Serving The Needs of Science and Industry Worldwide

Au service de la Science et de l’Industrie dans le monde entier

Weltweiter Lieferant für Wissenschaft und Industrie

Metals and Alloys
Métaux et Alliages
Metalle und Legierungen

Ceramics
Céramiques
Keramiken

Polymers
Polymères
Polymere

Composites
Composites
Verbundwerkstoffe
Goodfellow Corporation
125 Hookstown Grade Road
Coraopolis, PA 15108-9302 PA 15108-9302
USA
Tel: 1-800-821-2870 (USA and Canada)
or +1 724 695 7060
Fax: 1-800-283-2020 (USA and Canada)
or +1 724 695 7063

Goodfellow Cambridge Limited
Ermine Business Park
HUNTINGDON
PE29 6WR
England
Tel: 011 44 1480 424 800
or 011 44 1480 424 800
Fax: 011 44 1480 424 900
or 011 44 1480 424 900

Goodfellow SARL
229, rue Solférino
F-59000 Lille
France
Tel : 0800 917 241 (numéro vert)
or +44 1480 424 813
Fax : 0800 917 313 (numéro vert)
or +44 1480 424 900

Goodfellow GmbH
Am Alstertwiete 3
D-20099 Hamburg
Germany
Tel: 0800 1000 579 (freecall)
or +44 1480 424 810
Fax: 0800 1000 580 (freecall)
or +44 1480 424 900

Goodfellow (Shanghai) Trading Co., Ltd
Room 803, Centro Build, No. 568 Hengfeng Road
SHANGHAI
200070
The People’s Republic of China
Tel: 00 86 21 6112 1560
Standard Price List for All Sheets

## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Product Descriptions</td>
<td>5</td>
</tr>
<tr>
<td>Hazards Information</td>
<td>9</td>
</tr>
<tr>
<td>General Information</td>
<td>10</td>
</tr>
<tr>
<td>Order Information</td>
<td>11</td>
</tr>
<tr>
<td>Company Details</td>
<td>14</td>
</tr>
<tr>
<td>Conditions of Sale</td>
<td>15</td>
</tr>
<tr>
<td>Metal</td>
<td>19</td>
</tr>
<tr>
<td>Alloy</td>
<td>32</td>
</tr>
<tr>
<td>INDEX</td>
<td>36</td>
</tr>
</tbody>
</table>
Goodfellow is well known as a specialist supplier of small to medium size quantities of metals, alloys, ceramics, polymers and other materials to meet the research, development and specialist production requirements of science and industry worldwide. We realise that "small" means different things to different people, but we consider small to mean any quantity from a few grammes to a few kilos.

Goodfellow offers two distinct services to meet the requirements of our customers:

- The first meets the needs of our customers who need small quantities of products from our standard range of materials within 24-48 hours.
- The second service is for those who require larger quantities or further processing of our standard products or who need an item which falls within our general area of supply expertise.

The range of materials offered by Goodfellow is extensive, as are the forms in which the various products are available. This Catalog provides a detailed overview of our standard products which are available from stock. Full details of all of these items, including prices and technical information, can be found in our web Catalog at www.goodfellowusa.com.

Materials

Metals and Alloys
Goodfellow supplies virtually all of the pure metals from Aluminum to Zirconium as well as a comprehensive range of alloys. Most are available in a variety of forms, including rod, wire and foil. The Catalog details those materials which are available as standard products from stock. Custom-made items are also available, so please contact us if you are unable to identify the item you require.

Ceramics
The ceramic materials offered by Goodfellow have been carefully chosen and include both the established as well as more recently developed products. All are available as either standard or custom-made products in a variety of forms and sizes. The Catalog details those items which are available from stock. For ceramic components made to customer drawings, our Ceramic and Glass Division would be delighted to help. Please visit www.goodfellow-ceramics.com for further information.

Polymers
The range of polymers supplied by Goodfellow is broad and includes both the familiar as well as some of the more unusual or recently developed materials. The Catalog details those items which are available from stock; please contact us if you are unable to find the item you specifically require.

Compounds & Intermetallics
Goodfellow can supply aluminides, borides and silicides as well as other intermetallics and compounds. The majority of these items are made to order, and the Catalog details those which are available. Please contact us with details of your requirements.

Composites
Some examples of these materials are listed in the Catalog. As some of these are manufactured on a custom-made basis, please contact us with details of your requirements.

Glasses
Goodfellow offers two distinct types of glass products. The first are generally silica-based and transparent. Generally, these products are made to order for customers, so we do not list them in our Catalog, however, they are available through the Goodfellow Ceramic and Glass Division. Please contact us with your requirements.

The second type of glass product is commonly referred to as "metallic glasses" or "glassy metals". In contrast to crystalline metals and alloys with highly ordered atomic structures, these are non-crystalline (amorphous) metals or, more usually, alloys. Our Catalog details those glassy metals which are available from stock; please contact us if you are unable to find the item you specifically require.
# Product Descriptions

## Bar
A straight length of rectangular, square or oval section material.

**Tolerances**

<table>
<thead>
<tr>
<th>Section dimensions:</th>
<th>≤ 10mm</th>
<th>± 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 10mm</td>
<td>± 1%</td>
<td></td>
</tr>
<tr>
<td>Length:</td>
<td>&lt; 100mm</td>
<td>± 1mm</td>
</tr>
<tr>
<td>&gt; 100mm</td>
<td>± 5% / -1%</td>
<td></td>
</tr>
</tbody>
</table>

## Bolt
A threaded pin that can be screwed into a nut or a tapped hole to fasten items together. Bolts are available with different head styles and also in metric and inch-threaded sizes.

**Tolerances**

See item

## Chopped Fiber
Fibers cut into short lengths called cut, staple or chopped fiber.

**Tolerances**

<table>
<thead>
<tr>
<th>Fiber diameter:</th>
<th>± 25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of strands:</td>
<td>± 10%</td>
</tr>
<tr>
<td>Tex number:</td>
<td>± 10%</td>
</tr>
<tr>
<td>Length:</td>
<td>± 5% / -1%</td>
</tr>
</tbody>
</table>

## Crucible
A vessel in which other materials may be heated or melted, usually at high temperatures.

**Tolerances**

| Height: | ± 10% |
| Inside Dimensions: | ± 10% |
| Outside Dimensions: | ± 10% |

## Fabric
Woven fabrics are made by the regular interlacing of two arrays of yarns at right angles to each other, these being referred to as the warp and weft (see also Non-woven fabric).

**Tolerances**

| Fabric thickness: | ± 25% |
| Number of yarns: | ± 10% |
| Tex number: | ± 10% |
| Size (linear dimension): | < 100mm | ± 5mm |
| ≥ 100mm | ± 5% |

## Fiber
Yarns or tows consisting of several approximately parallel individual filaments, each filament usually being smaller in diameter than a monofilament. Yarns contain a defined number of filaments, typically three to several hundred; tows contain thousands of filaments whose number is only defined approximately. Both are primarily specified by their linear density measured in "tex", the weight in grams of a 1km length of material.

**Tolerances**

| Fiber diameter: | ± 25% |
| Number of strands: | ± 10% |
| Tex number: | ± 10% |
| Length: | ± 5% / -1% |

## Film
A non-metallic sheet material with a thickness < 0.5mm.

**Tolerances**

| Thickness: | ± 20% |
| Size (linear dimension): | < 100mm | ± 1mm |
| ≥ 100mm | ± 2% / -1% |

## Flake
Flat, irregularly shaped pieces of material. A maximum flake size is indicated but individual flakes may vary greatly in size.

**Tolerances**

Dimensions shown are nominal

---

Please visit [www.goodfellowusa.com](http://www.goodfellowusa.com) or email [info@goodfellowusa.com](mailto:info@goodfellowusa.com) for latest prices.
**Product Descriptions**

**Foam**
A low density, permeable structure of cells and continuous ligaments offering a high surface area to volume ratio, and also a high strength to weight ratio. Owing to the nature of this material, dimensions are nominal.

**Foil**
Thin sheets of pure metal and metal alloys. Due to their fragile nature, some foils are coated on one side with an acrylic or polyester support. Where foils are supported they are indicated in the detailed item description.

**Tolerances**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (&lt;0.010mm)</td>
<td>± 25%</td>
</tr>
<tr>
<td>0.01-0.05mm</td>
<td>± 15%</td>
</tr>
<tr>
<td>&gt;0.050mm</td>
<td>± 10%</td>
</tr>
<tr>
<td>Size (linear dimension) &lt;100mm</td>
<td>± 1mm</td>
</tr>
<tr>
<td>≥100mm</td>
<td>± 2% / -1%</td>
</tr>
</tbody>
</table>

**Granule**
Pellets of an approximately regular shape. Granules may vary in size and, therefore, the dimensions stated are nominal. In addition, the shape of a granule may vary from item to item.

**Tolerances**

Dimensions shown are nominal.

**Honeycomb**
A cellular structure similar in appearance to natural honeycomb. Owing to the nature of this material, dimensions are nominal.

**Insulated Wire**
A single or multiple flexible strand of metal or alloy with an insulating sheath.

**Tolerances**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire diameter</td>
<td>± 10%</td>
</tr>
<tr>
<td>Length</td>
<td>± 5% / -1%</td>
</tr>
<tr>
<td>Insulation thickness</td>
<td>Nominal values only</td>
</tr>
</tbody>
</table>

**Laminate**
Layers of material which have been bonded together by the use of heat, pressure and, possibly, adhesive.

**Tolerances**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>± 10%</td>
</tr>
<tr>
<td>Size (linear dimension) &lt;100mm</td>
<td>± 1mm</td>
</tr>
<tr>
<td>&gt;100mm</td>
<td>± 2% / -1%</td>
</tr>
</tbody>
</table>

**Lump**
A solid piece of material with no defined shape.

**Tolerances**

Dimensions shown are nominal.

**Mesh**
Mesh is available as either a woven wire or electroformed product; in all cases, the quoted aperture sizes are nominal. Wire mesh: a material which is woven from metal wires to provide a thin grid with a regular series of holes. Electroformed mesh: a product made by electroplating the mesh geometry through a mask onto a substrate which is subsequently etched away.

**Tolerances**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness: woven</td>
<td>± 10%</td>
</tr>
<tr>
<td></td>
<td>± 20%</td>
</tr>
<tr>
<td>Wire diameter</td>
<td>± 10%</td>
</tr>
<tr>
<td>Size (linear dimension) &lt;100mm</td>
<td>± 1mm</td>
</tr>
<tr>
<td>&gt;100mm</td>
<td>± 2% / -1%</td>
</tr>
</tbody>
</table>

**Metallized Film**
Film which is coated with a metal. The thickness of the metal is measured and described in terms of the material’s specific electrical resistance in ohms per square.

**Tolerances**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness:</td>
<td>± 10%</td>
</tr>
<tr>
<td>Size (linear dimension) &lt;100mm</td>
<td>± 1mm</td>
</tr>
<tr>
<td>≥100mm</td>
<td>± 2% / -1%</td>
</tr>
</tbody>
</table>
Microfoil
An extremely thin sheet of metal or alloy mounted on a permanent support. This support cannot be removed without destroying the Microfoil.

Tolerances
Thickness: ±30%
Size: ±20%

Microleaf
An extremely thin sheet of metal mounted on a removable support. Microleaf is not available for metals which are too brittle to be free standing.

Tolerances
Thickness: ±30%
Size: ±20%

Monofilament
A single strand of a non-metallic material.

Tolerances
Diameter: ±20%
Length: +5% / -1%

Non-Woven Fabric
Non-woven fabrics are made by methods other than weaving or knitting, the yarns and fibers being held together, often quite loosely, by means other than geometric interlacing. Due to the open and porous nature of this material, all other dimensions are nominal.

Tolerances
Size (linear dimension): <100mm ±5mm
≥100mm ±5%

Nut
Generally a flat piece of material with a threaded hole which can be screwed onto a bolt to fasten items together. Nuts typically have a hexagonal external shape. Nuts are available in metric and inch-threaded sizes.

Tolerances
See item

Powder
Small particles with an approximately defined size range. Those materials described as alloy precursors are not true alloys - they are made by sintering a blend of powders of the component metals to achieve alloying by diffusion. The resultant cake is ground and sieved to the required particle size range. Unless otherwise stated, the particle sizes shown are for guidance only. We do not guarantee either any particular size distribution between the quoted minimum and maximum sizes, or a specific particle shape.

Tolerances
Dimensions shown are nominal

Rod
A straight length of circular section material.

Tolerances
Diameter:
≤10mm ±10%
Polymer +20%/-10%
Ceramic +20%/-10%
>10mm ±5%
Ceramic +20%/-10%
Polymer +20%/-10%

Length:
<100mm ±1mm
≥100mm ±5% / -1%
### Product Descriptions

**Sheet**

Flat material with a thickness > 0.5mm.

**Tolerances**

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic</td>
<td>± 10%</td>
</tr>
<tr>
<td>Composite</td>
<td>± 20%</td>
</tr>
<tr>
<td>Polymer</td>
<td>± 20%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size (linear dimension)</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100mm</td>
<td>± 1mm</td>
</tr>
<tr>
<td>≥ 100mm</td>
<td>± 2% / -1%</td>
</tr>
</tbody>
</table>

---

**Single Crystal**

A material grown as a monocrystal, generally to a specific orientation, dimension and surface finish. It may contain a dopant. Single crystals are usually made to order.

