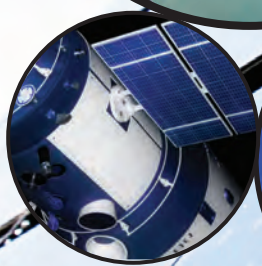
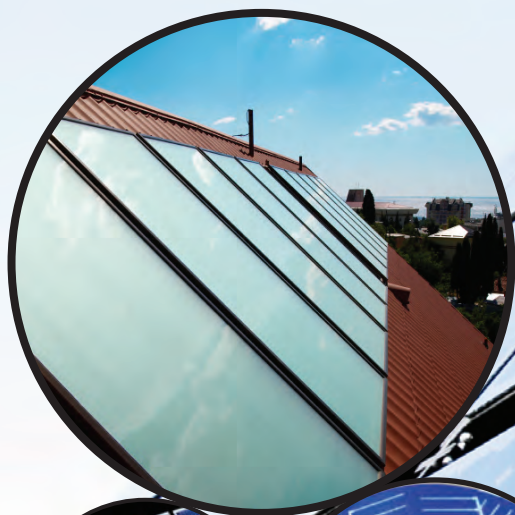


High Purity Materials for  
**Photovoltaics**



**Alfa Aesar**<sup>®</sup>

*A Johnson Matthey Company*

*A photovoltaic substance is a material used in the creation solar cells that convert sunlight directly into electricity. The long-term goal of photovoltaic (PV) devices has been to reduce our dependency on fossil fuel generated electricity.*

The main benefits of electricity produced by PV's are:

- Reliable operating systems
- Low operating costs
- Virtually zero environmental impact
- Modular design

Presently, most PV solar cells are produced from either single- or polycrystalline silicon with efficiencies of around 13-17%. This first generation of photovoltaics is heavily reliant on the supply of pure silicon in the form of single crystals. Technology has now been developed to produce polycrystalline silicon, specifically for the PV industry, with lower purity and lower costs. However, the main disadvantage of this material is the lower cell efficiency.

Therefore, critical to the long-term commercial success of PV technologies are advances in module efficiencies and improvements in cost and reliability. In an effort to circumnavigate these issues, two emerging technologies have developed based on either Copper Indium Gallium Selenide (CIGS) or Cadmium Telluride (CdTe) solar cell devices. The advantages of these thin-film PV's include lower cost, reduced material usage, lower energy requirement for manufacture and shorter payback time.

## Crystalline Silicon

By far, the most prevalent bulk material for solar cells is crystalline silicon, also known as solar grade silicon. Bulk silicon is separated into multiple categories according to crystallinity and crystal size in the resulting ingot, ribbon or wafer.

### Monocrystalline Silicon

Often made using the Czochralski process, single crystal wafer cells can be expensive. Since they are cut from cylindrical ingots, they do not typically cover a square solar cell module without a substantial waste of refined silicon. Therefore, most monocrystalline silicon panels have uncovered gaps at the four corners of the cell.

### Ribbon Silicon

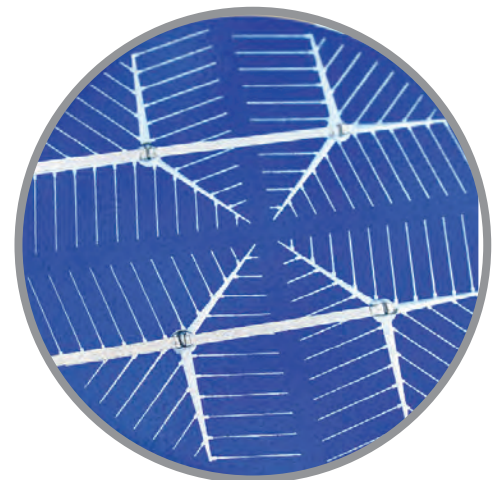
This type of monocrystalline silicon is formed by drawing flat thin films from molten silicon and has a multicrystalline structure. Although less efficient, ribbon silicon cells are more cost effective because their production does not require sawing from ingots.

