table>

Even completely benign chemicals are being lost from the market as a result of REACH
Other countries

- Canada, Korea, Japan, China
- Regulations often patterned on European (esp RoHS), but not identical
- Increasing moves to adopt REACH–like regs
- None as far reaching for US companies as European regulations
Impact of US regulations – emissions

- **OSHA**
  - Increasingly aggressive workplace compliance – mostly not materials-related

- **EPA**
  - Planning MACT for Cr\textsuperscript{6+} stack emissions
  - PFOS elimination for chromate processes
  - Drinking water standards for chromates

- Increasing environmental pressure from other sources
  - [12th Report on Carcinogens](#) – WC–Co probable carcinogen
  - ACGIH – developing Ni and Co Hazard Guidelines
Impact of US regulations – Materials

- Feb 2009 CPSC **Rules for Pb in toys**
  - Loss of non-haz products from market, including books
  - Example of consequences of materials regulations
- HR 2420 Environmental Design of Electrical Equipment Act
  - in Committee
  - Essentially US version of RoHS
- TSCA Reform – Safe Chemicals Act of 2011, S847
  - Prioritization, restriction similar to REACH
- **CA Green Chemistry Initiative**
  - Very REACH–like
- Growth of REACH–like regulations that do not base regulations on risk
The Future of Coatings – Drivers for new materials and coatings
Roadmap for Coatings

Summary of coatings and drivers

<table>
<thead>
<tr>
<th>Goals</th>
<th>Routes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting ESCH regulatory requirements</td>
<td>Compliance with REACH, RoHS, OSHA, DoD, customer requirements</td>
</tr>
<tr>
<td>Fuel efficiency – next GTEs and diesels</td>
<td>Lighter materials, higher operating temperatures, emission and noise reductions</td>
</tr>
<tr>
<td>Fuel efficiency – lighter materials</td>
<td>Improved manufacture and performance of composites, light alloys</td>
</tr>
<tr>
<td>Cost of ownership – materials performance</td>
<td>Lower susceptibility to damage and corrosion</td>
</tr>
<tr>
<td>Cost of ownership – overhaul and repair</td>
<td>Easier, cheaper, faster repair, reclamation</td>
</tr>
<tr>
<td>Underlying issues – Testing, IT and databases, modeling, design</td>
<td>Improve data, testing methods, and modeling of the underlying science of coating processes to improve prediction, reduce time and cost to reach implementation</td>
</tr>
<tr>
<td>Other Issues</td>
<td>Development of specialized coatings</td>
</tr>
</tbody>
</table>

Regulations

Efficient performance

Price and cost of ownership

NASF, Industry Canada Coatings Roadmap for Aerospace and Defense
Future – Coating and material cost

- Users always say they want minimum cost of ownership
  - But users always buy based on purchase price
- However we are seeing a shift toward minimizing energy cost (cost of ownership)
- Evident in aerospace, limited movement in automotive and equipment
- Automotive always want durable “cool finishes”
- Coatings can provide better performance, low maintenance, durable finishes
  - But, most new coatings cost more than the old standbys
  - So, what are people willing to pay for?
Where people will pay to reduce cost – better performance reduces cost of ownership

- Plastics and composites – polymer weight, metal wear
  - Wear and erosion resistant coatings
    - Electroless strike + electroplate
    - Metal and ceramic-filled polymers
- Paints – people will pay for durability
  - Powder and e-coat to reduce corrosion, flaking, abrasion
- Light metals (Al, Mg) – low weight, low wear/corrosion
  - Better anodizing, harder, thicker layers (especially for Mg)
  - Growing use of plasma electrolytic oxidation
- Decorative – PVD “lifetime coatings” on plumbing and door hardware well-established
  - Wider array of colors needed (different nitrides, carbides)

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Future – Performance

- Erosion/abrasion
  - PVD nitride composite coatings for metals
  - Urethanes for rotors, fans, pump impellers
    - Sprayed on to stop sand erosion in air and water
    - Same coatings used for pickup truck beds
- Increasing use of composite coatings
  - Electroless Ni/PTFE (/SiC /diamond)
    - Wear surfaces, internals, elec. connectors
  - Zn and Al–filled polymers and ceramics
    - Corrosion resistant fasteners
  - Paints filled with glass, metal, etc
    - Abrasion and durability
  - Erosion/cavitation resistance for ships – glass-filled vinyl ester, Ecospeed
Future – Regulatory compliance