**Tolerances**

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Tolerance</th>
<th>Size</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>± 3°</td>
<td></td>
<td>Sizes shown are nominal</td>
</tr>
</tbody>
</table>

---

**Sphere**

A regular solid or hollow three-dimensional form in which every cross-section is a circle. Spheres are available with standard or precision tolerances, and can be supplied with different surface finishes depending on the material.

**Tolerances**

<table>
<thead>
<tr>
<th>Diameter (standard)</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>± 5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diameter (precision)</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>see item</td>
</tr>
</tbody>
</table>

---

**Sputtering Target**

A high purity material used as a source for sputtering, a cold vaporization process in which atoms are physically removed from the target surface by ion bombardment.

**Tolerances**

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>± 0.5mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>± 0.5mm</td>
</tr>
</tbody>
</table>
HAZARDS

All materials listed in this catalog, whatever the quantity supplied, are sold for research or development purposes. We make no warranty that the materials are fit for a particular purpose. In purchasing materials from this catalog, customers should be aware that there may be hazards associated with their use and in the handling of them. Complete toxicological or hazard investigations are the responsibility of the customer. Ingestion or contact with the human body may be harmful. The responsibility for the safe use of our products rests with the customer. All materials should be handled by qualified personnel familiar with laboratory procedures and who are familiar with the nature of the material and any necessary precautions which should be taken in the handling, use and storage of the products. The customer shall be responsible for the control and use of the products offered in this catalog whether alone or in combination with other articles or substances or in any other manner whatsoever.

HAZARD SYMBOLS

**Corrosive**
Chemicals which may destroy living tissue when in contact with them.

**Dangerous when wet**
Chemicals which, in contact with water or damp air, evolve highly flammable or toxic gases and vapours in dangerous quantities.

**Explosive**
Chemicals which may react exothermically without atmospheric oxygen, quickly evolving gases, and which under defined test conditions detonate, quickly deflagrate or upon heating explode when partially confined.

Extremely Flammable
Chemicals which when finely divided (small particle size) are liable to ignite spontaneously.

Harmful
Chemicals which may cause death or acute or chronic damage to health when inhaled, ingested or absorbed via the skin.

Highly flammable
Chemicals which will ignite after contact with flame, or which will evolve highly flammable gases in contact with water.

Irritant
Non-corrosive chemicals which, through immediate, prolonged or repeated contact with the skin or mucous membrane may cause inflammation.

Radioactive
Chemicals which will emit ionising radiation without being subject to irradiation. General precautions for Toxic chemicals apply to those of low activity. For chemicals of medium or high activity special regulations apply.

Toxic
Chemicals which may cause death or acute or chronic damage to health when inhaled, ingested or absorbed via the skin.

Very Toxic
Chemicals which in low quantities cause death or acute or chronic damage to health when inhaled, ingested or absorbed via the skin.
Analyses

Typical Analysis:
Where appropriate a typical analysis is given. All figures are parts per million (ppm) by weight unless otherwise stated. It must be emphasised that this data is "typical" and no guarantee is given that the material supplied will conform to these analyses. The compositions shown under alloy headings are generally weight percent. Exceptions are the glassy alloys and the rare earth magnets where the convention of using atomic ratio is followed.

Purity
Purities listed are quoted with respect to total metallic impurities. Typical analyses may give additional information about likely non-metallic impurities.

High Purity
For materials described in the catalog as High Purity, the actual analysis of metallic impurities will be supplied free of charge. For other items, an actual analysis can be supplied and a charge will be made for the analysis and for the sample used.

If you require an analysis please tell us whether you require analysis of metallic impurities only or metallic and gaseous. Where an analysis is required the shipment of your order may be delayed.

Supports
Some items from our range of foils need to be supported on one side of the foil to enable both you and us to handle these very delicate materials. Two types of support can be used, the choice being governed by the material. Wherever possible we use a temporary support, a permanent support only being used when the material is brittle (for example Chromium or Manganese).

The temporary support is Acrylic, approximately 0.2mm thick. This may be removed by dissolving in 2-Propanone (Acetone).

Our permanent support is Polyester, thickness 0.125mm, which is hot-press laminated to one face of the foil. It cannot be removed without destroying the foil.

Microfoil is mounted on a permanent 3.5μm polyester support. This support cannot be removed without destroying the Microfoil.

Light Tight (LT) & Not Light Tested (NLT)
Light tight (LT) foils are supplied without visible pinholes after examination without magnification. Foils 0.025mm or more in thickness are supplied LT unless otherwise stated.

Foils less than 0.025mm thick are normally supplied Not-Light Tested (NLT), and will normally contain pinholes but may occasionally be free from pinholes. Foils less than 0.025mm in thickness can often be supplied LT but may incur additional charges. Please specify if you require LT foils.

Vacuum tight
Vacuum tight foils show no detectable leakage when tested with a helium mass spectrometer with a sensitivity of $10^{-9}$ atm-cm$^3$.s$^{-1}$.

Continuous Lengths
If you require material in continuous lengths please tell us when you place your order. Unless otherwise specified, we reserve the right to supply in more than one length.

Technical Data and Information
All information and technical data are given as a guide only. Although every effort has been made to ensure that the information is correct, no warranty is given as to its completeness or accuracy.

Tolerances
For details of our standard tolerances, please refer to the Product Description section. In many cases, closer tolerances are available but may be subject to an extra charge. If you have any special requirements it is important that you tell us at the time of ordering. This includes special tolerances, dimensional uniformity or any other special requirement which you may have (for example edge finish, packaging, labelling etc.). Please indicate precisely what is required and we shall do our best to meet your specification.
General Information
There are over 70,000 stock packs listed and if you cannot find what you need amongst them, please ask for special sizes, thicknesses, tolerances, dimensions or larger quantities. We are also able to offer many other pure metals, alloys, polymers and ceramics to special order.

Prices
All the prices listed are total (lot) prices for the sizes and quantities listed.
Prices shown are in US$ and include free delivery by our standard 48 hour service except for those items marked as "special offer" or dangerous goods with transport restriction. Prices are subject to change without notice and orders will be invoiced at prices ruling on the date of despatch.

Transport Restriction
Some of the materials supplied by Goodfellow are subject to special transport restrictions. Additional shipment charges may apply which are dependent on destination. Please check the individual item on our website or contact us for details of the charges. If you intend to have the material transported or sent onwards please ensure that you are aware of the relevant transport restrictions.

Delivery
Delivery by UPS or Federal Express is included in the prices, although alternative methods may be used depending on the materials ordered.

Split Shipment
All orders are accepted for one shipment on one date to one address. A charge will be made for split shipments made at the customer's request.

Special Analysis, Supports or Tolerances
An extra charge is made for non-standard supports, alternative tolerances and certificates of analysis. The analysis is free of charge for items marked "High Purity".

Cancellations
A charge for cancellation of orders may be made. The amount will depend on the circumstances.

Express Service
Please inform us if you need to have your goods shipped urgently. An administrative charge will be made for this service, details can be found on our website.

Shipment
We aim to have all items listed in this catalog in stock in the quantities and sizes listed. We can only undertake to ship an order on a particular date. The date of delivery at the customer's address is subject to the normal variations of the delivery service used.

Despatch
Orders will normally be shipped within 48 hours of receipt.

Non-delivery
If we have notified you of the shipment of goods and you have not received delivery within 5 days, please contact us.

Insurance
All consignments will be insured by us against the usual risks unless we are instructed in writing to the contrary.

Export Restrictions
A UK Government export licence may be required for some items to some destinations. If the item you require needs a special export licence or an end-use statement we will inform you at the time you order.

Materials Handling
Many of our materials are extremely delicate and it is essential every care is taken when handling them. Special attention is drawn to the extreme fragility of Microfoil, Microleaf and thinner and finer materials. All materials are carefully packed to ensure safe transport of goods to your address. We do not accept responsibility for damage caused by mishandling once the outer transit packaging has been removed.

Terms of payment
Our normal terms of payment are net 30 days from date of invoice. Any alternative terms of payment are to be agreed with us in writing at the time of placing an order. Customers may be asked to pay cash with order or cash against pro-forma

Please visit www.goodfellowusa.com or email info@goodfellowusa.com for latest prices
invoice with their first order. In order to establish a credit account we will require details of your bankers, along with two trade references.

**Credit account**

We endeavour to keep our costs down and customers are requested to pay our invoices on time. We reserve the right to delay delivery if there are overdue invoices on the account. Accounts which remain unpaid beyond the due date may incur an interest charge at a rate of 2% per month.

**Credit card payments**

We also accept payment using the following credit and charge cards:

Mastercard, VISA and American Express.

**VAT**

VAT number for Goodfellow Cambridge: GB 212 8527 79

**UK**

VAT will be added to the invoice at the rate ruling at the date of invoice. Where a customer is exempt, VAT will be charged unless we receive a copy of the exemption form at the time the order is placed.

**EU**

Customers registered for VAT who provide their local registration number will not be charged UK VAT.

Customers who are exempt from VAT will not be charged UK VAT provided we are given a copy of their exemption form at the time the goods are ordered.

Customers not registered for VAT or who fail to give us their registration number will be charged UK VAT at the current rate.

**Export**

All exports to countries outside the EU are zero-rated for UK VAT unless the invoice is being paid from within the EU.

**Return of goods**

We will only accept return of goods provided we are contacted BEFORE the goods are returned. When we agree to the return we will issue a Goods Return Number and give instructions for the method of return of the goods. Goods will not be accepted for return without a valid Goods Return Number. Due to the nature of some of our materials, it is imperative that you check any possible transport restrictions with your proposed freight company.

**Claims**

Great care is taken during manufacture and packing and all items are carefully inspected before shipment. Any claim in respect of short delivery, incorrect material or defective quality must be notified to us in writing within three days of delivery. Please retain ALL packaging for our inspection. Our liability for any such claim shall not exceed the cost of replacement of the goods free of charge, or crediting the customer with the invoice value thereof.

**Goods ordered in error**

We do not accept responsibility for customers’ errors in ordering. The amount of credit for returned goods will be at our discretion. Where we accept returned goods a restocking charge will be made.

**Conditions of sale**

All orders, contracts and quotations are subject to our standard terms and conditions of sale.

Information and statements provided are indicative only and do not form part of any offer or contract.

**Exclusions**

We supply materials according to our specification. All conditions warranties and representations regarding the quality, fitness for purpose or state, size, shape, capacity or color of goods supplied whether expressed or implied by common law or statute or otherwise are hereby expressly excluded. We shall not be liable for any damage direct or consequential arising from the use of goods supplied by us however such damage is caused, nor for delay in delivery.

**Law**

Customers in the USA: Contracts between Goodfellow Corporation and the customer shall be deemed to be subject in all respects to the laws of the Commonwealth of Pennsylvania, or the United States of America.

Customers in France: Contracts between Goodfellow SARL and the customer shall be deemed to be subject in all respects to French law unless otherwise agreed in writing.
Order information

Customers in Germany: Contracts between Goodfellow GmbH and the customer shall be deemed to be subject in all respects to German law unless otherwise agreed in writing.

Customers in the UK and all other countries: Contracts between Goodfellow Cambridge Limited and the customer shall be deemed to be subject in all respects to English law unless otherwise agreed in writing.

Copies of our General Terms and Conditions are available upon request or can be downloaded from our websites at www.goodfellow.com or www.goodfellowusa.com.
Company Structure
The Goodfellow Group consists of five companies:

**Goodfellow Cambridge Limited**
Goodfellow was established in the City of London in 1946. The Company now has subsidiary operations in France, Germany and North America with the Group’s research laboratories, workshop facilities & central administration located in Huntingdon, England.

**Goodfellow Corporation**
Established at the same time as our associate company in Germany, Goodfellow Corporation was set up to service the requirements of our customers in the USA.

**Goodfellow GmbH**
Since 1989, this member of the Goodfellow group of companies has been serving the needs of our German speaking customers within Europe.

**Goodfellow SARL**
Goodfellow established an operation in France in 1993 to meet the needs of our French-speaking customers in Europe.

**Goodfellow (Shanghai) Trading Co., Ltd**
Goodfellow established a representative office in Shanghai in 2006, and in 2012 followed this with the creation of a fully-fledged trading company, servicing the research and specialist manufacturing requirements of the Chinese market.

COMPANY DETAILS

**Goodfellow Cambridge Limited**
Ermine Business Park
HUNTINGDON
PE29 6WR
England
Registered in England and Wales no. 01188162
VAT registration GB 212 8527 79

**Goodfellow Corporation**
125 Hookstown Grade Road
Coraopolis, PA 15108-9302
USA
A Pennsylvania corporation
EIN 23-2557381

**Goodfellow SARL**
229, rue Solferino
F-59000 Lille
France
Registered in Lille : RCS : B 381 486 836
Siren : 381486836
Numéro de TVA Intracommuniaire :
FR 06 381 486 836

**Goodfellow GmbH**
Am Alstertwiete 3
D-20099 Hamburg
Germany
Registered in Hamburg No. HRB 152991
Import VAT number DE112610478

**Goodfellow (Shanghai) Trading Co., Ltd**
Room 803, Centro Build, No. 568 Hengfeng Road
SHANGHAI
200070
The People’s Republic of China
1 GENERAL

1.1 In these Conditions:

1.1.1 the following expressions shall have the following meanings:-

*Buyer* the individual firm company or other party from whom an order to supply Goods and/or Services is received by the Seller.