## Poly- or Multicrystalline Silicon

Large blocks of molten silicon are carefully cooled and solidified to create cast square ingots. Less expensive to produce than monocrystalline silicon cells, multicrystalline cells are also less efficient.

### Advantages of Crystalline Silicon

- Up to 30% efficiency
- Long life





## CIGS

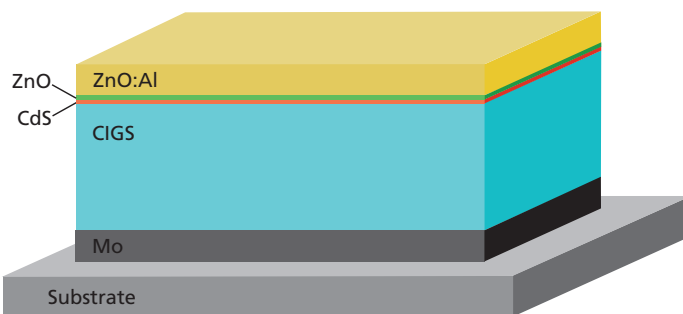
Unlike silicon solar cells which are based on a p-n junction, the structure of CIGS is a complex heterojunction.

Photovoltaic devices based on  $\text{Cu(In,Ga)Se}_2$  (CIGS) perform with 19% efficiency, the highest of any thin film technology. However, the possibilities for even higher performance are significant.

Typically, CIGS cells use either a glass, steel or polymer substrate, onto which a layer of molybdenum is sputtered (Back Contact). The 1.3-2.5 mm thick CIGS layer can be deposited in various ways including sputtering, co-evaporation, printing and electroplating.

A thin cadmium sulfide buffer is added next, prepared by chemical bath deposition. It is then over-coated with a transparent conductor (aluminium doped zinc oxide).

*Structure of a typical CIGS module*



## Advantages of CIGS

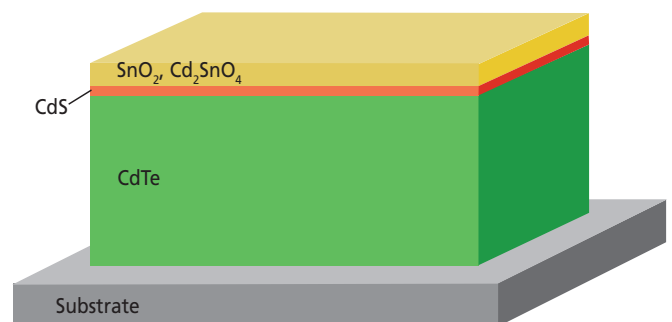
- Modules can be on glass, flexible steel or polymer substrates
- Able to produce lower-cost PV with less material usage
- Highest efficiency of thin-film technologies: 19.9% for single cells, 13% for large modules

## CdTe

Cadmium Telluride (CdTe) is an ideal semiconductor for use in photovoltaic applications, as the band gap (about 1.5 eV) almost perfectly matches the solar spectrum.

Thin-films of CdTe can be deposited onto a substrate by a variety of different methods, including evaporation, electrodeposition, and printing. Photovoltaic modules based on thin-film cadmium telluride technology are of great interest for large-scale grid connected applications, primarily due to cost benefits over other PV technologies.

*Structure of a typical CdTe module*



## Advantages of CdTe

- Simplified manufacturing
- Abundant supply of cadmium produced as a by-product of industrial metals such as zinc
- Absorbs sunlight at close to the ideal wavelength
- 10.6% efficiency for modules



Alfa Aesar produces a range of high purity materials specifically for the photovoltaic industry. The following is a representative listing only; if you require a specialized compound or metal not listed below, please contact us.

