The use of nano-scale Cirrus Dopant™ to Improve Existing Coatings
Agenda

• Nano-composite coatings & Cirrus Dopant™

• Dopant Science - how it works

• Use of Cirrus Dopant™ in different coatings
Innovation

Nano-composite Coatings & Cirrus Dopant™
Properties of Nano-composite Coatings

- Multiphase solid material
- 25 -100 nm secondary particles
- Superior properties especially in term of mechanical properties
• Electroplating process
• Issues:
  • Agglomeration & inconsistencies
  • Physical handling of nano-particles

Ni-TiO$_2$ (25 nm powder mixing)

10$\mu$m
Cirrus Dopant™

- Liquid to liquid – forms sub 20nm particles which do not agglomerate
- Designed to be stable and highly dispersed in the bath
- Safe to handle
Unlike powder mixing, Cirrus Dopant™ can create an even dispersion of sub 20nm particles throughout the coating.
Dopant Science

How does Cirrus Dopant™ Work?
1. In-situ generation of nanoparticles, stabilised by hydrate metal ions

2. Transported by convection diffusion and electrophoreses

3. Adsorbed onto the freshly deposited surface as metal ions reduce Cirrus Dopant™ in the plating bath
Cirrus Dopant™ Ti particles in Ag coating

- Uniformly distributed nano scale particles <20nm
- Particles at grain boundaries
- Amorphous particle structure
Ti doped NiP coatings

**Strengthening Mechanism**

- **No Dopant**
- **Optimum Dopant**
- **Too Much Dopant**

- **Substrate**

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**Ti dopant**

**Voids**

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**CIRRUS MATERIALS SCIENCE**
Negligible Impact on Coating Conductivity

**Change in hardness VS resistance – 22k Au**

- **Au**: Hardness (GPa) 2.5, Electrical Resistivity ($\times 10^{-5}$ Ω·cm)
- **Ti doped Au**: Hardness (GPa) 3.0, Electrical Resistivity ($\times 10^{-5}$ Ω·cm)
- **Zr doped Au**: Hardness (GPa) 2.7, Electrical Resistivity ($\times 10^{-5}$ Ω·cm)

**Change in scratch VS resistance – 22k Au**

- **Au**: Scratch normal displacement (nm) 60, Electrical Resistivity ($\times 10^{-5}$ Ω·cm)
- **Ti doped Au**: Scratch normal displacement (nm) 30, Electrical Resistivity ($\times 10^{-5}$ Ω·cm)
- **Zr doped Au**: Scratch normal displacement (nm) 30, Electrical Resistivity ($\times 10^{-5}$ Ω·cm)
Applications

The use of Cirrus Dopant™ in different coatings.
Nickel Boron versus Cirrus Ti doped nano-composite Nickel Boron on Mild Steel.

Hardness Improvement

- Ti doped NiB: More than 60% increase
- NiB coating: More than 550HV
- Adding Boron reducing agent: More than 30% increase
- Around 910HV
- Ti doped NiB coating
- Ni coating: Below 400HV
- Adding Ti dopant
Wear Test – Al$_2$O$_3$ ball on Cu coating

(a) No Dopant
(b) Optimum Dopant
(c) Too much Dopant

Wear Volume Loss ($\times 10^{-3}$ mm$^3$)

- No Dopant
- Optimum Dopant
- Too Much Dopant
Reduction in Stress and Porosity

(a) Zn-Ni

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<tr>
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<th>Corrosion Potential (mv)</th>
<th>Corrosion Current Density (µA/cm²)</th>
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<td>ZnNi</td>
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<tr>
<td>Al doped ZnNi</td>
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Cirrus Dopant™ - Applicability

**Dopants**
- Aqueous
- Organic
- Inorganic
  - Ti, Zr, Al, Si, Ce, Y

**Processes**
- Electroplating
- Electroless
- Pulse Plating

**Coatings**
- Au | Ag
- Ni | NiB
- Ni-Co | NiP
- Co | CoP
- CoW | Cr
- Cu | Zn-Ni
- Sn | Sn-Zn

(pH 1 to 14)
Nano-composite coatings without handling nano-particles

Enhanced coatings from electrolytic and electroless baths

Maintains coating functionality & conductivity

Applicable to a wide variety of coatings, substrates and finishes
Thank you
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