*Conditions* the standard terms and conditions of sale of the Seller as set out herein and including any additional terms and conditions of sale agreed in writing by the Seller.

*Contract* a contract for the Supply of Goods and/or Services by the Seller to the Buyer.

*Date of Delivery* the date on which delivery of the Goods or Services takes place pursuant to Condition 7.

*Goods* the goods which the Seller is to supply (or, if relevant, a Supplier) or any part thereof. The Buyer shall not be entitled to assign the Goods or Services or any part thereof. The Buyer shall not be entitled to assign the Contract nor be regarded as a warranty or representation relating to the Goods or Services.

*Prepayment* a payment to be made by the Buyer pursuant to Condition 6.2 to be used at the Seller's discretion for the purchase of materials and/or towards the costs of labour or any other costs relating to the supply of Goods;

*Recommendations* the recommendations (if any) relating to the use of the Goods, the storage, handling, application and/or use of any other materials which make up Goods, or to the Goods, or to the manufacture of products using the Goods or Services, or to the suitability and fitness of the specification, pattern or design but also that such specification, pattern or design does not infringe any patent, trade mark, registered design, copyright or any other proprietary right of any third party and the Buyer shall indemnify and keep the Seller indemnified in full against all loss, which term shall include (but without prejudice to the generality thereof) loss of profit, costs (including the cost of labour and materials, repairs, damages, charges and expenses incurred (directly or indirectly) by the Seller as a result of such variation.

2 ORDERS

2.1 Notwithstanding that the Seller may have given a detailed quotation or estimate either verbally or in writing no order or confirmation of order shall be binding on the Seller unless and until it has been acknowledged in writing by the Seller or the Goods are delivered. The Services are provided by the Seller to the Buyer pursuant to the order.

2.2 In order to avoid duplication of orders the Buyer shall be responsible for ensuring that any confirmation of an order previously placed is prominently marked as being a confirmation and not a new order. The Buyer acknowledges that any order or confirmation of order which is not so marked may be treated and accepted by the Seller as a new order to create a Contract in addition to any Contract arising out of the previous order.

2.3 These Conditions are incorporated in the Contract and together with any matter set out in the Seller's quotation or acceptance (acknowledgement of order) contain the entire obligations between the Seller and the Buyer. In the case of any inconsistency between any letter or quotation incorporating or referring to these Conditions and any order or a contract or term or order or form of contract sent by the Buyer to the Seller, whatever may be their prominence or any confirmation of order which is not so marked may be treated and accepted by the Seller as a new order to create a Contract in addition to any Contract arising out of the previously placed order.

2.4 No variation of the Contract by the Buyer shall be binding upon the Seller unless made in Writing and signed on behalf of the Seller. In the event of such variation the Buyer shall indemnify and keep indemnified the Seller in full against all loss, which term shall include (but without prejudice to the generality thereof) loss of profit, costs (including the cost of labour and materials, repairs, damages, charges and expenses incurred (directly or indirectly) by the Seller as a result of such variation.

2.5 Any representations (except fraudulent misrepresentations) or warranties made by or on behalf of the Seller prior to the Contract (whether verbally or in writing) are hereby expressly excluded and shall be of no effect.

3 DESCRIPTION

3.1 Any figures, statements, descriptions, illustrations, photographs, drawings, weights or any other matters contained in the Seller's catalogues, pamphlets, price lists or advertising literature are not guaranteed to be accurate and are intended merely to represent a general picture of the Seller's products and shall not form part of the Contract nor be regarded as a warranty or representation relating to the Goods or Services.

3.2 The Seller reserves the right to amend the specification of its products and services from time to time so that the descriptions thereof as set out in its catalogues, pamphlets, price lists or advertising literature may not be identical with the specification set out in the Seller's quotation and the Buyer is advised to check the specification set out in the Seller's quotation before placing an order.

4 SPECIFICATIONS AND INTELLECTUAL PROPERTY

4.1 Where goods are supplied to the Buyer's own specification, or where standard goods of the Seller are altered in accordance with the Buyer's instructions the Buyer warrants and undertakes full responsibility for the suitability and fitness of the specification, pattern or design but also that such specification, pattern or design does not infringe any patent, trade mark, registered design, copyright or any other proprietary right of any third party and the Buyer shall indemnify and keep the Seller indemnified in full against all loss, which term shall include (but without prejudice to the generality thereof) fluctuations in exchange rates between monetary currencies the action of any government or any other authority or any labour problems.

5 QUOTATIONS

5.1 The Seller’s quotations are provisional in so far as they are subject to alteration by reference to any changes in the price of raw materials, any item to be acquired by the Seller from a third party, rates of wages, other costs of production and any other circumstances beyond the Seller’s control taking place between the date of the quotation and the Buyer’s placing of an order in respect thereof.

6 PRICE

6.1 The Seller shall be entitled to adjust the Contract price of the Goods or Services whether before or after the making of the Contract in the event of any variation in the cost to the Buyer of supplying the same or any part thereof caused by:-

6.1.1 any increase in the cost of materials required by the Buyer for the completion of the Contract;

6.1.2 any increase in wages or production and manufacturing costs or other overheads;

6.1.3 any other reason whatsoever beyond the control of the Seller including (but without prejudice to the generality of the foregoing) fluctuations in exchange rates between monetary currencies the action of any government or any other authority or any labour problems.

6.2 In the Seller's absolute discretion, a Prepayment in respect of the Contract may be required to be paid by the Buyer set on the terms set out in this Condition. The Prepayment shall be applied as follows:-

6.2.1 in the event that the Contract is performed in full by both parties the Prepayment shall be retained by the Seller in reduction of the total price payable by the Buyer under the Contract;

6.2.2 in the event that the Buyer is either in default of any of its obligations under the Contract or cancels or suspends the Contract in accordance with Condition 10 the Prepayment shall be set off by the Seller against any damages arising in connection with the default and/or cancellation or suspension of the Contract.

6.3 Unless otherwise stated, the price set out in the Seller's quotation includes the cost of packaging, carriage, and (save as provided in Condition 6.4) insurance. In respect of supplies of Goods in the United States of America and Japan the price also includes import duties and sales taxes (if any). In respect of supplies of Goods in other countries the price does not include any health, VAT or other statutory requirement or provision and no such change by the Seller will constitute a breach of contract or impose upon the Seller any liability whatsoever.

6.4 Where the Buyer requests a particular means of delivery, the price set out in the Seller's quotation does not include any insurance, which is to be arranged at the responsibility of the Buyer.

7 DELIVERY

7.1 Delivery of Goods shall be deemed to be effected by the Seller at the following times

7.1.1 where Goods are collected by or on behalf of the Buyer by its servants or agents, or where Goods are collected in
8 QUANTITIES INSTAMNTS AND STORAGE
8.1 Where Goods are delivered or Services are by instalment each instalment shall be deemed to constitute a separate contract and in default in respect of any instalment such contract shall be liable accordingly but no default in respect of any one instalment shall effect due delivery of any other instalment.
8.2 The Seller will endeavour to deliver the quantity of Goods ordered and every delivery shall be deemed to comply with the order. If there is a surplus or shortage of more than 10% of the quantity specified in the order the Buyer shall have the right to return the Goods at the exclusive cost of the Buyer.
8.3 If Goods are or Services are to be delivered by instalments, the Seller shall be entitled to invoice each instalment as and when delivery is made of any part thereof and no instalment shall be due notwithstanding the non-delivery of any instalment or other default by the Buyer or the Seller responsible to the Buyer to make payment by the due date for any one instalment for whatever reason shall entitle the Seller to suspend deliveries of Goods or provision of Services under the Contract but without prejudice to any other right the Seller may have under any of the other provisions of these Conditions.
8.4 Notwithstanding that risk shall have passed to the Buyer pursuant to Condition 15 the Seller may in its absolute discretion arrange for storage of the Goods either at the request of the Buyer or as a result of the failure by the Seller to take delivery of the Goods under Condition 7. The Seller may insures the goods whilst in storage and the Buyer shall indemnify and keep indemnified the Seller in full against all costs, losses, damages and expenses whatsoever arising in connection with the storage provided for the Buyer and such costs, losses, damages and expenses will be added to and form part of the price of the Goods.
8.5 Unless otherwise agreed between the Buyer and the Seller, the Seller shall be entitled in its absolute discretion and without giving prior notice to the Buyer at the expiration of 3 months to sell or otherwise dispose of Goods kept in storage as provided in Condition 8.4.
9 TERMS OF PAYMENT
9.1 Unless otherwise agreed the price shall be due and payable at the Seller’s offices 30 days after the date of the Seller’s invoice.
9.2 If the Buyer does not pay the whole or any part of the price on the required day then the Buyer shall pay to the Seller or request interest on the amount outstanding from the due date until the actual date of payment at the rate of 2% p.a. over the base rate of Barclays Bank plc from time to time in force which shall accrue on a daily basis.
9.3 Condition 12 shall apply in the event of any alleged defect or failure in or of the Goods purchased and the Buyer shall not delay or refuse to make payment in any such event.
9.4 The Buyer shall not be entitled to withhold payment of any amount due to the Seller by reason of any dispute claimed by the Buyer in connection with the Contract nor shall the Buyer be entitled to set off against any amount payable under the Contract to the Seller any amount which is not due and payable by the Seller or for which the Seller disputes liability.
9.5 All payments payable to the Seller under the Contract shall become due immediately upon termination of the Contract despite any other provision.
10 SUSPENSION AND CANCELLATION
10.1 If the Buyer shall commit any breach of the Contract and fail to remedy the same within 7 days of receiving the Seller’s request in writing to do so the Seller may, or if the Seller expects to be paid, suspend the delivery of any goods or property of the Buyer or the Buyer makes any voluntary arrangement with its creditors or becomes subject to an administration order or (being an individual or firm) becomes bankrupt or (being an incorporated company) being wound up or (being a partnership) being dissolved or in liquidation for winding up otherwise than for the purpose of amalgamation or reconstruction) or, a Court makes an order to that effect or an encumbrancer takes possession, or an administrative receiver or receiver is appointed, of any of the property of the Buyer, or the Buyer ceases, or threatens to cease, to carry on business or is unable to pay its debts within the meaning of section 123 Insolvency Act, 1986, or the Seller reasonably apprehends that any of the events mentioned above is about to occur in relation to the Buyer and notifies the Buyer accordingly, the Seller may:
10.1.1 stop any Goods in transit and suspend any further deliveries;
14. The Seller will have the right to maintain an action against the Buyer for the price of the Goods notwithstanding that property in the Goods has not been passed.

15. The Buyer shall at all times take proper care of the same and will not obliterate the property in the Goods or fritillary cause the Seller to retain possession of the Goods.

16. The Seller shall have the right to enter on the Buyer's premises at any time during the continuation of the Contract to check that the Buyer is complying with the obligation contained in this Condition. The Buyer shall at all times give the Seller reasonable opportunity to carry out such inspection and to make such observations as the Seller may reasonably think fit.

17. The Seller may, if the Buyer is in default for any period exceeding fourteen days, give notice in writing to the Buyer requiring the Buyer to pay the price of the Goods at once and, if the Buyer fails to pay the price of the Goods within such period as is specified in the notice, the Seller may at any time afterwards sell the Goods or any part thereof and out of the proceeds, after deducting all costs and expenses reasonably incurred by the Seller in selling the Goods, the乙方 shall be entitled to receive the Buyer's full purchase money and to recover any balance from the乙方.

18. If the Buyer shall be in default for any period exceeding fourteen days, the Seller may suspend the supply of such Goods as the Seller may have agreed to supply to the Buyer, and may cancel the Contract or any portion thereof, and may also cancel any orders then or subsequently placed with the Buyer, and may claim and recover damages for any loss or expense which the Seller may incur through the Buyer's default or neglect or otherwise.

19. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

20. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

21. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

22. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

23. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

24. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

25. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

26. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

27. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

28. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

29. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

30. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

31. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

32. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

33. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

34. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

35. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

36. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

37. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

38. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

39. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

40. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

41. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

42. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

43. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

44. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

45. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

46. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

47. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

48. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

49. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.

50. The Seller may at any time terminate the Contract and recover damages for all losses sustained by the Seller as a result of the Buyer's default or neglect or otherwise.
21.1 No waiver by the Seller of any breach of any provision of the Contract by the Buyer shall be considered as a waiver of any subsequent breach of the same or any other provision and the Seller shall not be prejudiced by any forbearance or indulgence granted by it to the Buyer.
Bismuth

Discovered in the fifteenth century, although its discoverer is not known. Bismuth is a brittle metal which is silvery in color with a pink tinge. It is stable in air and water. It has poor thermal and electrical properties and finds applications in the manufacture of fusible alloys, a range of materials with low melting points which are suitable for various applications including solder and thermal fuses. Pure bismuth shows a high absorption of gamma rays which makes it useful as a filter or window for these particles, whilst at the same time permitting the passage of neutrons.