## Chemicals

Item No	Description	CAS #
40193	Ammonium chloride, ACS, 99.5% min, Crystalline	12125-02-9
12361	Ammonium chloride, 99.5% min, Granular	12125-02-9
10632	Ammonium chloride, Puratronic®, 99.999% (metals basis), Powder	12125-02-9
11566	Ammonium sulfate, ACS, 99.0% min, Granular	7783-20-2
89363	Ammonium sulfate, 99.95% (metals basis), Crystalline	7783-20-2
10639	Ammonium sulfate, Puratronic®, 99.999% (metals basis), Crystalline	7783-20-2
10641	Antimony(III) oxide, Puratronic®, 99.999% (metals basis), Powder	1309-64-4
10643	Antimony(V) oxide, Puratronic®, 99.998% (metals basis), Powder	1314-60-9
13130	Antimony(III) selenide, 99.999% (metals basis), 3-12mm Pieces	1315-05-5
36282	Antimony(III) telluride, 99.999% (metals basis), 3-12mm Lump	1327-50-0
11865	Cadmium acetate dihydrate, 99.999% (metals basis), Powder	5743-04-4
12373	Cadmium chloride hemipentahydrate, ACS, 79.5-81.0%, Crystalline	7790-78-5
20129	Cadmium chloride hydrate, 99.99% (metals basis), Powder	654054-66-7
10661	Cadmium chloride hydrate, Puratronic®, 99.998% (metals basis), Crystalline Powder	654054-66-7
36629	Cadmium chloride, anhydrous, ACS, 99.0% min, Powder	10108-64-2
11860	Cadmium chloride, anhydrous, 99.99% (metals basis), Powder	10108-64-2
35728	Cadmium chloride, ultra dry, 99.9% (metals basis), -10 Mesh Beads, Ampouled under argon	10108-64-2
42852	Cadmium chloride, ultra dry, 99.996% (metals basis), Powder, Ampouled under argon	10108-64-2
13667	Cadmium chloride, ultra dry, 99.998% (metals basis), -10 Mesh Beads, Ampouled under argon	10108-64-2
11057	Cadmium selenide, 99.995% (metals basis), Powder	1306-24-7
A10168	Cadmium sulfate hydrate, 98%	15244-35-6
12340	Cadmium sulfate octahydrate, ACS, 98.0-102.0%, Crystalline	7790-84-3
10675	Cadmium sulfate hydrate, Puratronic®, 99.996% (metals basis), Crystalline	15244-35-6
11861	Cadmium sulfate, anhydrous, ACS, 99+%, Powder	10124-36-4
41511	Cadmium sulfide, 99.99% (metals basis), 3-12mm Sintered Lump	1306-23-6
38342	Cadmium sulfide, 99.999% (metals basis), -325 Mesh Powder	1306-23-6
45455	Cadmium sulfide, 99.999% (metals basis), 3-12mm Pieces	1306-23-6
14367	Cadmium telluride, 99.999% (metals basis), -325 Mesh Powder	1306-25-8
14365	Cadmium telluride, 99.999% (metals basis), Lump	1306-25-8
45457	Cadmium telluride, 99.999% (metals basis), 6mm & down pieces	1306-25-8
14364	Cadmium telluride, 99.9999+% (metals basis)	1306-25-8
10996	Calcium carbonate, 99.95% (metals basis), Powder	471-34-1
10679	Calcium carbonate, Puratronic®, 99.99% (metals basis), Powder	471-34-1
10998	Calcium fluoride, 99.95% (metals basis), -325 Mesh Powder	7789-75-5
36555	Copper(I) chloride, ACS, 90+%, Powder	7758-89-6
41837	Copper(I) chloride, 99% (metals basis), -80 Mesh Powder	7758-89-6
14644	Copper(I) chloride, 99.999% (metals basis), Powder	7758-89-6
14177	Copper(II) acetate monohydrate, ACS, 98.0-102.0%, Powder	6046-93-1
35481	Copper(II) acetate monohydrate, 99.9% (metals basis), -4 Mesh	6046-93-1
44355	Copper(II) acetate, 99.999% (metals basis), Powder	142-71-2
B23615	Copper(II) acetate, anhydrous, 98%	142-71-2
12458	Copper(II) chloride dihydrate, ACS, 99+%, Granular	10125-13-0
A16064	Copper(II) chloride dihydrate, 99%	10125-13-0
10692	Cobalt(II) chloride hexahydrate, Puratronic®, 99.998% (metals basis), Crystalline Aggregates	7791-13-1

