NS³ Multiple Source Plasma Apparatus

AIMCAL Fall Conference
October 2006
Nano Matrix Thin Films
• Nano-composite thin film deposition process that incorporates metals, plastics or other materials into a silicon dioxide (or similar ceramic) matrix
  – Advantages over current/competing technologies
    • Single source technology applicable for flat and 3D objects
    • Incorporation of metals and plastics into composite structures
    • Modular design – readily scalable
    • Achieves the properties of both materials in single thin film examples are:
      – Teflon and SiO2
      – Lithium and SiO2
      – Polyethylene and SiO2
      – Aluminum and SiO2
• Nanoporous structures that can absorb liquids
Chemistry Examples

- We use one of 2 organosilicones to form the silicon dioxide (note these materials are decomposed by the activated Argon from the hollow cathode tip):

  - Hexamethyldisiloxane:
    \[
    \text{CH}_3 \quad \text{CH}_3 \\
    \text{H}_3\text{C} -- \text{Si} - \text{O} - \text{Si} \quad \text{CH}_3 \quad \text{CH}_3
    \]

  - 1,1,3,3-tetramethyldisiloxane:
    \[
    \text{CH}_3 \quad \text{CH}_3 \\
    \text{H} -- \text{Si} - \text{O} - \text{Si} -- \text{H} \\
    \text{CH}_3 \quad \text{CH}_3
    \]
Specific Examples

Lithium Battery

- Lipon is a desirable material in the construction of lithium batteries; unfortunately, deposition rate is very low (<4 Å/second – note thicknesses of >2000Å are required)
- Furthermore, if a high rate material could be developed that provided ionic conductivity and gas and water vapor barrier properties, an excellent passivation layer could be used on lithium metal (as well as use as a possible electrolyte)
- Ns3 developed the following:
  1. Utilizing Multiple Source Apparatus (US#6,177,142) and Alcoa 2195-OM as insert
  2. Use source to force Li+ out of alloy into plasma where it is incorporated in SiO2
  3. Ionically conductive, forming a lithiated silicate (per ESCA analysis).
  4. High Rate > 60Å/second
Specific Examples (con’t.)

Teflon™ Doped Dioxide

• Display and similar applications desire the COF and wetting characteristics of PTFE or similar fluropolymers without the optical and chemical (adhesion) issues
• Ns3 developed the following:
  1. Utilizing Multiple Source Apparatus and PTFE as insert
  2. Use source to force decompose the PTFE into plasma where it is incorporated in SiO2
  3. High contact angle to water (106 degrees)
  4. Thin – little to no optical impact on substrate
  5. High Rate > 60Å/second
Specific Examples (con’t.)

Teflon™ Doped Dioxide

[Graphs and charts depicting Teflon™ and other materials]
Specific Examples *(con’t.)*

Polyethylene Nano-Sponge

- Adsorbing very small volumes of liquids is desirable in the medical and chemical industries
- Furthermore, FTIR or similar infra-red analysis is useful for determining structure and composition
- Ns3 developed the following:
  1. Utilizing Multiple Source Apparatus and HDPE as insert
  2. Use source to force decompose the HDPE into plasma where it is deposited as a pure polyethylene film
  3. Pressure can be used (higher pressures) for force gas phase growth resulting in a porous structure
  4. High Rate > 60Å/second
Specific Examples (con’t.)

Polyethylene Nano-Sponge
Specific Examples (con’t.)

Polyethylene Nano-Sponge
Current application
NS3 Glass coated 96-Well plates

Currently being marketed and sold by:

- SUN – SRI (Plate+™ Glass Coated Microplates)
Features/Benefits

*NS3 Technology/Process*

- Thin film coatings that can be coated onto 3D shapes or Web
- Composite structures that can be tailored to specific properties
- Low or High temperature process (can coat polymeric materials, for example)
- Can achieve very high temperatures at insert location (>400 oC)
- Thickness down to 50 Angstrom
- Transparent or pigmented
- Smooth, Rough or Porous file surfaces
- Little or no material waste
- Relatively low process cost
- Multiple sources
<table>
<thead>
<tr>
<th>Matrix (Base)</th>
<th>Insert</th>
<th>Resulting Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organosilicon</td>
<td>PTFE (or similar)</td>
<td>Silicon dioxide with low COF also hydroscopic</td>
</tr>
<tr>
<td>None</td>
<td>PTFE (or similar)</td>
<td>Fluorine polymer film (similar to insert material)</td>
</tr>
<tr>
<td>Organosilicon</td>
<td>PE or PP</td>
<td>Silicon dioxide with porous structure (ablate the polymer at high temp cure</td>
</tr>
<tr>
<td>None</td>
<td>PE or PP</td>
<td>Low index of refraction coating</td>
</tr>
<tr>
<td>Organosilicon</td>
<td>Li doped Aluminum</td>
<td>Lithiated silicon dioxide</td>
</tr>
<tr>
<td>Organosilicon</td>
<td>Metal</td>
<td>Metal doped silicon dioxide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colored coatings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catalytic coatings</td>
</tr>
<tr>
<td>Methanol</td>
<td>Carbon</td>
<td>Carbon coatings – Nano tubes?</td>
</tr>
</tbody>
</table>
Potential Markets

- **Powder Coatings**: Coating powders with thin film materials that could enhance it’s catalytic interaction, interaction with water, etc.
- **Powder Formation**: If we run the source at high enough pressures, we can make powders with nano dimensions
- **Implants**: Coating of implants with non-active coatings to reduce interactions within the body
- **Batteries**: See Lithium/SiO2 example above
- **Displays**: See Teflon/SiO2 example above
- **Membranes/Fuel Cells**: thickness, material, porosity control for selective ion/solid passage
- **Composites**: Through either powder formation and/or coating of fiber materials
- **Aerospace**: Coatings tailored to specific properties by combining materials that cannot be produced otherwise
- **Corrosion/solvent/chemical resistance
- **Hydrophilic/Hydrophobic
- **High volume research and assay tools and equipment**: Microfluidics, electrophoresis, etc.
Related Patents

• The following are the patent portfolio currently available for licensing:
  – US #6,180,185 – Method of Forming a Film on a Substrate. J. Felts, Jan. 30, 2001
  – US #6,539,890 – Multiple Source Deposition Apparatus. April 1, 2003
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