Self-Lubricating Bearing and Seal Materials for Applications to 900 °C
There are many applications in general industry as well as in the aerospace industry that would benefit from the availability of self-lubricating bearing and seal materials with temperature capabilities well beyond those of the current state of the art. Such materials would be enabling for some designs where high-temperature lubrication is critically needed and would simplify others where the high-temperature lubrication problem is currently "designed around" by cooling or other complexities. It was with the goal of developing materials for such needs that the PS/PM200 class of self-lubricating materials described in this brochure was developed by research personnel in the Surface Science Branch of the Materials Division at the Lewis Research Center. PS200 coatings and PM200 free-standing powder metallurgy composites are unique, not only for their self-lubricating capability at high temperature but, perhaps even more importantly, for that self-lubricating capability over the extremely large temperature spectrum of -160 to 900 °C (-250 to 1650 °F). The purpose of this brochure is to communicate information about these unique coatings and powder metallurgy composites to U.S. industry.

NASA funding for the development of the PS/PM200 class of materials was supplemented with support from the Heavy Duty Transport Office of the U.S. Department of Energy. This cooperation underscores the fact that these materials are intended for terrestrial as well as aerospace applications.

Harold E. Sliney
Senior Scientist
Surface Science Branch
Bearing and seal materials are needed that are self-lubricating at very high temperatures. Such materials must have lubricating capabilities well beyond those of the present oils, greases, and conventional solid lubricants.

RELEVANT APPLICATION AREAS

• Manufacturing
  — Glass-forming equipment bearings
  — Metal-working equipment bearings

• Reciprocating Engines
  — Cylinder liner coatings
  — Valve guides and seats

• Rotary Engines
  — Apex seals
  — Combustion chamber coating

• Gas Turbine Engines
  — Shaft seals
  — Variable stator vane bushings
  — Variable geometry gas path mechanisms

• Auxiliary Turbomachinery
  — Gas bearings
    Backup lubricant for start-stop
    and high-speed rubs

• Super- and Hypersonics
  — Control surface bearings and seals
  — Airframe thermal expansion joints
The PS/PM200 system is a series of self-lubricating composites with a duplex microstructure consisting of a hard carbide phase with soft noble metal and stable fluoride phases.

PS200 composites are plasma-sprayed coatings, and PM200 composites are free-standing sintered or hot isostatically pressed (HIPed) Powder Metallurgy parts.

The ratio of carbide to soft phases can be tailored depending on design requirements such as conformability and hardness.

Typical preferred weight ratios of nickel-alloy-bonded chromium carbide to silver to barium fluoride/calcium fluoride eutectic are as follows:

PS200: 80-10-10
PS212 and PM212: 70-15-15

The Concept

<table>
<thead>
<tr>
<th>COMPOSITION</th>
<th>CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>32% Ni ALLOY</td>
<td>WEAR AND OXIDATION RESISTANT METAL BONDED CARBIDE</td>
</tr>
<tr>
<td>48% Cr₃C₂</td>
<td>LOW TEMPERATURE START UP LUBRICANT WITH HIGH TEMPERATURE OXIDATION RESISTANCE</td>
</tr>
<tr>
<td>10% Ag</td>
<td>HIGH TEMPERATURE LUBRICANT</td>
</tr>
<tr>
<td>10% BaF₂/CaF₂ EUTECTIC</td>
<td></td>
</tr>
</tbody>
</table>

- LUBRICATES IN AIR, HELIUM, OR HYDROGEN TO +900 °C
These materials consist of a matrix of metal bonded chromium carbide containing dispersed silver and a eutectic of calcium fluoride and barium fluoride. The microstructure of plasma-sprayed PS212 is stratified by the application method—multiple passes with a spray torch. The powder metallurgy versions contain randomly dispersed solid lubricants.
Basic friction and wear properties were measured in atmospheres of air, hydrogen, and helium over a wide range of temperatures and sliding velocities.