### Atomic Properties
- **Atomic number**: 83
- **Atomic radius (Pauling)**: 1.35 Å
- **Density at 20°C**: 9.80 g cm⁻³
- **Boiling point**: 1560°C
- **Atomic weight**: 208.9804 amu
- **Crystal structure**: Rhombohedral
- **Electronic structure**: Xe 4f¹⁴ 5d¹⁰ 6s² 6p³
- **Melting point**: 271.3°C
- **Valences shown**: 3, 5

### Physical Properties
- **Photo-electric work function**: 4.4 eV
- **Electrical resistivity at 20°C**: 117 mΩ cm
- **Thermal neutron absorption cross-section**: 0.034 Barns
- **Temperature coefficient at 0-100°C**: 0.0046 K⁻¹
- **Thermal emf against Pt (cold 0°C - hot 100°C)**: -7.34 mV
- **Coefficient of thermal expansion at 0-100°C**: 13.4 x 10⁻⁶ K⁻¹
- **Latent heat of fusion**: 52.6 J g⁻¹
- **Thermal conductivity at 0-100°C**: 7.9 W m⁻¹ K⁻¹
- **Bulk modulus**: 31.3 GPa
- **Poisson’s ratio**: 0.33
- **Tensile modulus**: 34.0 GPa

### Mechanical Properties
- **Material condition**: Polycrystalline
- **Condition**: Multi-Walled Nanotubes
- **Condition**: Free standing carpet

### Carbon - Nano-Materials

#### Sheet

**NC003060**
- **Thickness**: 1 (nominal) mm
- **Color**: Black
- **Material condition**: Free standing carpet
- **Purity**: >90%

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web Code</td>
<td>Quantity</td>
</tr>
<tr>
<td>907-836-037</td>
<td>USD 630.00</td>
</tr>
<tr>
<td>330-862-467</td>
<td>USD 344.00</td>
</tr>
</tbody>
</table>

Typical Analysis: Not applicable

### Copper - O.F.H.C.

#### Sheet

**CV003020**
- **Thickness**: 3.0 mm
- **Purity**: 99.95 %

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web Code</td>
<td>Quantity</td>
</tr>
<tr>
<td>354-703-790</td>
<td>USD 282.00</td>
</tr>
<tr>
<td>534-937-457</td>
<td>USD 344.00</td>
</tr>
<tr>
<td>037-130-596</td>
<td>USD 528.00</td>
</tr>
</tbody>
</table>

Typical Analysis: Ag 100, Al 1, Bi 1, Ca 3, Cd 1, Fe 2, Mg 1, Pb 3, Si 2, Sn 2.

---

Goodfellow Corporation 125 Hookstown Grade Road, Coraopolis, PA 15108-9302. USA
Tel: 1-800-821-2870 : Fax 1-800-283-2020

Printed prices are correct as at April 17 2020. For current prices see www.goodfellowusa.com
# Copper - O.F.H.C.

**Cu - OFHC**

## Sheet

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
<th>Web Code</th>
<th>Size</th>
<th>Quantity</th>
<th>1pc</th>
<th>2pcs</th>
<th>5pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.76mm</td>
<td>99.95+%</td>
<td>978-828-359</td>
<td>50 x 50 mm</td>
<td>USD 237.00</td>
<td>USD 305.00</td>
<td>USD 476.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>236-502-083</td>
<td>100 x 150 mm</td>
<td>USD 314.00</td>
<td>USD 415.00</td>
<td>USD 652.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>370-530-414</td>
<td>300 x 300 mm</td>
<td>USD 392.00</td>
<td>USD 524.00</td>
<td>USD 624.00</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Ag 100, Al 1, Bi 1, Ca 3, Cd 1, Fe 2, Mg 1, Pb 3, Si 2, Sn 2.

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
<th>Web Code</th>
<th>Size</th>
<th>Quantity</th>
<th>1pc</th>
<th>2pcs</th>
<th>5pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.35mm</td>
<td>99.95+%</td>
<td>901-650-234</td>
<td>50 x 50 mm</td>
<td>USD 249.00</td>
<td>USD 322.00</td>
<td>USD 506.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>706-275-294</td>
<td>100 x 150 mm</td>
<td>USD 338.00</td>
<td>USD 449.00</td>
<td>USD 706.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>284-407-495</td>
<td>150 x 150 mm</td>
<td>USD 428.00</td>
<td>USD 575.00</td>
<td>USD 750.00</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Ag 100, Al 1, Bi 1, Ca 3, Cd 1, Fe 2, Mg 1, Pb 3, Si 2, Sn 2.

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
<th>Web Code</th>
<th>Size</th>
<th>Quantity</th>
<th>1pc</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.6mm</td>
<td>99.95+%</td>
<td>336-680-283</td>
<td>65 x 170 mm</td>
<td>POA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>848-482-048</td>
<td>65 x 440 mm</td>
<td>POA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>149-414-580</td>
<td>120 x 220 mm</td>
<td>POA</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Ag 100, Al 1, Bi 1, Ca 3, Cd 1, Fe 2, Mg 1, Pb 3, Si 2, Sn 2.

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
<th>Web Code</th>
<th>Size</th>
<th>Quantity</th>
<th>1pc</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.7mm</td>
<td>99.99+%</td>
<td>008-031-026</td>
<td>150 x 150 mm</td>
<td>USD 871.00</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Ag 70, Al 1, Bi 1, Ca 1, Cr <1, Fe 2, Mg 1, Mn <1, Na <1, Ni 2, Pb 2, Si 2, Sn 1.

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
<th>Web Code</th>
<th>Size</th>
<th>Quantity</th>
<th>1pc</th>
<th>2pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.7mm</td>
<td>99.95+%</td>
<td>414-314-131</td>
<td>102 x 102 mm</td>
<td>USD 417.00</td>
<td>USD 561.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>242-036-073</td>
<td>150 x 150 mm</td>
<td>USD 539.00</td>
<td>USD 733.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>463-231-431</td>
<td>300 x 305 mm</td>
<td>USD 1112.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Ag 100, Al 1, Bi 1, Ca 3, Cd 1, Fe 2, Mg 1, Pb 3, Si 2, Sn 2.

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
<th>Web Code</th>
<th>Size</th>
<th>Quantity</th>
<th>1pc</th>
<th>2pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.4mm</td>
<td>99.95+%</td>
<td>938-599-255</td>
<td>102 x 102 mm</td>
<td>USD 524.00</td>
<td>USD 712.00</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Ag 100, Al 1, Bi 1, Ca 3, Cd 1, Fe 2, Mg 1, Pb 3, Si 2, Sn 2.
Germanium
Ge

Discovered in 1886 by C.A. Winkler at Freiberg, Germany. Germanium is a silvery white brittle metalloid member of the carbon group of elements, its physical properties being similar to those of silicon, the element which precedes it in the group. Other elements within the carbon group are relatively common, but germanium is found only in trace amounts in some coals and as a minor component in some ores, the principle one being argentorite, a double sulfide of silver and germanium (the mineral from which germanium was first isolated). It has an abundance within the Earth’s crust of 1.8 ppm and the element is produced by reduction of the oxide, ultra-high purity material being obtained by zone refining (a process in which the element is formed into a rod which is then heated at one end to produce a narrow molten zone. The heater is moved along the length of the rod so that the molten zone travels from one end of the rod to the other. Impurities are more soluble in the molten metal than in the solid and thus concentrate in the liquid zone as it moves to one end of the rod).

Germanium is stable in air and water and is unaffected by alkalis and acids, with the exception of nitric acid. It is a poor conductor of electricity but has exceptional properties as a semiconductor material and it is in this area where germanium is primarily used. However, other applications for the material include its use as an alloying element in the production of specific alloys and as an addition to glass in the manufacture of infrared devices.

**Atomic Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic number</td>
<td>32</td>
</tr>
<tr>
<td>Atomic radius - Goldschmidt</td>
<td>0.139 nm</td>
</tr>
<tr>
<td>Atomic weight</td>
<td>72.59 amu</td>
</tr>
<tr>
<td>Crystal structure</td>
<td>Diamond</td>
</tr>
<tr>
<td>Electronic structure</td>
<td>Ar 3d&lt;sup&gt;10&lt;/sup&gt; 4s&lt;sup&gt;2&lt;/sup&gt; 4p&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Photo-electric work function</td>
<td>4.8 eV</td>
</tr>
<tr>
<td>Thermal neutron absorption cross-section</td>
<td>2.3 Barns</td>
</tr>
<tr>
<td>Valences shown</td>
<td>2, 4</td>
</tr>
</tbody>
</table>

**Physical Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling point</td>
<td>2830 C</td>
</tr>
<tr>
<td>Density</td>
<td>5.32 g cm&lt;sup&gt;-3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Melting point</td>
<td>937.4 C</td>
</tr>
<tr>
<td>Crystal structure</td>
<td>Diamond</td>
</tr>
<tr>
<td>Electronic work function</td>
<td>4.8 eV</td>
</tr>
<tr>
<td>Thermal emissivity</td>
<td>46x10&lt;sup&gt;6&lt;/sup&gt; μVcm</td>
</tr>
<tr>
<td>Thermol conductivity</td>
<td>60.2 W m&lt;sup&gt;-1&lt;/sup&gt; K&lt;sup&gt;-1&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**Mechanical Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionization potential</td>
<td>No. eV</td>
</tr>
<tr>
<td>Bulk modulus</td>
<td>73.9 GPa</td>
</tr>
<tr>
<td>Hardness - Mohs</td>
<td>6.25</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.32</td>
</tr>
<tr>
<td>Tensile modulus</td>
<td>79.9</td>
</tr>
</tbody>
</table>

**Metal – Germanium**

Goodfellow Corporation 125 Hookstown Grade Road, Coraopolis, PA 15108-9302. USA

Tel: 1-800-821-2870 : Fax 1-800-283-2020

Printed prices are correct as at April 17 2020. For current prices see www.goodfellowusa.com
<table>
<thead>
<tr>
<th>Code</th>
<th>Thickness</th>
<th>Condition</th>
<th>Electrical Type</th>
<th>Purity</th>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Price</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE003052</td>
<td>0.5mm</td>
<td>Single Crystal</td>
<td>N-Type</td>
<td>99.999%</td>
<td>50 x 50 mm</td>
<td>1pc</td>
<td>736-191-074</td>
<td></td>
<td>1pc</td>
<td>736-191-074</td>
<td></td>
<td>1pc</td>
<td>USD 611.00</td>
<td>USD 931.00</td>
</tr>
</tbody>
</table>

Typical Analysis: Ag < 1, Al < 1, Ba < 1, Ca < 1, Cd < 1, Co < 5, Cu < 1, Fe < 1, Mg < 1, Mn < 1, Mo < 2, Ni < 1, Pb < 2, Si < 1, Sn < 2, Ti < 3, Zn < 1. Optical Grade.

<table>
<thead>
<tr>
<th>Code</th>
<th>Thickness</th>
<th>Condition</th>
<th>Electrical Type</th>
<th>Purity</th>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Price</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE003054</td>
<td>0.5mm</td>
<td>Single Crystal</td>
<td>N-Type</td>
<td>99.999%</td>
<td>50.8 mm</td>
<td>1pc</td>
<td>759-749-233</td>
<td></td>
<td>1pc</td>
<td>759-749-233</td>
<td></td>
<td>1pc</td>
<td>USD 664.00</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Ag < 1, Al < 1, Ba < 1, Ca < 1, Cd < 1, Co < 5, Cu < 1, Fe < 1, Mg < 1, Mn < 1, Mo < 2, Ni < 1, Pb < 2, Si < 1, Sn < 2, Ti < 3, Zn < 1. Optical Grade.

<table>
<thead>
<tr>
<th>Code</th>
<th>Thickness</th>
<th>Condition</th>
<th>Electrical Type</th>
<th>Purity</th>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Price</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE003055</td>
<td>0.6mm</td>
<td>Single Crystal</td>
<td>N-Type</td>
<td>99.999%</td>
<td>10 x 10 mm</td>
<td>1pc</td>
<td>457-272-413</td>
<td></td>
<td>1pc</td>
<td>457-272-413</td>
<td></td>
<td>1pc</td>
<td>USD 206.00</td>
<td>USD 254.00</td>
</tr>
</tbody>
</table>

Typical Analysis: Ag < 1, Al < 1, Ba < 1, Ca < 1, Cd < 1, Co < 5, Cu < 1, Fe < 1, Mg < 1, Mn < 1, Mo < 2, Ni < 1, Pb < 2, Si < 1, Sn < 2, Ti < 3, Zn < 1. Optical Grade.

<table>
<thead>
<tr>
<th>Code</th>
<th>Thickness</th>
<th>Condition</th>
<th>Electrical Type</th>
<th>Purity</th>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Price</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE003070</td>
<td>0.7mm</td>
<td>Polycrystalline</td>
<td>N-Type</td>
<td>99.999%</td>
<td>35 x 35 mm</td>
<td>1pc</td>
<td>934-831-968</td>
<td></td>
<td>1pc</td>
<td>934-831-968</td>
<td></td>
<td>1pc</td>
<td>USD 527.00</td>
<td>USD 697.00</td>
</tr>
</tbody>
</table>

Typical Analysis: Ag < 1, Al < 1, Ba < 1, Ca < 1, Cd < 1, Co < 5, Cu < 1, Fe < 1, Mg < 1, Mn < 1, Mo < 2, Ni < 1, Pb < 2, Si < 1, Sn < 2, Ti < 3, Zn < 1. These sheets are N-type with a resistivity of 5-40 Ohm.cm. Very limited stock available.

