# Vacuum Handbook Appendix 1: Approved Material List

**MPEX-00-ENG-002-A1**

# MATERIAL PLASMA EXPOSURE EXPERIMENT

# (MPEX)

Prepared by

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, TN 37831-6283

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**Vacuum Handbook Appendix 1: Approved Materials List**
**for the**
**Material Plasma Exposure Experiment Project**

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**Authors(s):**

Digitally signed by Jeffrey Ulreich
Date: 2022.02.09 14:37:15 -05'00'

Jeff Ulreich, Preparer, Class 1-5 Date

Andrei Petrov

Digitally signed by Andrei Petrov
Date: 2022.02.17 20:10:55 -05'00'

Andrei Petrov, Preparer, Class 6 Date

Earle Burkhardt

Digitally signed by Earle Burkhardt
Date: 2022.11.03 11:54:08 -04'00'

Earle Burkhardt, Preparer, Class 7 Date

**Reviewer(s):**

Jonathan E Perry

Digitally signed by Jonathan E Perry
Date: 2022.11.07 09:40:45 -05'00'

Jonathan Perry, Vacuum SME Date

Digitally signed by Adam M. Aaron
Reason: signing for Rob Crowell, retired
Date: 2022.11.07 09:55:03 -05'00'

Rob Crowell, Water Chemistry SME Date

**Approver(s):**

Digitally signed by Adam M. Aaron
Date: 2022.11.07 09:55:30 -05'00'

Adam Aaron, Vacuum Systems CAM Date

LaTravia Harmon

Digitally signed by LaTravia Harmon
Date: 2022.11.07 17:37:56 -05'00'

LaTravia Harmon, QA Representative Date

Aftab Hussain

Digitally signed by Aftab Hussain
Date: 2022.11.08 08:50:20 -05'00'

Arnold Lumsdaine, MPEX Lead Engineer Date

# Vacuum Handbook Appendix 1: Approved Materials List for the Material Plasma Exposure Experiment Project

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## Change Log

| Revision History | | |
|---|---|---|
| **Revision** | **Date** | **Description of Changes** |
| 0 | 2021-01-04 | Initial issue |
| | | |

The MPEX materials list has been created to assist in the correct choice of materials to meet the scientific requirements of the facility.

MPEX materials are classified for use using the following classes:

Class 1 – Plasma Interacting - materials that interact directly with the plasma during operation

Class 2 – Near Plasma – materials that may, but generally do not directly interact with the plasma

Class 3 – UHV/HV/Plasma Facing – materials that are in UHV or HV but do not interact with the plasma

Class 4 – Rough vacuum – materials that are used in the rough vacuum system

Class 5 – Atmosphere – materials used outside of the vacuum systems

Class 6 – Wetted Demin – components with wetted surfaces in the Demineralized Water loops

Class 7 – Magnetic Field Sensitive - components used inside the influence of the magnetic field lines

Materials are approved, restricted, or prohibited for each class and category using the following qualification system.

 Material approved for usage

 Material restricted to specific use; program approval required

 Material prohibited from use

Components may fall under the limitations for us of multiple classes. For example, vacuum chambers inside of the magnets, that are water cooled, fall under Class 3, 6, and 7 limitations. Material selection must be compatible with the limitations of all classes the component falls under.

Restricted materials are application specific. Contact the MPEX Vacuum Systems Team for approval of specific uses. The Vacuum Systems Team (Section 6) will review the material for vacuum compatibility and escalate to review with program science compatibility as needed.

Many materials are approved for certain classes but may not meet the temperature or other functional requirements of a specific use. Material selection must take all application specific requirements and environmental conditions into consideration.

Materials not shown on this list are not approved for use in the MPEX vacuum system. If a material is not on the list is needed, contact the MPEX Vacuum Systems Team. The Vacuum Systems team will review for vacuum compatibility and escalate the material to the science team as necessary for approved, restricted use, or prohibited status.

| | | MPEX Environment Class | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Material Type | Material Grade | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Class 6 | Class 7 | Comments |
| Metals | | | | | | | | | |
| Austenitic Stainless Steels | 316<br>316L<br>316LN<br>316LN-ESR | ⊘ | ◆ | ★ | ★ | ★ | ★ | ★ | Class 2 restriction: for use as a vacuum barrier material only<br>Weld processes must be verified for magnetic permeability<br>NOTE: 316LN and LN-ESR are not permitted for PV use by BPVC section II D, Table 1A |
| | 310 series | ⊘ | ◆ | ★ | ★ | ★ | ★ | ★ | Higher nickel content, not susceptible to magnetic work hardening effects, good choice for non-magnetic welds |
| | 304 | ⊘ | ⊘ | ◆ | ◆ | ★ | ★ | ⊘ | Class 3 and 4 restrictions: Must be used outside of the magnetic fields (work hardened relative permeability can be as high 10) |
| | 302/303 or any sulfur added free machining grade | ⊘ | ⊘ | ⊘ | ⊘ | ★ | ⊘ | ⊘ | |
| | 321/347 | ⊘ | ⊘ | ◆ | ◆ | ★ | ★ | ⊘ | Class 3 and 4 restrictions: Must be used outside of the magnetic fields (work hardened relative permeability can be as high 10). Alloyed with Ti and Ta that act as martensite stabilizer, very likely to be |