Further evaluation was performed with actual mechanical components such as the PS200-lubricated journal bearing shown under test in this photograph. (One side of the furnace was briefly removed to expose the bearing for this illustration.)
6 PROPERTIES OF PM212

SUPERIOR MAXIMUM SERVICE TEMPERATURE

<table>
<thead>
<tr>
<th>Oil-lubricated bronze</th>
<th>Carbon-graphite</th>
<th>PM212</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Temperature, °C

NONGALLING AND MODERATE FRICTION TO 900 °C

Friction coefficient, $\mu$

MECHANICAL STRENGTH COMPARES FAVORABLY WITH CONVENTIONAL SLIDING BEARING MATERIALS

0.2-Percent compressive yield strength, ksi

Temperature, °C
### LINEAR THERMAL EXPANSION

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature range, °C</th>
<th>Thermal expansion coefficient, °C⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM212</td>
<td>25 to 550</td>
<td>12.2e⁻⁶</td>
</tr>
<tr>
<td></td>
<td>25 to 850</td>
<td>14.2</td>
</tr>
<tr>
<td>Bonded</td>
<td>25 to 550</td>
<td>12.2</td>
</tr>
<tr>
<td>Cr₂C₃</td>
<td>25 to 850</td>
<td>13.3</td>
</tr>
<tr>
<td>Cr₃C₂</td>
<td>25 to 900</td>
<td>28.4a</td>
</tr>
<tr>
<td>Ni</td>
<td>25 to 927</td>
<td>36.6a</td>
</tr>
<tr>
<td>Ag</td>
<td>25 to 900</td>
<td>25.8a</td>
</tr>
<tr>
<td>CaF₂</td>
<td>25 to 627</td>
<td>12.1a</td>
</tr>
<tr>
<td>BaF₂</td>
<td>25 to 577</td>
<td>18.3a</td>
</tr>
</tbody>
</table>


### THERMAL CONDUCTIVITY PARAMETERS

<table>
<thead>
<tr>
<th>Composite</th>
<th>Temperature, °C</th>
<th>Density, gm/cm³</th>
<th>Specific heat, W·sec/gm·K</th>
<th>Diffusivity, cm²/sec</th>
<th>Conductivity, W/cm·K</th>
<th>Btu·in./hr·ft²·°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sintered PM212</td>
<td>23.0</td>
<td>5.141</td>
<td>0.4780</td>
<td>0.04050</td>
<td>0.09952</td>
<td>69.01</td>
</tr>
<tr>
<td></td>
<td>100.0</td>
<td>5.111</td>
<td>0.4770</td>
<td>0.04100</td>
<td>0.10670</td>
<td>73.98</td>
</tr>
<tr>
<td></td>
<td>200.0</td>
<td>5.077</td>
<td>0.4750</td>
<td>0.04150</td>
<td>0.11320</td>
<td>78.49</td>
</tr>
<tr>
<td></td>
<td>300.0</td>
<td>5.037</td>
<td>0.4730</td>
<td>0.04200</td>
<td>0.11855</td>
<td>82.20</td>
</tr>
<tr>
<td></td>
<td>400.0</td>
<td>5.005</td>
<td>0.4720</td>
<td>0.04260</td>
<td>0.12711</td>
<td>86.13</td>
</tr>
<tr>
<td></td>
<td>500.0</td>
<td>4.972</td>
<td>0.4710</td>
<td>0.04320</td>
<td>0.13463</td>
<td>93.34</td>
</tr>
<tr>
<td></td>
<td>600.0</td>
<td>4.940</td>
<td>0.4700</td>
<td>0.04380</td>
<td>0.14222</td>
<td>102.08</td>
</tr>
<tr>
<td></td>
<td>700.0</td>
<td>4.907</td>
<td>0.4690</td>
<td>0.04450</td>
<td>0.15074</td>
<td>109.37</td>
</tr>
<tr>
<td></td>
<td>800.0</td>
<td>4.874</td>
<td>0.4680</td>
<td>0.04520</td>
<td>0.15932</td>
<td>115.69</td>
</tr>
<tr>
<td></td>
<td>900.0</td>
<td>4.840</td>
<td>0.4670</td>
<td>0.04590</td>
<td>0.16866</td>
<td>118.11</td>
</tr>
<tr>
<td>HIPed PM212</td>
<td>23.0</td>
<td>6.566</td>
<td>0.4870</td>
<td>0.04240</td>
<td>0.13558</td>
<td>94.00</td>
</tr>
<tr>
<td></td>
<td>100.0</td>
<td>6.536</td>
<td>0.4860</td>
<td>0.04240</td>
<td>0.14672</td>
<td>101.73</td>
</tr>
<tr>
<td></td>
<td>200.0</td>
<td>6.506</td>
<td>0.4850</td>
<td>0.04310</td>
<td>0.15763</td>
<td>109.29</td>
</tr>
<tr>
<td></td>
<td>300.0</td>
<td>6.476</td>
<td>0.4840</td>
<td>0.04380</td>
<td>0.16818</td>
<td>116.60</td>
</tr>
<tr>
<td></td>
<td>400.0</td>
<td>6.446</td>
<td>0.4830</td>
<td>0.04450</td>
<td>0.17999</td>
<td>124.80</td>
</tr>
<tr>
<td></td>
<td>500.0</td>
<td>6.416</td>
<td>0.4820</td>
<td>0.04520</td>
<td>0.19441</td>
<td>134.79</td>
</tr>
<tr>
<td></td>
<td>600.0</td>
<td>6.385</td>
<td>0.4810</td>
<td>0.04600</td>
<td>0.21008</td>
<td>145.66</td>
</tr>
<tr>
<td></td>
<td>700.0</td>
<td>6.355</td>
<td>0.4800</td>
<td>0.04680</td>
<td>0.22614</td>
<td>156.79</td>
</tr>
<tr>
<td></td>
<td>800.0</td>
<td>6.325</td>
<td>0.4790</td>
<td>0.04760</td>
<td>0.24171</td>
<td>167.59</td>
</tr>
<tr>
<td></td>
<td>900.0</td>
<td>6.295</td>
<td>0.4780</td>
<td>0.04860</td>
<td>0.24252</td>
<td>168.15</td>
</tr>
</tbody>
</table>
Coatings