<table>
<thead>
<tr>
<th>Code</th>
<th>Thickness</th>
<th>Condition</th>
<th>Electrical Type</th>
<th>Purity</th>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Price</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE003120</td>
<td>1.0mm</td>
<td>Polycrystalline</td>
<td>N-Type</td>
<td>99.999%</td>
<td>6 x 6 mm</td>
<td>1pc</td>
<td>319-263-661</td>
<td></td>
<td>1pc</td>
<td>319-263-661</td>
<td></td>
<td>1pc</td>
<td>USD 229.00</td>
<td>USD 275.00</td>
</tr>
</tbody>
</table>

Typical Analysis: Ag < 1, Al < 1, Ba < 1, Ca < 1, Cd < 1, Co < 5, Cu < 1, Fe < 1, Mg < 1, Mn < 1, Mo < 2, Ni < 1, Pb < 2, Si < 1, Sn < 2, Ti < 3, Zn < 1. These sheets are N-type with a resistivity of 5-40 Ohm.cm.

<table>
<thead>
<tr>
<th>Code</th>
<th>Thickness</th>
<th>Condition</th>
<th>Electrical Type</th>
<th>Purity</th>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Price</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE003100</td>
<td>1.0mm</td>
<td>Single Crystal</td>
<td>N-Type</td>
<td>99.999%</td>
<td>20 mm</td>
<td>1pc</td>
<td>907-548-585</td>
<td></td>
<td>1pc</td>
<td>907-548-585</td>
<td></td>
<td>1pc</td>
<td>USD 376.00</td>
<td>USD 580.00</td>
</tr>
</tbody>
</table>

Typical Analysis: Ag < 1, Al < 1, Ba < 1, Ca < 1, Cd < 1, Co < 5, Cu < 1, Fe < 1, Mg < 1, Mn < 1, Mo < 2, Ni < 1, Pb < 2, Si < 1, Sn < 2, Ti < 3, Zn < 1. These sheets are N-type with a resistivity of 5-40 Ohm.cm.

<table>
<thead>
<tr>
<th>Code</th>
<th>Thickness</th>
<th>Condition</th>
<th>Electrical Type</th>
<th>Purity</th>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Price</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE003120</td>
<td>1.0mm</td>
<td>Polycrystalline</td>
<td>N-Type</td>
<td>99.999%</td>
<td>6 x 6 mm</td>
<td>1pc</td>
<td>372-083-692</td>
<td></td>
<td>1pc</td>
<td>372-083-692</td>
<td></td>
<td>1pc</td>
<td>USD 229.00</td>
<td>USD 275.00</td>
</tr>
</tbody>
</table>

Typical Analysis: Ag < 1, Al < 1, Ba < 1, Ca < 1, Cd < 1, Co < 5, Cu < 1, Fe < 1, Mg < 1, Mn < 1, Mo < 2, Ni < 1, Pb < 2, Si < 1, Sn < 2, Ti < 3, Zn < 1. These sheets are N-type with a resistivity of 5-40 Ohm.cm.

<table>
<thead>
<tr>
<th>Code</th>
<th>Thickness</th>
<th>Condition</th>
<th>Electrical Type</th>
<th>Purity</th>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Quantity</th>
<th>Price</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE003101</td>
<td>1.0mm</td>
<td>Single Crystal</td>
<td>N-Type</td>
<td>99.999%</td>
<td>25 x 25 mm</td>
<td>1pc</td>
<td>443-569-780</td>
<td></td>
<td>1pc</td>
<td>443-569-780</td>
<td></td>
<td>1pc</td>
<td>USD 517.00</td>
<td>USD 757.00</td>
</tr>
</tbody>
</table>

Typical Analysis: Ag < 1, Al < 1, Ba < 1, Ca < 1, Cd < 1, Co < 5, Cu < 1, Fe < 1, Mg < 1, Mn < 1, Mo < 2, Ni < 1, Pb < 2, Si < 1, Sn < 2, Ti < 3, Zn < 1. Optical Grade.
# Germanium

## Sheet

<table>
<thead>
<tr>
<th>Description</th>
<th>Code</th>
<th>Thickness</th>
<th>Purity</th>
<th>Condition</th>
<th>Electrical Type</th>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Diameter</th>
<th>Size</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE003105 Disk</td>
<td>951-104-229</td>
<td>1.0mm</td>
<td>99.999%</td>
<td>Single Crystal Oriented</td>
<td>N-Type</td>
<td>25 mm</td>
<td>1 Disks</td>
<td>USD 669.00</td>
<td>USD 937.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE003122 Disk</td>
<td>997-206-478</td>
<td>1.0mm</td>
<td>99.999%</td>
<td>Polycrystalline</td>
<td>N-Type</td>
<td>50 x 50 mm</td>
<td>1pc</td>
<td>USD 590.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE003123 Disk</td>
<td>692-305-944</td>
<td>1.0mm</td>
<td>99.999%</td>
<td>Polycrystalline</td>
<td>N-Type</td>
<td>25 x 25 mm</td>
<td>1pc</td>
<td>USD 630.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE003124 Disk</td>
<td>244-163-885</td>
<td>1.2mm</td>
<td>99.999%</td>
<td>Single Crystal Oriented</td>
<td>N-Type</td>
<td>10 x 24 mm</td>
<td>1pc</td>
<td>USD 374.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE003125 Disk</td>
<td>205-580-224</td>
<td>2.0mm</td>
<td>99.999%</td>
<td>Polycrystalline</td>
<td>N-Type</td>
<td>25 x 25 mm</td>
<td>1pc</td>
<td>USD 598.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE003130 Disk</td>
<td>580-814-514</td>
<td>3.0mm</td>
<td>99.999%</td>
<td>Polycrystalline</td>
<td>N-Type</td>
<td>50 x 50 mm</td>
<td>1pc</td>
<td>USD 990.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Ag <1, Al <1, Ba <1, Ca <1, Cd <1, Co <5, Cu <1, Fe <1, Mg <1, Mn <1, Mo <2, Ni <1, Pb <2, Si <1, Sn <2, Ti <3, Zn <1.

Optical Grade.

Very limited stock available.

These sheets are N-type with a resistivity of 5-40 Ohm.cm.
Molybdenum

Mo

Discovered in 1871 by P.J. Hjelm in Uppsala, Sweden.

Molybdenum is a lustrous, silvery colored metal which has an abundance of 1.5 ppm in the earth’s crust. In many instances, it shows a resemblance to tungsten with which it tends to be paired in the transition series in the periodic table, but their chemistries tend to show more distinct differences than might be expected.

Molybdenum has a high melting point and applications for the pure metal take advantage of this; for example, the pure material is used as resistance heating elements in furnaces, as filament supports in electric lamps, and as electrodes for mercury vapour lamps. Molybdenum is used as an alloying agent in certain grades of steel, Permalloys and Stellites (a series of alloys which contain varying proportions of Cr, Co, W and Mo, are very hard and are used in cutting tools and to protect surfaces subject to heavy wear).

<table>
<thead>
<tr>
<th>Atomic Properties</th>
<th>Physical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic number</td>
<td>42</td>
</tr>
<tr>
<td>Atomic radius - Goldschmidt</td>
<td>0.140 nm</td>
</tr>
<tr>
<td>Atomic weight</td>
<td>95.94 amu</td>
</tr>
<tr>
<td>Crystal structure</td>
<td>Body centred cubic</td>
</tr>
<tr>
<td>Electronic structure</td>
<td>kr 4d5 5s1</td>
</tr>
<tr>
<td>Photo-electric work function</td>
<td>4.2 eV</td>
</tr>
<tr>
<td>Thermal neutron absorption cross-section</td>
<td>2.65 Barns</td>
</tr>
<tr>
<td>Valences shown</td>
<td>3, 4, 5, 6</td>
</tr>
<tr>
<td>Natural isotope distribution</td>
<td>Mass No. %</td>
</tr>
<tr>
<td>Mass No.</td>
<td>%</td>
</tr>
<tr>
<td>92</td>
<td>14.8</td>
</tr>
<tr>
<td>94</td>
<td>9.3</td>
</tr>
<tr>
<td>95</td>
<td>15.9</td>
</tr>
<tr>
<td>96</td>
<td>16.7</td>
</tr>
<tr>
<td>97</td>
<td>9.6</td>
</tr>
<tr>
<td>98</td>
<td>24.1</td>
</tr>
<tr>
<td>100</td>
<td>9.6</td>
</tr>
<tr>
<td>Ionization potential</td>
<td>No. eV</td>
</tr>
<tr>
<td>No.</td>
<td>eV</td>
</tr>
<tr>
<td>1</td>
<td>7.10</td>
</tr>
<tr>
<td>2</td>
<td>16.15</td>
</tr>
<tr>
<td>3</td>
<td>27.2</td>
</tr>
<tr>
<td>4</td>
<td>46.4</td>
</tr>
<tr>
<td>5</td>
<td>61.2</td>
</tr>
<tr>
<td>6</td>
<td>68</td>
</tr>
<tr>
<td>Material condition</td>
<td>Soft, Hard, Polycrystalline</td>
</tr>
<tr>
<td>Bulk modulus</td>
<td>261.2 GPa</td>
</tr>
<tr>
<td>Hardness - Vickers</td>
<td>200, 250</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.293</td>
</tr>
<tr>
<td>Tensile modulus</td>
<td>324.8 GPa</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>485-550 MPa</td>
</tr>
<tr>
<td>Yield strength</td>
<td>415-450 MPa</td>
</tr>
<tr>
<td>Mechanical Properties</td>
<td></td>
</tr>
<tr>
<td>Thermal Properties</td>
<td>Coefficient of thermal expansion @0-100°C</td>
</tr>
<tr>
<td>Latent heat of evaporation</td>
<td>6153 J g^{-1}</td>
</tr>
<tr>
<td>Latent heat of fusion</td>
<td>290 J g^{-1}</td>
</tr>
<tr>
<td>Specific heat @25C</td>
<td>251 J K^{-1}</td>
</tr>
<tr>
<td>Thermal conductivity @0-100°C</td>
<td>138 W m^{-1} K^{-1}</td>
</tr>
<tr>
<td>Thermal Properties</td>
<td></td>
</tr>
<tr>
<td>Electrical Properties</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>4612 C</td>
</tr>
<tr>
<td>Density @20C</td>
<td>10.22 g cm^{-3}</td>
</tr>
<tr>
<td>Melting point</td>
<td>2617 C</td>
</tr>
<tr>
<td>Electrical resistivity @20C</td>
<td>5.7 µm/ohm</td>
</tr>
<tr>
<td>Temperature coefficient @0-100C</td>
<td>0.00435 K^{-1}</td>
</tr>
<tr>
<td>Superconductivity critical temperature</td>
<td>0.915 K</td>
</tr>
<tr>
<td>Thermal emf against Pt (cold 0C - hot 100C)</td>
<td>+1.45 mV</td>
</tr>
<tr>
<td>Electrical Properties</td>
<td></td>
</tr>
<tr>
<td>Atomic Properties</td>
<td></td>
</tr>
<tr>
<td>Atomic number</td>
<td>42</td>
</tr>
<tr>
<td>Atomic radius - Goldschmidt</td>
<td>0.140 nm</td>
</tr>
<tr>
<td>Atomic weight</td>
<td>95.94 amu</td>
</tr>
<tr>
<td>Crystal structure</td>
<td>Body centred cubic</td>
</tr>
<tr>
<td>Electronic structure</td>
<td>kr 4d5 5s1</td>
</tr>
<tr>
<td>Photo-electric work function</td>
<td>4.2 eV</td>
</tr>
<tr>
<td>Thermal neutron absorption cross-section</td>
<td>2.65 Barns</td>
</tr>
<tr>
<td>Valences shown</td>
<td>3, 4, 5, 6</td>
</tr>
<tr>
<td>Natural isotope distribution</td>
<td>Mass No. %</td>
</tr>
<tr>
<td>Mass No.</td>
<td>%</td>
</tr>
<tr>
<td>92</td>
<td>14.8</td>
</tr>
<tr>
<td>94</td>
<td>9.3</td>
</tr>
<tr>
<td>95</td>
<td>15.9</td>
</tr>
<tr>
<td>96</td>
<td>16.7</td>
</tr>
<tr>
<td>97</td>
<td>9.6</td>
</tr>
<tr>
<td>98</td>
<td>24.1</td>
</tr>
<tr>
<td>100</td>
<td>9.6</td>
</tr>
<tr>
<td>Ionization potential</td>
<td>No. eV</td>
</tr>
<tr>
<td>No.</td>
<td>eV</td>
</tr>
<tr>
<td>1</td>
<td>7.10</td>
</tr>
<tr>
<td>2</td>
<td>16.15</td>
</tr>
<tr>
<td>3</td>
<td>27.2</td>
</tr>
<tr>
<td>4</td>
<td>46.4</td>
</tr>
<tr>
<td>5</td>
<td>61.2</td>
</tr>
<tr>
<td>6</td>
<td>68</td>
</tr>
<tr>
<td>Material condition</td>
<td>Soft, Hard, Polycrystalline</td>
</tr>
<tr>
<td>Bulk modulus</td>
<td>261.2 GPa</td>
</tr>
<tr>
<td>Hardness - Vickers</td>
<td>200, 250</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.293</td>
</tr>
<tr>
<td>Tensile modulus</td>
<td>324.8 GPa</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>485-550 MPa</td>
</tr>
<tr>
<td>Yield strength</td>
<td>415-450 MPa</td>
</tr>
</tbody>
</table>

Sheet

MO003025

Thickness ............. 25.0mm

Size

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Size</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>692-511-605</td>
<td>50 x 50 mm</td>
<td>1pc POA</td>
</tr>
</tbody>
</table>

Typical Analysis: Al < 20, Ca < 20, Cr < 50, Cu < 20, Fe 50, K < 2, Mg < 20, Pb < 30, Si < 50, Ti < 30, W 10, C 40, H 5, N 10, O 30.