Item No	Description	CAS #
10698	Copper(II) chloride hydrate, Puratronic®, 99.999% (metals basis), Crystalline Aggregates	10125-13-0
12457	Copper(II) chloride, anhydrous, 98% min, Powder	7447-39-4
35673	Copper(II) chloride, ultra dry, 99.995% (metals basis), Powder, Ampouled under argon	7447-39-4
12933	Gallium antimonide, 99.99% (metals basis), 6mm & down Pieces	12064-03-8
88458	Gallium arsenide, 99.999% (metals basis), 25mm & Down Polycrystalline Pieces	1303-00-0
35698	Gallium(II) chloride, ultra dry, 99.999% (metals basis), -10 Mesh Beads, Ampouled under argon	13450-90-3
43879	Gallium(III) chloride, ultra dry, 99.999% (metals basis), Crystalline, Ampouled under argon	13450-90-3
35698	Gallium(III) chloride, ultra dry, 99.999% (metals basis), -10 Mesh Beads, Ampouled under argon	13450-90-3
45026	Gallium(III) chloride, ultra dry, 99.999% (metals basis), 8mm and down Granules, Ampouled under argon	13450-90-3
41881	Gallium(II) telluride, 99.999% (metals basis), 6mm & down	12024-14-5
40033	Indium(I) chloride, anhydrous, 99.995% (metals basis), Crystalline, Packaged under argon	13465-10-6
11859	Indium(III) chloride hydrate, 99.99% (metals basis), Crystalline	143983-91-9
L18758	Indium(III) chloride, anhydrous, 98+%	10025-82-8
41977	Indium(III) chloride, anhydrous, 99.99% (metals basis), Crystalline	10025-82-8
11856	Indium(III) chloride, anhydrous, 99.999% (metals basis), Crystalline	10025-82-8
44349	Indium(III) chloride, ultra dry, 99.999% (metals basis), Powder, Ampouled under argon	10025-82-8
45460	Indium(III) oxide, 99.995% (metals basis), 6mm & down pieces	1312-43-2
36386	Indium(III) oxide, 99.999% (metals basis), 3-6mm Sintered Granules	1312-43-2
88280	Indium(III) selenide, 99.99% (metals basis), 3-6mm Pieces	12056-07-4
36391	Magnesium fluoride, 99.9% (metals basis excluding Ca & Na), Ca+Na <1%, 3-6mm Vacuum Melted Lump	7783-40-6
11365	Niobium(V) oxide, 99.5% (metals basis), -100 Mesh Powder	1313-96-8
11366	Niobium(V) oxide, 99.9% (metals basis), Powder	1313-96-8
42216	Potassium fluoride, ACS, 99% min, Powder	7789-23-3