Coatings are suitable for areas readily accessible for nearly perpendicular spraying. Some examples of PS200-coated components are illustrated.
Powder Metallurgy Parts

Powder metallurgy (PM) parts are ideal for small bore cylindrical bearings, valve stem guides, variable stator vane bushings for gas turbine machinery, plain spherical bearings, and combustion chamber liners for small engines.

![PM bushing](image)

![Control surface bearing](image)

![Valve application](image)

![HIPed bearing cage and wear test specimens](image)
Reentry Vehicle

- Rudder and elevon seals and pivot bearings

Hypersonic Aircraft

- Engine inlet ramp seals
- Engine main shaft seals and variable stator vane bushings
The concept of carbide/fluoride/silver self-lubricating composites and the general preparation methods with emphasis on plasma spraying are described in—

Issued: March 1, 1988
Inventor: Harold E. Sliney
Assignee: U.S. Government, NASA

Method for making free-standing carbide/fluoride/silver parts by metallurgy processes is described in—

Issued: July 23, 1991
Inventors: Harold E. Sliney and Christopher DellaCorte
Assignee: U.S. Government, NASA

Licensing is available. For details contact:
Office of Patent Counsel
NASA Code—LeLAW
Lewis Research Center
Cleveland, OH 44135


# PM200/PS200: Self-Lubricating Bearing and Seal Materials for Applications to 900 °C

## Abstract

This brochure is intended to inform both the technical and nontechnical reader of a new class of wear-resistant composite materials that can be prepared as coatings by the plasma spray process or as free-standing bearings by powder metallurgy processing. These new materials can be used over an exceptionally large temperature range from -100 to 900 °C. They are corrosion resistant at high temperatures in strong reducing atmospheres such as hydrogen and in oxidizing atmospheres such as air. The coating (PS200) and free-standing (PM200) variations are complimentary in their applicability. The PM composites can be readily fabricated into parts that cannot be readily plasma sprayed such as bushings and cylinders with small bore diameters and/or large length to diameter ratios. Suggested applications for PS200 coatings and PM200 parts are described.

## Key Words

- Solid lubricants
- High temperature lubricants
- Sprayed coatings
- Plasma spraying
- Powder metallurgy
- Bearings
- Self-lubricating materials
- Self-lubrication
- Metal matrix composites
- Composite materials

## Distribution Statement

Unclassified — Unlimited

Subject Category 24

## Security Classif. (of this report)

Unclassified

## Security Classif. (of this page)

Unclassified

## No. of pages

16

## Price

A03

*For sale by the National Technical Information Service, Springfield, Virginia 22161*
If you would like to receive a LOTUS spreadsheet which summarizes the properties of PM212 complete the card below and return with a formatted diskette to:

Mr. Harold E. Sliney or Dr. Christopher DellaCorte
NASA Lewis Research Center
Mail Stop 23-2
21000 Brookpark Road
Cleveland, Ohio 44135

Yes, I would like to receive the LOTUS program which summarizes the properties of PM212. Enclosed is a formatted diskette:

☐ 5¼ in. diameter
  ☐ 360 KB
  ☐ 1.2 MB
☐ 3½ in. diameter
  ☐ 760 KB
  ☐ 1.44 MB

Name: ____________________________________________
Organization: ______________________________________
Address: __________________________________________
City: _______________________________________________
State: _______________________ Zip: _______________
Country: __________________________________________