Very limited stock available.
Silicon was discovered in 1824 by J.J. Berzelius in Stockholm, Sweden. After carbon, silicon is the most abundant element on earth, the abundance being 277,000 ppm. It is generally present as a silicate, these being found in many rocks, clays and soils. Silicon is obtained by reducing silica (sand, SiO$_2$), with carbon. Further purification of the element for applications requiring high purity material (e.g. semi conductor devices) is achieved by zone refining, the resulting purity being better than 1:10$^{19}$. Silicon exists in two allotropic forms; brown silicon is a powder, whereas crystalline (metallic) silicon is grey and it is the latter which is more widely used. Bulk silicon is unreactive towards oxygen, water, acids (excluding HF), but is soluble in hot alkalis.

Silicon has many applications in various industries; for example, ultra high purity silicon is used in the semiconductor industry as a result of its semiconducting properties. Silicon is also used as an alloying element in the manufacture of certain alloys (e.g. ferrosilicon, an alloy of iron and silicon which is used to introduce silicon into steel and cast iron). It is also used in the manufacture of glass.

<table>
<thead>
<tr>
<th>Atomic Properties</th>
<th>Physical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic number</td>
<td>14</td>
</tr>
<tr>
<td>Atomic radius</td>
<td>0.117 nm</td>
</tr>
<tr>
<td>Atomic weight</td>
<td>28.0855 amu</td>
</tr>
<tr>
<td>Crystal structure</td>
<td>Diamond</td>
</tr>
<tr>
<td>Electronic structure</td>
<td>Ne$^{3+}$ 3p$^2$</td>
</tr>
<tr>
<td>Photo-electric work function</td>
<td>4.2 eV</td>
</tr>
<tr>
<td>Thermal neutron absorption cross-section</td>
<td>0.16 Barns</td>
</tr>
<tr>
<td>Valences shown</td>
<td>4</td>
</tr>
</tbody>
</table>

Natural isotope distribution:
- Mass No. %
  - 28 92.23
  - 29 4.67
  - 30 3.10

Ionization potential:
- No. eV
  - 1 8.15
  - 2 16.3
  - 3 33.5
  - 4 45.1
  - 5 167
  - 6 205

<table>
<thead>
<tr>
<th>Atomic Properties</th>
<th>Physical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting point</td>
<td>1410 °C</td>
</tr>
<tr>
<td>Boiling point</td>
<td>2355 °C</td>
</tr>
<tr>
<td>Density @20°C</td>
<td>2.34 g cm$^{-3}$</td>
</tr>
<tr>
<td>Atomic weight</td>
<td>28.0855 amu</td>
</tr>
<tr>
<td>Crystal structure</td>
<td>Diamond</td>
</tr>
<tr>
<td>Electronic structure</td>
<td>Ne$^{3+}$ 3p$^2$</td>
</tr>
<tr>
<td>Photo-electric work function</td>
<td>4.2 eV</td>
</tr>
<tr>
<td>Thermal neutron absorption cross-section</td>
<td>0.16 Barns</td>
</tr>
<tr>
<td>Valences shown</td>
<td>4</td>
</tr>
</tbody>
</table>

Thermal Properties:
- Coefficient of thermal expansion @0-100°C: 4.7-7.6 x 10$^{-6}$ K$^{-1}$
- Thermal conductivity @0-100°C: 80-150 W m$^{-1}$ K$^{-1}$
- Latent heat of fusion: 1650 J g$^{-1}$
- Latent heat of evaporation: 13700 J g$^{-1}$
- Specific heat @25°C: 703 J K$^{-1}$ kg$^{-1}$
- Thermal emf against Pt (cold 0°C - hot 100°C): -41.56 mV
- Ionization potential:
  - No. eV
    - 1 8.15
    - 2 16.3
    - 3 33.5
    - 4 45.1
    - 5 167
    - 6 205

Mechanical Properties:
- Bulk modulus: 100 GPa
- Poisson’s ratio: 0.42
- Tensile modulus: 113 GPa
- Elastic moduli:
  - 1 8.15
  - 2 16.3
  - 3 33.5
- Density:
  - 2355 g cm$^{-3}$

Metal – Silicon

Goodfellow Corporation 125 Hookstown Grade Road, Coraopolis, PA 15108-9302. USA
Tel: 1-800-821-2870 : Fax 1-800-283-2020

Printed prices are correct as at April 17 2020. For current prices see www.goodfellowusa.com
### Silicon Sheet

**Material Properties**

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Condition</th>
<th>Electrical Type</th>
<th>Purity</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5mm</td>
<td>Single Crystal</td>
<td>P-Type</td>
<td>99.999%</td>
<td>(110)</td>
</tr>
</tbody>
</table>

**Disks**

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Diameter (mm)</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>904-048-279</td>
<td>50.8</td>
<td>1 Disks</td>
</tr>
<tr>
<td>263-809-642</td>
<td>76.2</td>
<td>1 Disks</td>
</tr>
<tr>
<td>311-767-723</td>
<td>101.6</td>
<td>1 Disks</td>
</tr>
</tbody>
</table>

**Typical Analysis:**

- $\text{Al} < 1$, $\text{Ba} < 2$, $\text{Bi} < 2$, $\text{Ca} < 1$, $\text{Cd} < 1$, $\text{Cu} < 1$.
- Optical Grade.

---

### Disks Details

**SIO03075**

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Diameter (mm)</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>904-048-279</td>
<td>50.8</td>
<td>1 Disks</td>
</tr>
</tbody>
</table>

**Typical Analysis:**

- $\text{Al} < 1$, $\text{Ba} < 2$, $\text{Bi} < 2$, $\text{Ca} < 1$, $\text{Cd} < 1$, $\text{Cu} < 1$.
- Optical Grade.

---

### Disks Details

**SIO03074**

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Diameter (mm)</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>311-767-723</td>
<td>101.6</td>
<td>1 Disks</td>
</tr>
</tbody>
</table>

**Typical Analysis:**

- $\text{Al} < 1$, $\text{Ba} < 2$, $\text{Bi} < 2$, $\text{Ca} < 1$, $\text{Cd} < 1$, $\text{Cu} < 1$.
- Optical Grade.

---

### Disks Details

**SIO03076**

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Diameter (mm)</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>561-356-173</td>
<td>79</td>
<td>1 Disks</td>
</tr>
</tbody>
</table>

**Typical Analysis:**

- $\text{Al} < 1$, $\text{Ba} < 2$, $\text{Bi} < 2$, $\text{Ca} < 1$, $\text{Cd} < 1$, $\text{Cu} < 1$.
- Optical Grade.

---

### Disks Details

**SIO03080**

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Diameter (mm)</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>849-809-045</td>
<td>14</td>
<td>1pc</td>
</tr>
</tbody>
</table>

**Typical Analysis:**

- $\text{Al} < 1$, $\text{Ba} < 2$, $\text{Bi} < 2$, $\text{Ca} < 1$, $\text{Cd} < 1$, $\text{Cu} < 1$.
- Optical Grade.
## Silicon Sheet

**SI003100**  
Thickness: 1.0mm  
Purity: 99.999%  
Condition: Single Crystal  
Condition Oriented: (100)  

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Size</th>
<th>1pc</th>
<th>2pcs</th>
<th>5pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>756-832-127</td>
<td></td>
<td>14 x 14 mm</td>
<td>USD 340.00</td>
<td>USD 423.00</td>
<td>USD 608.00</td>
<td></td>
</tr>
<tr>
<td>417-824-931</td>
<td></td>
<td>25 x 25 mm</td>
<td>USD 470.00</td>
<td>USD 677.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Al < 1, Ba < 2, Bi < 2, Ca < 1, Cd < 1, Cu < 1.  
Optical Grade.

**SI003105**  
Thickness: 1.0mm  
Purity: 99.999%  
Condition: Single Crystal  
Condition Oriented: (110)  

**SI003121**  
Thickness: 1.0mm  
Purity: 99.999%  
Condition: Polycrystalline  
Condition Oriented: Not identified  

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Size</th>
<th>1pc</th>
</tr>
</thead>
<tbody>
<tr>
<td>735-290-519</td>
<td></td>
<td>52 x 52 mm</td>
<td>USD 722.00</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Al < 1, Ba < 2, Bi < 2, Ca < 1, Cd < 1, Cu < 1.  
Optical Grade.

**SI003106**  
Thickness: 1.0mm  
Purity: 99.999%  
Condition: Single Crystal  
Condition Oriented: (110)  

**SI003109**  
Thickness: 1.0mm  
Purity: 99.999%  
Condition: Polycrystalline  
Condition Oriented: Not identified  

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Size</th>
<th>1pc</th>
</tr>
</thead>
<tbody>
<tr>
<td>332-334-310</td>
<td></td>
<td>55 x 55 mm</td>
<td>USD 1303.00</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Al < 1, Ba < 2, Bi < 2, Ca < 1, Cd < 1, Cu < 1.  
Optical Grade.

**SI003110**  
Thickness: 2.0mm  
Purity: 99.999%  
Condition: Polycrystalline  

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Size</th>
<th>1pc</th>
</tr>
</thead>
<tbody>
<tr>
<td>059-177-219</td>
<td></td>
<td>35 x 55 mm</td>
<td>USD 761.00</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Al < 1, Ba < 2, Bi < 2, Ca < 1, Cd < 1, Cu < 1.  
Optical Grade.

**SI003140**  
Thickness: 3.0mm  
Purity: 99.999%  
Condition: Single Crystal  
Electrical Type: P-Type  

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Size</th>
<th>1pc</th>
</tr>
</thead>
<tbody>
<tr>
<td>856-219-232</td>
<td></td>
<td>40 x 40 mm</td>
<td>USD 657.00</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Al < 1, Ba < 2, Bi < 2, Ca < 1, Cd < 1, Cu < 1.  
Optical Grade.

**SI003142**  
Thickness: 3.0mm  
Purity: 99.999%  
Condition: Single Crystal  
Electrical Type: P-Type  

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
<th>Web Code</th>
<th>Size</th>
<th>1pc</th>
</tr>
</thead>
<tbody>
<tr>
<td>273-211-621</td>
<td></td>
<td>100 x 100 mm</td>
<td>POA</td>
<td></td>
</tr>
</tbody>
</table>

Typical Analysis: Al < 1, Ba < 2, Bi < 2, Ca < 1, Cd < 1, Cu < 1.  
Optical Grade.
Tin was known and used by ancient civilizations. Tin is a silvery white metal which is soft and pliable, and which emits the characteristic sound of "tin cry" when bent. It is a relatively common element, its abundance being 2.2 ppm in the earth’s crust. Its principal ore is cassiterite, SnO₂, from which the metal is obtained by reduction. Tin forms a stable oxide coating on its surface which makes it unreactive in water; however, it is soluble in both acids and alkalis, and reacts readily with halogens.

As tin has good chemical resistance, it is used as a coating of other metals to prevent corrosion, the coating of steel to produce tin plate being an important example of this application. Tin is widely used in the manufacture of soft solders where it is alloyed with other elements to produce a wide range of alloys with different characteristics. Tin is also a constituent of bronzes, pewter, certain bearing materials and fusible alloys.

### Atomic Properties
- Atomic number: 50
- Atomic radius - Goldschmidt: 0.158 nm
- Atomic weight: 118.69 amu
- Crystal structure: Tetragonal
- Electronic structure: Kr 4d¹⁰ 5s² 5p²

### Physical Properties
- Boiling point: 2270 C
- Density (γ20°C): 7.26 g cm⁻³
- Melting point: 231.9 C
- Electrical resistivity (γ20°C): 12.6 μΩcm
- Temperature coefficient (γ0-100°C): 0.0046 K⁻¹
- Superconductivity critical temperature: 3.722 K
- Thermal conductivity against Pt (cold 0°C - hot 100°C): +0.42 mV

### Thermal Properties
- Coefficient of thermal expansion (γ0-100°C): 23.5 x10⁻⁶ K⁻¹
- Latent heat of evaporation: 2497 J g⁻¹
- Latent heat of fusion: 59.6 J g⁻¹
- Specific heat (γ25°C): 0.63 J g⁻¹ K⁻¹
- Thermal conductivity (γ0-100°C): 42.3 W m⁻¹ K⁻¹

### Mechanical Properties
- Tensile modulus: 132 GPa
- Young’s modulus: 149 GPa
- Poisson’s ratio: 0.357
- Hardness - Mohs: 1.5-1.8
- Bulk modulus: 58.2 GPa
- Young’s modulus bulk modulus: 58.2 GPa
- Tensile modulus: 49.9 GPa
Titanium was discovered by Rev. William Gregor in 1791 in Creed, Cornwall, England and, independently, by M.H. Klaproth in 1795 in Berlin, Germany.