10854	Selenium(IV) oxide, Puratronic®, 99.999% (metals basis), Powder/Lump	7446-08-4
11003	Sodium fluoride, 99.99% (metals basis), Powder	7681-49-4
12964	Sodium fluoride, Puratronic®, 99.995% (metals basis excluding K), K ~60ppm, Powder	7681-49-4
A12173	Sodium hydrogen selenite, 98%	7782-82-3
97046	Sodium selenate 99.0% min ( minus 150 ) Grade AG	13410-01-0
97061	Sodium selenate, 99.98% (min.), Grade DG, -60 mesh	13410-01-0
12613	Sodium selenate, anhydrous, 99.8+% (metals basis), Powder	13410-01-0
14239	Sodium selenate decahydrate, 99.9% (metals basis), Crystalline	10102-23-5
A14313	Sodium selenite hydrate, 99%	10102-18-8
12585	Sodium selenite, anhydrous, 99% min, typically 99.75% min (metals basis), Powder	10102-18-8
35793	Strontium carbonate, 99.99% (metals basis), Powder	1633-05-2
36618	Strontium carbonate, Puratronic®, 99.994% (metals basis), -22 Mesh Powder	1633-05-2
12284	Tellurium(IV) chloride, 99.9% (metals basis), Crystalline	10026-07-0
10882	Tellurium(IV) oxide, Puratronic®, 99.9995% (metals basis), Powder	7446-07-3
36609	Thiourea, ACS, 99+%, Crystalline	62-56-6
A12828	Thiourea, 99%, Crystalline	62-56-6
10897	Titanium(IV) oxide, Puratronic®, 99.995% (metals basis), -22 Mesh Powder	13463-67-7
36302	Tin(IV) oxide, 99.9% (metals basis), 3-12mm Sintered Lump	18282-10-5
12307	Zinc chloride, ACS, 97%, Lump	7646-85-7
41247	Zinc chloride hydrate, 99.99% (metals basis), Crystalline Aggregates	
35782	Zinc chloride hydrate, Puratronic®, 99.999% (metals basis), -10 Mesh Crystalline Aggregates	
87900	Zinc chloride, anhydrous, 99.99% (metals basis), Lump	7646-85-7
A16281	Zinc chloride, anhydrous, 98+%	7646-85-7
13694	Zinc chloride, ultra dry, 99.99% (metals basis), -10 Mesh Beads, Ampouled under argon	7646-85-7
35726	Zinc chloride, ultra dry, 99.999% (metals basis), Powder, Ampouled under argon	7646-85-7
44198	Zinc chloride, ultra dry, 99.999% (metals basis), -10 Mesh Beads, Ampouled under argon	7646-85-7
36595	Zinc telluride, 99.998% (metals basis), 3-12mm Lump	1315-11-3