- Corrosion control coatings are especially affected
  - Chromate conversion (of Zn, Al) not allowed under RoHS
    - Cr\(^{6+}\) being replaced by Cr\(^{3+}\), Co, Mn, Zr, Mo, Pr, Y, Ce
      - Cr\(^{3+}\) quite effective, widely used, but temporary option (Cr\(^{3+}\) and Cr\(^{6+}\) maintain a pH-dependent equilibrium in solution)
      - Most of the rest considered suspect as well, with restrictions likely eventually
  - Cd plate restricted by RoHS, REACH
  - Even Zn plate frowned upon in Scandinavia
    - Zn\(_{16}\)Ni replacing Cd, Zn, Zn\(_{8}\)Ni (but see above!)
    - Also electroplated Al (but non-aqueous)
    - Latest development for electroplating – Ionic Liquids
  - Ni plate next against the wall – most Ni salts REACH SVHCs

Legg’s Law: “Any material active enough for corrosion control will be a health and environmental hazard”
People are getting around metal corrosion and SVHCs for protection by using polymers and composites
- There will be a need for more coatings for polymers
  - Need abrasion, erosion, impact, wear coatings
  - Coatings to inhibit fluid damage
- “Full metal jacket” for polymers/composites electroless + electroplated Ni, etc.
  - Provides additional rigidity for structural applications
New materials and coatings create new design challenges – new computational methods

- New materials = many more materials combinations = more opportunities for galvanic corrosion
  - E.g. C-fiber composite + Al airframe = galvanic corrosion
  - E.g. Electroless Ni vs Al

Computational methods to predict galvanic corrosion in design stage
- Pumps
- Valves
- Fasteners
- Water heaters

Elsyca
Chemical regulated

Supplier thinks chemical will be regulated

Supplier reformulates product

Supplier informs Emerson

Production/product problems

Search for substitute

Release new product design

Modify product/process

Test substitute

Product failures, recalls, warranty claims, damage to reputation
Customer demand for “clean products” to keep them compliant
Minimize cost/time from unexpected changes, redesigns
Constant changes – Do not pass GO, do not collect $200
Intended to give you a way to anticipate changes, and deal with the ones you could not anticipate
Headache to opportunity

- We will increasingly see loss or change in manufacturing chemicals
- How can we anticipate?
- How can we judge the impact?
- How can we accommodate the change?
- Create opportunity for Emerson “green” products in market
  - But remember, “green” has to work!
Reacting to change

Anticipate change

Material loss identified

Is it real?

Does it matter?

Analyze impact

Identify best alternative

Test, qualify alternative

Bring to production

Anticipate change

Material loss identified

Is it real?

Does it matter?

Analyze impact

Identify best alternative

Test, qualify alternative

Bring to production

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Anticipating change

- Be aware of what product is made of
- Lists
  - 67/548/EEC, List of Lists, SIN
  - REACH Annex XIV Candidates
  - Suppliers
- Similarity to existing SVHCs
- Granta MI Database (now includes Coatings)
  (Dan Williams, Granta, Tue aft)
  - Includes ESOH data on constituents
  - Both in coating and process
  - Same for bulk materials

Granta EH&S Table for a trivalent conversion

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Does it matter?

- Our supplier told us he will no longer use Chemical X

  - Is it in our product?
    - Do we use it to make our product?
      - Is it in bought-in parts?
        - Is it part of the supplier’s process?
          - NO
            - Not our problem
          - YES
            - Assess impact
Analyzing the impact

Where is the impact?

Supply chain impact
Production impact
Performance impact
Business/cost impact

How big?

Criticality

Impact

Slight     Moderate     Large

High

Medium

Low
Identifying the best alternative

- Unless it is obvious recommend consulting Emerson Advanced Design Center, or ask an expert
  - Info on materials can be found on Granta MI Database
  - Also on [www.asetdefense.org](http://www.asetdefense.org) Database
- There are various options depending on how serious the problem is and how much the effort is worth

1. Find new supplier
2. Find substitute
3. Modify process
4. Modify product
5. Drop product
6. Drop market
Summary

- A combination of customer demand and environmental regulation is creating major changes in materials and coatings
- Design is becoming much more challenging and if we merely react we will have to constantly redesign
  - There is engineering and ESOH data available to help
  - There are new computational methods to avoid mistakes
- So, we need to anticipate the changes, and wherever possible turn them from headaches to opportunities

The world is changed.
I feel it in the water.
I feel it in the earth.
I smell it in the air.