CHARACTERIZATION OF RHENIUM OXIDES
USING ESCA

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RHENIUM AS AN ENGINEERING MATERIAL

• High Melting Point – one of the Refractory metals
• High Strength at Elevated Temperature
• Excellent Toughness at Room Temperature
• Low vapor Pressure at Melting Point
• Low Co-efficient of Thermal Expansion
• High Impact and Wear Resistance
• Compatibility with Elements such as Carbon and Platinum
• Conservation of Properties in Presence of Hydrogen, water Vapor, and Oxides of Nitrogen
• Poor Oxidation Resistance
OVERVIEW

- HISTORY
  - Rhenium as an Engineering Material
  - Testing of Rhenium Thrusters
  - Sample for Oxidation Evaluation

- EXPERIMENTAL PROCEDURE
  - Available Data
  - Data Comparison

- OXIDES OF RHENIUM

- ANALYSIS OF OXIDES
  - Spectrum from Oxides
  - Effects of Ion Sputtering

- SUMMARY OF RESULTS

- CONCLUSIONS
Test Arrangements for the Rhenium Engine
Appearance of Sample Extract on Gold Sheet
AVAILABLE DATA

<table>
<thead>
<tr>
<th>OXIDES</th>
<th>LINE POSITIONS IN ELECTRON VOLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4f7/2</td>
</tr>
<tr>
<td>Pure Re</td>
<td>40.3</td>
</tr>
<tr>
<td>Re₂O₇</td>
<td>51.6</td>
</tr>
<tr>
<td>Re O₃</td>
<td>46.7</td>
</tr>
<tr>
<td>Re O₂</td>
<td>43.5</td>
</tr>
</tbody>
</table>

Ref. – (a) Handbook of X-ray Photoelectron Spectroscopy Published by Physical Electronics Inc.
OXIDES OF RHENIUM

• As many as seven Oxides
• Three Oxides are well-known – Heptoxide (Re₂O₇), Trioxide (ReO₃), and Dioxide (ReO₂)
• Heptoxide absorbs moisture and converts to a transparent perrhinic acid with in seconds
• Heptoxide can be reduced to lower Oxides by CO or SO₂
• Trioxide can breakdown to lower oxides in vacuum
• Heptoxide can breakdown to lower oxides when heated in air above 120C

CHARACTERIZATION OF Rhenium Oxides USING ESCA

Scans From Rhenium Heptoxide
CHARACTERIZATION OF Rhenium Oxides USING ESCA

Scans From Rhenium Trioxide
CHARACTERIZATION OF RHENIUM OXIDES USING ESCA

Scans From Rhenium Dioxide
## SUMMARY OF RESULTS

<table>
<thead>
<tr>
<th>OXIDE / SAMPLE</th>
<th>POSITION OF RHENIUM LINES (eV)</th>
<th>POSITION OF OXYGEN LINE(eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SAMPLE</strong></td>
<td>Not Sputtered</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sputtered</td>
<td>48.7, 46.2, 43.7, 41.4</td>
</tr>
<tr>
<td><strong>Re₂O₇</strong></td>
<td>Not Sputtered</td>
<td>48.6, 46.2, 43.7</td>
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<tr>
<td></td>
<td>Sputtered</td>
<td>48.6, 46.2, 43.8, 41.4</td>
</tr>
<tr>
<td><strong>ReO₃</strong></td>
<td>Not Sputtered</td>
<td>49.1, 48.1, 46.8, 45.5, 44.3,</td>
</tr>
<tr>
<td></td>
<td>Sputtered</td>
<td>47.0, 45.6, 44.6, 43.1, 41.3</td>
</tr>
<tr>
<td><strong>ReO₂</strong></td>
<td>Not Sputtered</td>
<td>47.1, 44.9, 43.3, 41.0</td>
</tr>
<tr>
<td></td>
<td>Sputtered</td>
<td>46.1, 44.4, 43.2, 42.0, 40.6, 39.6</td>
</tr>
</tbody>
</table>
CONCLUSIONS

(1) From ESCA Evaluations and the Physical Characteristics it is Clear that the Test Sample Collected from Testing is Rhenium Heptoxide

(2) Ion Beam Sputtering Changes Oxidation States of Samples to Oxides of Lower Oxidation States

(3) Pure Oxides Showed other Forms of Oxides on the Surface

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