# Metals

Item No	Description	CAS #
42323	Aluminum slug, 6.35mm (0.25in) d x 6.35mm (0.25in) l, Puratronic®, 99.999% (metals basis)	7429-90-5
13375	Arsenic polycrystalline lump, 2-8mm (0.08-0.3in), Puratronic®, 99.9999% (metals basis)	7440-38-2
14454	Barium crystalline dendritic solid, 99.9% (metals basis)	7440-39-3
11353	Cadmium powder, -200 mesh, 99.99% (metals basis)	7440-43-9
11351	Cadmium shot, 1-3mm, Puratronic®, 99.9999% (metals basis)	7440-43-9
14457	Calcium crystalline dendritic pieces, 99.98% (metals basis)	7440-70-2
39682	Copper powder, -100 mesh, 99.999% (metals basis)	7440-50-8
10955	Copper shot, 9mm (0.35in) & down, Puratronic®, 99.9999% (metals basis)	7440-50-8
42961	Copper slug, 6.35mm (0.25in) d x 12.7mm (0.50in) l, Puratronic®, 99.9999% (metals basis)	7440-50-8
10187	Gallium ingot, 99.999% (metals basis)	7440-55-3
10185	Gallium ingot, 99.9999% (metals basis)	7440-55-3
10186	Gallium ingot, 99.99999% (metals basis)	7440-55-3
44418	Gallium metal, packaged in poylethylene bottle, 99.999% (metals basis)	7440-55-3
44324	Gallium pellets, 6mm dia, 99.9999% (metals basis)	7440-55-3
44325	Gallium pellets, 6mm dia, 99.99999% (metals basis)	7440-55-3
11024	Indium powder, -325 mesh, 99.99% (metals basis)	7440-74-6
40338	Indium shot, 1mm (0.04in), Puratronic®, 99.999% (metals basis)	7440-74-6
11359	Indium shot, 4-8mm, Puratronic®, 99.9999% (metals basis)	7440-74-6
10613	Indium shot, 5mm & down, Puratronic®, 99.9995% (metals basis)	7440-74-6
10614	Indium shot, 5mm (0.2in) & down, Puratronic®, 99.9999+% (metals basis)	7440-74-6
10615	Indium shot, 5mm (0.2in) & down, Puratronic®, 99.9999% (metals basis)	7440-74-6
43414	Indium slug, 6.35mm (0.25in) dia x 6.35mm (0.25in) length, 99.998% (metals basis)	7440-74-6
11462	Indium wire, 1.0mm (0.04in) dia, Puratronic®, 99.998+% (metals basis)	7440-74-6
00470	Indium wire, 1.0mm (0.04in) dia, Puratronic®, 99.999% (metals basis)	7440-74-6
11381	Iron foil, 0.1mm (0.004in) thick, Puratronic®, 99.995% (metals basis)	7439-89-6
12958	Iron lump, vacuum remelted, low Oxygen, 99.99% (metals basis)	7439-89-6
10621	Iron powder, -22 mesh, Puratronic®, 99.998% (metals basis)	7439-89-6
43355	Magnesium rod, 7.9mm (0.31in) dia x 25mm (1in) length, 99.9% (metals basis)	7439-95-4
12972	Molybdenum powder, -22 mesh, Puratronic®, 99.999% (metals basis excl. W), W <1000ppm	7439-98-7
42361	Molybdenum slug, 3.175mm (0.125in) dia x 3.175mm (0.125in) length, 99.95% (metals basis)	7439-98-7
42359	Molybdenum slug, 6.35mm (0.25in) dia x 6.35mm (0.25in) length, 99.95% (metals basis)	7439-98-7
42331	Nickel slug, 6.35mm (0.25in) dia x 6.35mm (0.25in) length, Puratronic®, 99.995% (metals basis)	7440-02-0
43131	Nickel wire, 0.25mm (0.01in) dia, annealed, 99.98% (metals basis)	7440-02-0
A12592	Selenium, powder, 99+%	7782-49-2
36208	Selenium powder, -200 mesh, 99.999% (metals basis)	7782-49-2
10601	Selenium powder, -325 mesh, 99.5% (metals basis)	7782-49-2
10603	Selenium shot, amorphous, 1-3mm (0.04-0.1in), Puratronic®, 99.999% (metals basis)	7782-49-2
00290	Selenium shot, amorphous, 2-4mm (0.08-0.16in), 99.999+% (metals basis)	7782-49-2
38542	Silicon granular, virgin poly fines, 99.999% (metals basis)	7440-21-3
43006	Silicon lump, 0.1-2.5cm, 99.9999% (metals basis)	7440-21-3
39101	Silicon lump, 15cm & doesn, 99.999+% (metals basis)	7440-21-3
44185	Silicon powder, nodular, APR 1-5micron, 99.999% (metals basis)	7440-21-3
38715	Silicon powder, crystalline/amorphous, typically 1-20 micron, 99.9985% (metals basis)	7440-21-3
35662	Silicon powder, crystalline, -325mesh, 99.999% (metals basis)	7440-21-3
36212	Silicon powder, crystalline, -100+325mesh, 99.999% (metals basis)	7440-21-3
43926	Silicon slugs, 9.5mm dia x 9.5mm length, 99.9999% (metals basis)	7440-21-3