Titanium is a hard, lustrous, silvery metal which is obtained by magnesium or calcium reduction of the tetrachloride. It is a relatively abundant element, there being 5600 ppm in the earth’s crust. It forms a protective oxide coating and, hence, resists corrosion, although powdered metal burns in air. Titanium tends to be inert at low temperatures but will combine with a variety of reagents at elevated temperatures.

Titanium and its alloys are characterized by their lightness, strength and corrosion resistance and are used widely in aerospace applications. In addition, these properties also make the material suitable for medical applications (e.g. replacement hip joints). Titanium dioxide, TiO₂ is used as a white pigment in paints and plastics as it provides great opacity. The same material is also used in the manufacture of heat resisting and durable glass, the TiO₂ replacing certain proportions of the soda. Titanium carbide is used to manufacture cemented carbides.

### Atomic Properties

| Atomic number | 22 |
| Atomic radius - Goldschmidt | 0.147 nm |
| Atomic weight | 47.88 amu |
| Crystal structure | Hexagonal close packed |
| Electronic structure | Ar 3d² 4s² |

### Physical Properties

| Boiling point | 3287 °C |
| Density @20°C | 4.5 g cm⁻³ |
| Melting point | 1660 °C |
| Temperature coefficient @0-100°C | 0.0038 K⁻¹ |
| Superconductivity critical temperature | 0.40 K |

### Electrical Properties

| Photo-electric work function | 4.1 eV |
| Electrical resistivity @20°C | 54 μΩ cm⁻¹ |
| Thermal neutron absorption cross-section | 6.1 Barns |

### Thermal Properties

| Coefficient of thermal expansion @0-100°C | 8.9 x 10⁻⁶ K⁻¹ |
| Latent heat of fusion | 365 J g⁻¹ |
| Thermal conductivity @0-100°C | 21.9 W m⁻¹ K⁻¹ |

### Mechanical Properties

| Material condition | Annealed Polycrystalline |
| Tensile modulus | 108.4 GPa |
| Tensile strength | 230-460 MPa |
| Yield strength | 140-250 MPa |

### Sheet

**T1003140**

| Thickness | 4.0mm |
| Purity | 99.6+% |
| Temper | Annealed |

**Disks**

| Web Code | Diameter | Quantity |
| 192-447-187 | 26 mm | 1 pcs, 2 pcs, 5 pcs, 10 pcs |

**T1003150**

| Thickness | 5.0mm |
| Purity | 99.6+% |
| Temper | 20% |

**T1003151**

| Thickness | 5.0mm |
| Purity | 99.6+% |
| Temper | 20% |

**T1003200**

| Thickness | 7.0mm |
| Purity | 99.6+% |

**T1003230**

| Thickness | 8.0mm |
| Purity | 99.6+% |
Titanium

Sheet

T103250

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>. . . . . .</td>
<td>12.0mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size Code</th>
<th>Size</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>089-629-444</td>
<td>150 x 150 mm</td>
<td>POA</td>
</tr>
<tr>
<td>176-182-493</td>
<td>300 x 300 mm</td>
<td>POA</td>
</tr>
</tbody>
</table>

Typical Analysis: Al 2, Cr 10, Cu 20, Fe 50, Mg 0.1, Mn 20, Ni 30, Sn 20, Ti 10, V 50.

Tungsten

W

Tungsten was isolated in 1783 by J.J. and F. Ehuijar in Vergara, Sweden.

Tungsten metal is lustrous and silvery white in color, and does not occur naturally (it has an abundance of 1 ppm in the earth’s crust). It is found in the ore Wolframite, a tungstate of iron and manganese, (FeMn)WO₄, which is converted to the trioxide and then reduced to the metal by reduction in hydrogen (carbon cannot be used as the very stable carbide would result). Tungsten metal is relatively inert, resisting attack by oxygen, acids and alkalis, although it will react with fused, oxidising alkali media. It has the highest melting point of all metals and, when pure, it can be worked with relative ease; however, the presence of impurities renders tungsten extremely brittle and, therefore, difficult to fabricate.

The high melting point of tungsten makes it suitable for use as electric filaments (e.g. in electric light bulbs). It is also the basis of a range of alloys containing tungsten, copper and nickel which are used for radiation shielding as they provide a 50% increase in density compared to lead. Tungsten and its alloys also find uses in military applications (e.g. armour and shells), as well as counterbalance materials. Tungsten carbide powder (with possible additions of titanium and tantalum carbides) along with nickel or cobalt powders, are compressed and sintered to produce cemented carbides. These products are used in place of high speed steel to form the tip of cutting and drilling tools, or for parts which will be subjected to heavy useage.

Atkin Properties

| Atomic number | 74 |
| Atomic radius - Goldschmidt | 0.141 nm |
| Atomic weight | 183.85 amu |
| Crystal structure | Body centred cubic |
| Electronic structure | Xe 4f¹⁴ 5d⁴ 6s² |
| Photo-electric work function | 4.55 eV |
| Thermal neutron absorption cross-section | 18.5 Barns |
| Valences shown | 2, 3, 4, 5, 6 |

Natural isotope distribution

| Mass No. | No. % |
| 180 | 0.1 |
| 182 | 36.3 |
| 183 | 14.3 |
| 184 | 30.7 |
| 186 | 26.6 |

Ionization potential

| No. | eV |
| 1 | 7.98 |
| 2 | 17.7 |

Physical Properties

| Boiling point | 5660 C |
| Density @20C | 19.3 g cm⁻³ |
| Melting point | 3410 C |

Metal – Titanium

Goodfellow Corporation
125 Hookstown Grade Road, Coraopolis, PA 15108-9302. USA
Tel: 1-800-821-2870 : Fax 1-800-283-2020

Printed prices are correct as at April 17 2020. For current prices see www.goodfellowusa.com

© Goodfellow Corporation
### Tungsten

**W 003200**

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mm</td>
<td>99.95%</td>
</tr>
</tbody>
</table>

**Sheet**

**Size**

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Size 1pc</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>805-801-804</td>
<td>50 x 50 mm</td>
<td>POA</td>
</tr>
<tr>
<td>687-671-058</td>
<td>30 x 80 mm</td>
<td>POA</td>
</tr>
<tr>
<td>462-485-210</td>
<td>75 x 75 mm</td>
<td>POA</td>
</tr>
<tr>
<td>037-930-573</td>
<td>100 x 100 mm</td>
<td>POA</td>
</tr>
<tr>
<td>710-580-348</td>
<td>150 x 150 mm</td>
<td>POA</td>
</tr>
</tbody>
</table>

**Typical Analysis:**

- Ca < 20, Cu < 20, Fe 20, Mg < 10, Mo 150, Ni < 20, Pb < 50, Si < 50, Sn < 30, Ti < 20, C 30, H 6, N 10, O 30.

---

**W 003250**

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mm</td>
<td>99.95%</td>
</tr>
</tbody>
</table>

**Sheet**

**Size**

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Size 1pc</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>949-835-532</td>
<td>20 x 40 mm</td>
<td>POA</td>
</tr>
</tbody>
</table>

**Typical Analysis:**

- Ca < 20, Cu < 20, Fe 20, Mg < 10, Mo 150, Ni < 20, Pb < 50, Si < 50, Sn < 30, Ti < 20, C 30, H 6, N 10, O 30.

---

**W 003280**

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>50mm</td>
<td>99.95%</td>
</tr>
</tbody>
</table>

**Sheet**

**Size**

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Size 1pc</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>919-143-077</td>
<td>75 x 75 mm</td>
<td>POA</td>
</tr>
</tbody>
</table>

**Typical Analysis:**

- Ca < 20, Cu < 20, Fe 20, Mg < 10, Mo 150, Ni < 20, Pb < 50, Si < 50, Sn < 30, Ti < 20, C 30, H 6, N 10, O 30.

---

### Vanadium

**V 003060**

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>6mm</td>
<td>99.8%</td>
</tr>
</tbody>
</table>

**Sheet**

**Size**

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Size 1pc</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>495-381-888</td>
<td>127 x 381 mm</td>
<td>POA</td>
</tr>
</tbody>
</table>

**Typical Analysis:**

- Ag 1, Al 2, Ca < 1, Cr 15, Cu 15, Fe 70, Mg < 1, Mn 1, Si 300.
- One piece only remaining.

---

**Atomic Properties**

- Atomic number: 23
- Atomic radius - Goldschmidt: 0.136 nm
- Atomic weight: 50.9415 amu
- Crystal structure: Body centred cubic
- Electronic structure: $\text{Ar} 3d^3 4s^2$
- Photo-electric work function: 4.3 eV
- Thermal neutron absorption cross-section: 5.06 Barns

**Electronic Properties**

- Electrical resistivity @20°C: 19.6 $\mu\Omega\text{cm}$
- Temperature coefficient @0-100°C: 0.0039 K$^{-1}$
- Thermal emf against Pt (cold 0°C - hot 100°C): 0.63 mV

**Thermal Properties**

- Coefficient of thermal expansion @0-100°C: 8.3 x 10$^{-6}$ K$^{-1}$
- Latent heat of fusion: 345 J g$^{-1}$
- Specific heat @25°C: 486 J K$^{-1}$ kg$^{-1}$
- Thermal conductivity @0-100°C: 30.7 W m$^{-1}$ K$^{-1}$

**Mechanical Properties**

- Material condition: Soft, Hard
- Polycrystalline: 158 GPa
- Bulk modulus: 80 150 GPa
- Hardness - Vickers: 10-136 J m$^{-2}$
- Tensile modulus: 127.6 GPa
- Tensile strength: 260-585 530-730 MPa
- Yield strength: 170-400 515-690 MPa
- Tensile modulus: 80 150 GPa
- Hardness - Vickers: 10-136 J m$^{-2}$
- Tensile modulus: 127.6 GPa
- Tensile strength: 260-585 530-730 MPa
- Yield strength: 170-400 515-690 MPa

**Boiling point:** 3380°C
**Density:** 6.1 g cm$^{-3}$
**Melting point:** 1890°C

---

Goodfellow Corporation 125 Hookstown Grade Road, Coraopolis, PA 15108-9302, USA
Tel: 1-800-821-2870 : Fax 1-800-283-2020

Printed prices are correct as at April 17 2020. For current prices see www.goodfellowusa.com
© Goodfellow Corporation
Permendur 49<sup>®</sup>
Co49/Fe49/V 2

**Common Brand Names:** Permendur 49<sup>®</sup>

Soft magnetic alloy. Uses include instrument, radar and radio transformers.

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>Electrical Properties</th>
<th>Thermal Properties</th>
<th>Mechanical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>8.15 g cm&lt;sup&gt;-3&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnetic Properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curie temperature</td>
<td>940°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturation flux density</td>
<td>2.34 T</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical resistivity</td>
<td>40 μOhm cm&lt;sup&gt;-3&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of thermal expansion @20°C</td>
<td>9.5 x 10&lt;sup&gt;-6&lt;/sup&gt; K&lt;sup&gt;-1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation at break</td>
<td>6%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Sheet

**CO153025**
Thickess ................. 0.25mm
Temper ................. As Rolled

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
<th>1pc</th>
<th>2pcs</th>
<th>5pcs</th>
<th>10pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>039-839-459</td>
<td>50 x 50 mm</td>
<td>USD 177.00</td>
<td>USD 209.00</td>
<td>USD 285.00</td>
<td>USD 396.00</td>
</tr>
<tr>
<td>854-931-883</td>
<td>100 x 100 mm</td>
<td>USD 217.00</td>
<td>USD 265.00</td>
<td>USD 369.00</td>
<td>USD 565.00</td>
</tr>
<tr>
<td>896-481-036</td>
<td>150 x 150 mm</td>
<td>USD 258.00</td>
<td>USD 325.00</td>
<td>USD 630.00</td>
<td>USD 965.00</td>
</tr>
<tr>
<td>310-135-250</td>
<td>180 x 500 mm</td>
<td>USD 484.00</td>
<td>USD 846.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CO153035**
Thickess ................. 0.35mm
Temper ................. As Rolled

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
<th>1pc</th>
<th>2pcs</th>
<th>5pcs</th>
<th>10pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>461-996-275</td>
<td>60 x 100 mm</td>
<td>USD 211.00</td>
<td>USD 256.00</td>
<td>USD 360.00</td>
<td>USD 593.00</td>
</tr>
<tr>
<td>531-981-796</td>
<td>95 x 100 mm</td>
<td>USD 230.00</td>
<td>USD 283.00</td>
<td>USD 452.00</td>
<td>USD 782.00</td>
</tr>
<tr>
<td>395-933-305</td>
<td>100 x 150 mm</td>
<td>USD 270.00</td>
<td>USD 362.00</td>
<td>USD 722.00</td>
<td></td>
</tr>
<tr>
<td>140-201-315</td>
<td>195 x 200 mm</td>
<td>USD 348.00</td>
<td>USD 573.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CO153050**
Thickess ................. 0.50mm
Temper ................. As Rolled

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
<th>1pc</th>
<th>2pcs</th>
<th>5pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>438-520-791</td>
<td>50 x 50 mm</td>
<td>USD 194.00</td>
<td>USD 232.00</td>
<td>USD 323.00</td>
</tr>
<tr>
<td>721-609-698</td>
<td>100 x 100 mm</td>
<td>USD 251.00</td>
<td>USD 312.00</td>
<td>USD 581.00</td>
</tr>
<tr>
<td>653-811-609</td>
<td>150 x 150 mm</td>
<td>USD 311.00</td>
<td>USD 498.00</td>
<td></td>
</tr>
<tr>
<td>640-478-322</td>
<td>300 x 300 mm</td>
<td>USD 831.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Constantan<sup>®</sup> - Resistance Alloy
Cu55/Ni45

**Common Brand Names:** Ferry<sup>®</sup>, Hecnur<sup>®</sup>, Telconstan<sup>®</sup>, Constantan<sup>®</sup>

Resistance alloy with moderate resistivity and low temperature coefficient of resistance with a flat resistance/temperature curve over a wider range than the "manganins". Constantan also shows better corrosion resistance than the manganins. Uses tend to be restricted to ac circuits. Constantan is also the negative element of the type J thermocouple with Iron being the positive; type J thermocouples are used in heat treating applications. Also, it is the negative element of the type T thermocouple with OFHC Copper the positive; type T thermocouples are used at cryogenic temperatures.