| | | MPEX Environment Class | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Material Type | Material Grade | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Class 6 | Class 7 | Comments |
| | | | | | | | | | ferromagnetic after cold working or welding |
| | Nitronic 50<br>Nitronic 60 | ⊘ | | ★ | ★ | ★ | ★ | ★ | |
| Precipitation hardened Stainless Steel | Grade 660 (UNS S66286)<br>(A286) | ⊘ | ◆ | ★ | ★ | ★ | ★ | ★ | Class 2 restriction: for use as a vacuum barrier material only<br>High temperature, high strength, PH alloy, relative permeability 1.01 |
| Titanium | Grade 1<br>Grade 2<br>Grade 5<br>(Ti6Al4V)<br>Grade6 | | | ★ | ★ | ★ | ★ | ★ | |
| Aluminum | 1100<br>2024<br>3003<br>4043<br>5052,5083<br>6061, 6063<br>7050, 7075 | ⊘ | ⊘ | ★ | ★ | ★ | | ★ | No anodized coatings in vacuum |
| Ferritic stainless steel | 400 series<br>17-4<br>17-7 | ⊘ | ⊘ | ⊘ | ⊘ | ◆ | ⊘ | ⊘ | Not compatible with vacuum (oxidation) or magnetic fields. Must have corrosion protection for atmospheric use. Must be reviewed for magnetic field compatibility. |
| Carbon Steel | | ⊘ | ⊘ | ⊘ | ⊘ | ◆ | ⊘ | ⊘ | Not compatible with vacuum (oxidation) or magnetic fields.<br>Class 5 Restrictions: Must have corrosion protection for atmospheric use. |

| | | MPEX Environment Class | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Material Type | Material Grade | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Class 6 | Class 7 | Comments |
| | | | | | | | | | Must be reviewed for magnetic field compatibility. |
| Tungsten | Pure<br>Non-magnetic<br>Class 1<br>Class 2<br>Class 3 | ★ | ★ | ★ | ★ | ★ | | ★ | Sintered tungsten must be vacuum baked after machining and cleaning. |
| | **Magnetic**<br>Class 1-4 | ◆ | ◆ | ◆ | ◆ | ◆ | ◆ | ⊘ | Restricted to uses that do not impact magnetic field lines, requires program approval for each use |
| OFE Copper (formerly OFHC) | C10100<br>C10200 | ⊘ | ◆ | ★ | ★ | ★ | | ★ | Class 2 use restricted to gaskets and seals for vacuum barriers<br><br>Note: Copper is diamagnetic and may impact magnetic field lines |
| CuCrZr alloys | UNS C18150, C18160, C18400 | | | ★ | ★ | ★ | | ★ | High strength, High temperature, High conductivity copper |
| GLIDCOP | UNS C15725 (AL-15),<br><br>UNS C15725 (AL-25),<br><br>UNS C15760 (AL-60) | | | ★ | ★ | ★ | | ★ | High strength, High temperature, High conductivity copper. Copper mixed with Aluminum Oxide |
| CuCrNb alloys | GRCop-42<br>GRCop-84 | | | ★ | ★ | ★ | | ★ | High strength, High temperature, High conductivity copper. |
| Gold | | ⊘ | | ★ | ★ | ★ | | ★ | |

| | | MPEX Environment Class | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Material Type | Material Grade | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Class 6 | Class 7 | Comments |
| | | | | | | | | | |
| Silver | | ⊘ | | ★ | ★ | ★ | | ★ | |
| Molybdenum | | | | ★ | ★ | ★ | | ★ | |
| TiZrMo | TZM | ★ | ★ | ★ | ★ | ★ | | ★ | |
| Platinum | | | ★ | ★ | ★ | ★ | | ★ | |
| Beryllium Copper | | ⊘ | ⊘ | ★ | ★ | ★ | | ★ | |
| Aluminum Bronze | UNS 62400<br>UNS 62500<br>UNS C63200<br>(82Cu-9Al5Ni4Fe) | ⊘ | ⊘ | ★ | ★ | ★ | | ★ | |
| Tantalum | sheet | | ★ | ★ | ★ | ★ | | | |
| Silicon | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Specifically Prohibited Materials | | | | | | | | | |
| Beryllium | | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | Health prohibition of use |
| Lead | | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | Health prohibition of use |
| Selenium | | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | Program or vacuum prohibition |

