Implementing VIBE™ to Polish Ceramic Materials and Tangent Ogives

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NASA Mirror Technology Days
Outline

• Introduction
  – VIBE technology
  – Hard ceramic materials

• Efficient material removal with VIBE
  – Compare VIBE polishing to conventional polishing CeraLumina™ PCA
  – VIBE polishing of hard ceramic materials
  – VIBE lapping

• Spherical CeraLumina PCA Concentric Dome

• Aerodynamic Infrared Dome

CeraLumina is a trademark of the CeraNova Corporation
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Introduction of VIBE into today’s CNC manufacturing process

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<th>b) CNC</th>
<th>c) CNC and VIBE</th>
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Traditional

CNC

CNC and VIBE
Comparison of mechanical properties of several IR materials

- ZnS (multispectral)
- BK-7
- FS
- Spinel
- ALON
- Sapphire
- PCA

Microhardness (GPa)
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VIBE polishes PCA 13x faster than conventional polishing

- Material removal rate comparisons made with identical polishing slurries

Surface roughness measurements made with Zygo NewView 7200, 20x Mirau, unfiltered, 10um scan length, 4 phase averages
As expected, VIBE polishing material removal rates increase with decreasing material hardness.

- Relationship similar to Lambropoulos et al. correlation between conventional lapping rates and mechanical material properties \([E/K_{C,H}]^2\).
VIBE lapping has similar correlation with material hardness

- Correlations include polycrystalline materials, single crystalline materials and amorphous glass.
  - Large gap between Spinel and NBK-7 data point – more research is needed
Although, VIBE removal mechanism is also dependent on carrier fluid chemistry

- VIBE lapping experiment with PCA showed 20% higher removal rates by adjusting the carrier fluid chemistry
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Spherical Dome Specifications

- **Convex**
  - Radius = 39.95mm
  - Irregularity = 2 fringes over 25.4mm

- **Concave**
  - Radius = 34.95 +/- 0.025mm
  - Irregularity = 2 fringes over 25.4mm

- **Overall**
  - Concentricity
    - Less than 0.025mm
  - CT = 5.001 +/- 5.026 mm
  - Cosmetics: Scratch/Dig less than 80/50

- **Material**
  - CeraLumina PCA
Optimax’s first attempt to finish PCA spherical dome

• Timeline
  – December 8th 2009
    • Started generation, created dome to near net shape
  – December 15th 2009
    • Sent dome to CeraNova for annealing
  – December 22nd 2009
    • Started processing annealed near net shape dome
  – January 8th 2010
    • Completed 1st CeraLumina Dome in 11 working days!
Optimax’s first attempt to finish PCA spherical dome

- **Convex**
  - Radius = 39.953mm (in tolerance)
  - Irregularity = 0.771 fringes over 25.4mm (in tolerance)

- **Concave**
  - Radius = 35.000mm (in tolerance)
  - Irregularity = 0.316mm over 25.4mm (in tolerance)

- **Overall**
  - Concentricity
    - Less than 4 microns! (In tolerance)
    - Measured mechanically on center and four places on the edge
  - CT = 4.959mm (17μm thin)
  - Cosmetics: Scratch/Dig less than 60/40 (in tolerance)
Optimax polished PCA spherical domes
Yield: 3 for 3
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VIBE polishing tangent ogives

- Concave ogive VIBE polishing
  - Complete

- Convex ogive VIBE polishing
  - Platform currently under construction

- VIBE polish “thicker” N-BK7 ogive
  - Estimated completion Q1 2011

- VIBE polish PCA ogive
VIBE polishing tangent ogive: concave

- Material: NBK-7
- Finished surface was within 5μm of nominal curve
Conclusion and Future work

- VIBE is an order of magnitude faster than conventional polishing methods for hard ceramic materials
- Successfully polished three PCA spherical domes
  - less than two microns concentricity
- Successfully demonstrated VIBE polishing concave tangent ogive

- Additional work to completely understand VIBE removal mechanism
- Completion of VIBE platform to polish convex portion of tangent ogive
- Expectation: completed successful completion of PCA tangent ogive by Q3 2011
Acknowledgements

- Mark Parish – CeraNova Corporation
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- John Gardner
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Optimax Systems, Inc.
Ontario, NY

INNOVATION

The Optimax VIBE process is a full-aperture, high speed, conformal polishing process incorporating high frequency and random motion to create material high removal rates on hard ceramic, glass and crystalline materials.

ACCOMPLISHMENTS

◆ Currently in year 1 of Phase II SBIR – Prototype Stage
◆ We have demonstrated VIBE has 10 – 30x higher removal rates than conventional polishing
◆ We have successfully demonstrated VIBE polishing the concave portion of an ogive
◆ We were able to produce three for three PCA concentric spherical domes

COMMERCIALIZATION

◆ Optimax VIBE™ Technology
◆ U.S Patent Number 6942554 B1
◆ Primary target applications: Optical imaging systems using hard optical ceramic and crystalline materials
◆ Optimax currently provides high precision optics to the aerospace, defense, medical and imaging markets, VIBE technology will enhance our capabilities
◆ Current customers are designing using softer materials due to high cost and long processing times associated with hard ceramic materials
◆ VIBE pre-polishing can also be utilized for any optical material to reduce the processing time associated with pre-polishing before final sub-aperture deterministic finishing processes

GOVERNMENT/SCIENCE APPLICATIONS

◆ Hard optical ceramic material applications
  ◆ Infrared aerodynamic domes
  ◆ Hemispherical and Spherical concentric domes
  ◆ Transparent Armor
  ◆ Conformal IR windows
  ◆ Infrared Lenses
◆ Cost effective polishing solution
  ◆ VIBE can be introduced to reduce cost by reducing manufacturing time
◆ Optical glass, crystal and polycrystalline applications

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Optimax polished PCA spherical domes
Yield: 3 for 3