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>Thermal Properties</th>
<th>Mechanical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>8.9 g cm&lt;sup&gt;-3&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Melting point</td>
<td>1225-1300°C</td>
<td></td>
</tr>
<tr>
<td>Electrical Properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical resistivity</td>
<td>52.0 μOhm cm&lt;sup&gt;-3&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Temperature coefficient</td>
<td>+/−0.00002 K&lt;sup&gt;-1&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coefficient of thermal expansion @20-100°C</td>
<td>14.9 x 10&lt;sup&gt;-6&lt;/sup&gt; K&lt;sup&gt;-1&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Maximum use temperature in air</td>
<td>500°C</td>
</tr>
<tr>
<td></td>
<td>Thermal conductivity @23°C</td>
<td>19.5 W m&lt;sup&gt;-1&lt;/sup&gt; K&lt;sup&gt;-1&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Elongation at break</td>
<td>&lt;45%</td>
</tr>
<tr>
<td></td>
<td>Hardness - Brinell</td>
<td>100-300</td>
</tr>
<tr>
<td></td>
<td>Izod impact strength</td>
<td>107 J m&lt;sup&gt;-1&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Modulus of elasticity</td>
<td>162 GPa</td>
</tr>
<tr>
<td></td>
<td>Tensile strength</td>
<td>400-500 MPa</td>
</tr>
</tbody>
</table>

### Sheet

**CU043211**
Thickness ................. 11mm
Temper ................. Annealed

<table>
<thead>
<tr>
<th>Size</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>895-939-358</td>
<td>113 x 158 mm</td>
</tr>
</tbody>
</table>

Very limited stock available.
## Phosphor Bronze

**Cu94/Sn 6**

**Physical Properties**
- Density: 8.9 g cm\(^{-3}\)
- Melting point: 900-1050°C

**Electrical Properties**
- Electrical resistivity: 11.0-16.0 μΩcm
- Temperature coefficient: 0.0006-0.0007 K\(^{-1}\)

**Thermal Properties**
- Coefficient of thermal expansion: 17.0 x 10\(^{-6}\) K\(^{-1}\)
- Thermal conductivity: 50-75 W m\(^{-1}\) K\(^{-1}\)

**Mechanical Properties**
- Elongation at break: <60%
- Hardness - Brinell: 80-225
- Izod impact strength: 62 J m\(^{-1}\)
- Modulus of elasticity: 90-120 GPa
- Shear strength: 250-430 MPa
- Tensile strength: 320-740 MPa

### Sheet

**CU053120**

**Thickness:** 2.0mm

<table>
<thead>
<tr>
<th>Size</th>
<th>Web Code</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>559-226-322</td>
<td>100 x 150 mm</td>
</tr>
<tr>
<td>Size</td>
<td>442-572-486</td>
<td>300 x 300 mm</td>
</tr>
</tbody>
</table>

Very limited stock available.

**CU053150**

**Thickness:** 3.2mm

<table>
<thead>
<tr>
<th>Size</th>
<th>Web Code</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>559-226-322</td>
<td>150 x 150 mm</td>
</tr>
<tr>
<td>Size</td>
<td>442-572-486</td>
<td>300 x 300 mm</td>
</tr>
</tbody>
</table>

### Iron/Nickel

**Fe52/Ni48**

**Physical Properties**
- Density: 8.2 g cm\(^{-3}\)
- Melting point: 1450°C

**Electrical Properties**
- Electrical resistivity: 49 μΩcm
- Temperature coefficient: -0.0037 K\(^{-1}\)

**Thermal Properties**
- Coefficient of thermal expansion: 8.5 x 10\(^{-6}\) K\(^{-1}\)
- Maximum use temperature in air: 450°C
- Specific heat: 502 J K\(^{-1}\) kg\(^{-1}\)
- Thermal conductivity: 16.7 W m\(^{-1}\) K\(^{-1}\)

**Mechanical Properties**
- Elongation at break: <30%
- Modulus of elasticity: 248 GPa
- Tensile strength: 450-550 MPa

### Sheet

**FF013100**

**Thickness:** 7.0mm

<table>
<thead>
<tr>
<th>Size</th>
<th>Web Code</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>497-076-691</td>
<td>108 x 108 mm</td>
</tr>
</tbody>
</table>

### Glass Sealing Alloy

**Fe54/Ni29/Co17**

**Physical Properties**
- Density: 8.36-8.50 g cm\(^{-3}\)
- Melting point: 1450°C

**Electrical Properties**
- Electrical resistivity: 48.9 μΩcm

**Thermal Properties**
- Coefficient of thermal expansion: 4.81 x 10\(^{-6}\) K\(^{-1}\)
- Specific heat: 439 J K\(^{-1}\) kg\(^{-1}\)
- Thermal conductivity: 17.3 W m\(^{-1}\) K\(^{-1}\)

**Magnetic Properties**
- Curie temperature: 435°C

**Mechanical Properties**
- Elongation at break: 30%
- Modulus of elasticity: 207 GPa
- Tensile strength: 510-520 MPa
### Sheet

**Glass Sealing Alloy**  
**Fe54/Ni29/Co17**

<table>
<thead>
<tr>
<th>Web Code</th>
<th>Size</th>
<th>Thickness</th>
<th>Quantity</th>
<th>1pc (USD)</th>
<th>2pcs (USD)</th>
<th>5pcs (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FE043200</td>
<td>893-129-912</td>
<td>3.2mm</td>
<td>100 x 100 mm</td>
<td>272.00</td>
<td>375.00</td>
<td>695.00</td>
</tr>
<tr>
<td></td>
<td>857-911-062</td>
<td></td>
<td>150 x 150 mm</td>
<td>360.00</td>
<td>634.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>628-848-394</td>
<td></td>
<td>300 x 300 mm</td>
<td>1080.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FE043250</td>
<td>124-666-166</td>
<td>5.0mm</td>
<td>100 x 100 mm</td>
<td>308.00</td>
<td>491.00</td>
<td></td>
</tr>
<tr>
<td>FE043300</td>
<td>776-131-388</td>
<td>6.35mm</td>
<td>50 x 50 mm</td>
<td>229.00</td>
<td>311.00</td>
<td>434.00</td>
</tr>
<tr>
<td></td>
<td>381-731-695</td>
<td></td>
<td>102 x 112 mm</td>
<td>362.00</td>
<td>637.00</td>
<td></td>
</tr>
<tr>
<td>FE043350</td>
<td>711-115-287</td>
<td>12.7mm</td>
<td>50 x 50 mm</td>
<td>271.00</td>
<td>373.00</td>
<td>691.00</td>
</tr>
<tr>
<td></td>
<td>880-107-262</td>
<td></td>
<td>100 x 100 mm</td>
<td>539.00</td>
<td>990.00</td>
<td></td>
</tr>
<tr>
<td>FE043370</td>
<td>147-066-046</td>
<td>25.4mm</td>
<td>62 x 255 mm</td>
<td>POA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>432-591-595</td>
<td></td>
<td>113 x 161 mm</td>
<td>POA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Temper** - Annealed

**Size**

- **Thickness**
  - 3.2mm
  - 5.0mm
  - 6.35mm
  - 12.7mm
  - 25.4mm

**Quantity**

- 1pc
- 2pcs
- 5pcs

**Price**

- USD

- **Web Code**

**Note**

- Very limited stock available.

Printed prices are correct as at April 17, 2020. For current prices see www.goodfellowusa.com
<table>
<thead>
<tr>
<th>INDEX</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Audiolloy® 33</td>
</tr>
<tr>
<td>B</td>
<td>Bismuth (Bi) 19</td>
</tr>
<tr>
<td>C</td>
<td>Carbon - Nano-Materials (C) 19</td>
</tr>
<tr>
<td></td>
<td>Constantan® 32</td>
</tr>
<tr>
<td></td>
<td>Constantan® - Resistance Alloy (Cu55/Ni45) 32</td>
</tr>
<tr>
<td></td>
<td>Copper - O.F.H.C. (Cu - OFHC) 19</td>
</tr>
<tr>
<td>D</td>
<td>Dilver P® 33</td>
</tr>
<tr>
<td>F</td>
<td>Ferry® 32</td>
</tr>
<tr>
<td>G</td>
<td>Germanium (Ge) 21</td>
</tr>
<tr>
<td></td>
<td>Glass Sealing Alloy (Fe54/Ni29/Co17) 33</td>
</tr>
<tr>
<td>H</td>
<td>Hecnum® 32</td>
</tr>
<tr>
<td>I</td>
<td>Iron/Nickel (Fe52/Ni48) 33</td>
</tr>
<tr>
<td>K</td>
<td>Kvar® (CRS Holdings Inc a subsidiary of Carpenter Technology Corporation) 33</td>
</tr>
<tr>
<td>M</td>
<td>Molybdenum (Mo) 24</td>
</tr>
<tr>
<td>N</td>
<td>Nicoseal® 33</td>
</tr>
<tr>
<td></td>
<td>Nicosel® 33</td>
</tr>
<tr>
<td></td>
<td>Nilo® alloy 48 33</td>
</tr>
<tr>
<td></td>
<td>Nilo® K 33</td>
</tr>
<tr>
<td>P</td>
<td>Permendur 49® 32</td>
</tr>
<tr>
<td></td>
<td>Permendur 49® (Co49/Fe49/V 2) 32</td>
</tr>
<tr>
<td></td>
<td>Phosphor Bronze (Cu94/Sn 6) 33</td>
</tr>
<tr>
<td>R</td>
<td>Rodar® 33</td>
</tr>
<tr>
<td>S</td>
<td>Sheet 19</td>
</tr>
<tr>
<td></td>
<td>Bismuth 19</td>
</tr>
<tr>
<td></td>
<td>Carbon - Nano-Materials 19</td>
</tr>
<tr>
<td></td>
<td>Constantan - Resistance Alloy 32</td>
</tr>
<tr>
<td></td>
<td>Copper - O.F.H.C. 19</td>
</tr>
<tr>
<td></td>
<td>Germanium 21</td>
</tr>
<tr>
<td></td>
<td>Glass Sealing Alloy 34</td>
</tr>
<tr>
<td></td>
<td>Iron/Nickel 33</td>
</tr>
<tr>
<td></td>
<td>Molybdenum 24</td>
</tr>
<tr>
<td></td>
<td>Permendur 49® 32</td>
</tr>
<tr>
<td></td>
<td>Phosphor Bronze 33</td>
</tr>
<tr>
<td></td>
<td>Silicon 25</td>
</tr>
<tr>
<td></td>
<td>Tin 28</td>
</tr>
<tr>
<td></td>
<td>Titanium 29</td>
</tr>
<tr>
<td></td>
<td>Tungsten 30</td>
</tr>
<tr>
<td></td>
<td>Vanadium 31</td>
</tr>
<tr>
<td></td>
<td>Silicon (Si) 25</td>
</tr>
<tr>
<td>T</td>
<td>Telconstan® 32</td>
</tr>
<tr>
<td></td>
<td>Telcoseal 1® 33</td>
</tr>
<tr>
<td></td>
<td>Tin (Sn) 28</td>
</tr>
<tr>
<td></td>
<td>Titanium (Ti) 29</td>
</tr>
<tr>
<td></td>
<td>Tungsten (W) 30</td>
</tr>
<tr>
<td>V</td>
<td>Vanadium (V) 31</td>
</tr>
</tbody>
</table>