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|---|---|---|---|---|---|---|---|---|---|
| Material Type | Material Grade | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Class 6 | Class 7 | Comments |
| Potassium | | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | Program or vacuum prohibition |
| Phosphorous | | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | Program or vacuum prohibition |
| Sodium | | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | Program or vacuum prohibition |
| Magnesium | | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | Program or vacuum prohibition |
| Zinc | | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | Program or vacuum prohibition |
| Cadmium | | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | ⊘ | Program or vacuum prohibition |
| | | | | | | | | | |
| | | | | | | | | | |
| Glass/Ceramics - Use only demineralized water as a coolant when machining ceramics and machinable glass as Cutting fluids will contaminate the components and render them unsuitable for vacuum service. | | | | | | | | | |
| $Al_2O_3$ | Alumina<br>Sapphire<br>Ruby | | | ★ | ★ | ★ | | ★ | |
| Borosilicate Glass | BK-7 | | | ★ | ★ | ★ | | ★ | Vacuum windows, Max working temp 350 C |
| Fused Silica | | | ★ | ★ | ★ | ★ | | ★ | Vacuum windows, Max working temp 1100 C |
| Quartz | | | ★ | ★ | ★ | ★ | | ★ | |
| Silicon Nitride | | | | ★ | ★ | ★ | | ★ | |

| | | MPEX Environment Class | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Material Type | Material Grade | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Class 6 | Class 7 | Comments |
| Silicon Carbide | | | | ★ | ★ | ★ | | ★ | |
| Tungsten Carbide | | | | ★ | ★ | ★ | | ★ | |
| Macor | | | | ★ | ★ | ★ | | ★ | |
| Boron Nitride | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Finishes and Coatings | | | | | | | | | |
| PVD (physical vapor deposition) | TiN<br>TiCN<br>TiAlN/AlTiN<br>CrN<br>ZrN | | | ★ | ★ | ★ | ★ | ★ | |
| | Magic Black<br>Fractal Black | | | ★ | ★ | ★ | | ★ | ACKTAR PVD metal oxide coatings for optical and stray light absorption in UHV environments |
| Thin Dense Chrome (TDC) | Armoloy | | | ★ | ★ | ★ | | ★ | Max working temp 1600 F |
| Thermal Spray Coatings | Tungsten | | | | | | | | |
| Nickel plating | Low phosphor electroless nickel | | | ★ | ★ | ★ | | ★ | required for gold plating components, good coating for EMI/EMP mitigation |
| Anodized coatings | | ⊘ | ⊘ | ⊘ | ⊘ | ★ | | ★ | Anodized coatings are not permitted in vacuum, are permissible for applications in atmosphere |

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|---|---|---|---|---|---|---|---|---|---|
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| Powder Coating | | ⛔ | ⛔ | ⛔ | ⛔ | ★ | | ★ | Powder coatings are preferred for carbon steel structures |
| Paint | | ⛔ | ⛔ | ⛔ | ⛔ | ◆ | | ◆ | Specific paint must be approved for use |
| | | | | | | | | | |
| Plastics | | | | | | | | | |
| Polyimide | Kapton<br>Vespel<br>Meldin | ⛔ | ⛔ | ◆ | ★ | ★ | | ★ | Class 3 restriction: Specific uses must be program approved, working temperature limitations |
| PTFE | Teflon | ⛔ | ⛔ | ◆ | ◆ | ◆ | | ★ | Specific uses must be program approved, not good in radiation environment, working temp limited |
| PEEK | | ⛔ | ⛔ | ◆ | ★ | ★ | | ★ | Class 3 restriction: Specific uses must be program approved, working temperature limitations |
| Poylamide/imide (PAI) | Torlon | ⛔ | ⛔ | ◆ | ★ | ★ | | ★ | Class 3 restriction: Specific uses must be program approved, working temperature limitations |
| | | | | | | | | | |
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| | | | | | | | | | |
| Lubricants and Greases | | | | | | | | | |
| Molybdenum Disulfide | $MoS_2$ | ⛔ | ◆ | ★ | ★ | ◆ | | ★ | Max operating temp of 1000 C<br><br>Class 5 restriction: not a good lubricant when in the presence of moisture or when oxidized |
| Tungsten Disulfide | $WS_2$ | ⛔ | ◆ | ★ | ★ | ★ | | ★ | 650 C in atm, 1315 C in vacuum |

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|---|---|---|---|---|---|---|---|---|---|
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| Apiezon Vacuum Grease | Apiezon H (High Temp) | ⊘ | ⊘ | ◆ | ◆ | ★ | | ★ | Working temp 240 C, doesn't melt, vapor pressure 1.7x10-9 torr, must have program approval |
| | Apiezon L | ⊘ | ⊘ | ◆ | ◆ | ★ | | ★ | Working temp 86 C, radiation resistant, vapor pressure 7x10-11 torr, must have program approval |
| | Apiezon 100 | ⊘ | ⊘ | ◆ | ◆ | ★ | | ★ | Working temp 86 C, contains PTFE, vapor pressure 1.7x10-9 torr, must have program approval |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Adhesives and Epoxies | | | | | | | | | |
| None approved at this time | | | | | | | | | |
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