Item No	Description	CAS #
42922	Silver slug, 6.35mm (0.25in) dia x 6.35mm (0.25in) length, 99.99% (metals basis)	7440-22-4
00781	Silver powder, -120 mesh, Premion®, 99.999% (metals basis)	7440-22-4
38624	Strontium, distilled dendritic pieces, 99.95% (metals basis)	7440-24-6
10755	Sulfur pieces, Puratronic®, 99.999% (metals basis)	7704-34-9
10343	Sulfur pieces, Puratronic®, 99.9995% (metals basis)	7704-34-9
12607	Tellurium broken ingot, Puratronic®, 99.9999+% (metals basis)	13494-80-8
11073	Tellurium broken ingot, 99.99% (metals basis)	13494-80-8
10758	Tellurium lump, typically 12mm, 99.9999% (metals basis)	13494-80-9
11076	Tellurium pieces, 99.9999% (metals basis), zone refined	13494-80-9
43960	Tellurium powder, -18+60 mesh, Puratronic, 99.999% (metals basis)	13494-80-9
42213	Tellurium shot, 2-5mm (0.08-0.20in) dia, 99.9999% (metals basis)	13494-80-8
11009	Tin shot, 3mm (0.1in), Puratronic®, 99.9999% (metals basis)	7440-31-5
10417	Tungsten foil, 0.05mm (0.002in) thick, 99.95% (metals basis)	7440-33-7
10415	Tungsten foil, 0.25mm (0.01in) thick, 99.95% (metals basis)	7440-33-7

Alfa Aesar also has a full line of sputtering targets. Please visit our website at [www.alfa.com](http://www.alfa.com) for further details and to search for products.

## How to Order/General Information

### PRICING

Most current pricing may be found at our website. In cases where the selling price has changed significantly, we will contact you prior to filling your order.

### SHIPPING

Whenever possible, we will ship products by the method specified on your order.

### TECHNICAL SERVICE

At your request, we will furnish technical assistance and information with respect to our products. Our Technical Service Representatives are trained in specific product lines to answer your questions regarding applications, specifications, product properties and handling.

### TERMS OF SALE

Please refer to your local sales office for full details of Terms and Conditions.

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A Material Data Safety Sheet (MSDS) for each product is available on our website and also automatically accompanies your order. If one is not immediately available, a copy will be sent via mail as soon as possible. If an MSDS is needed prior to shipment of a product please contact us or visit [www.alfa.com](http://www.alfa.com).

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# High Purity Materials for **Photovoltaics**

## **ALFA AESAR NORTH AMERICA**

(International Headquarters)  
26 Parkridge Road  
Ward Hill, MA 01835 USA

### Catalog Sales

Tel: 1-800-343-0660 or 1-978-521-6300  
Fax: 1-800-322-4757 or 1-978-521-6350  
Email: info@alfa.com

### Specialty & Bulk Sales

Tel: 1-888-343-8025 or 1-978-521-6401  
Fax: 1-978-521-6366  
Email: specialquotes@alfa.com

## **ALFA AESAR UNITED KINGDOM**

Shore Road, Port of Heysham Industrial Park  
Heysham, Lancashire LA3 2XY, England  
Tel: +0800 801812 or +44 (0)1524 850506  
Fax: +44 (0)1524 850608  
Email: UKsales@alfa.com

## **ALFA AESAR GERMANY**

Postbox 11 07 65  
76057 Karlsruhe, Germany  
Tel: +49 721 84007 115  
Fax: +49 721 84007 201  
Email: Eurosales@alfa.com

## **ALFA AESAR FRANCE**

2 allée d'Oslo  
67300 Schiltigheim, France  
Tel: 0800 03 51 47 or +33 (0)3 8862 2690  
Fax: 0800 10 20 67 or +33 (0)3 8862 6864  
Email: FrVentes@alfa.com

## **ALFA AESAR CHINA**

Room 1509  
CBD International Building  
No. 16 Yong'An Dong Li  
Chao Yang District, Beijing, China 100022  
Tel: 800-810-6000 or 86 (010)-8567-8600  
or 400 610 6006  
Bulk Sales: 800 810 6006  
Fax: 86 (010)-8567-8601  
Email: saleschina@alfa-asia.com

## **ALFA AESAR KOREA**

7th Floor Mirae-Plaza Building  
165-1 Donggyo-Dong, Mapo-Gu  
Seoul, 121-753, Korea  
Tel: 82-2-3140-6000  
Fax: 82-2-3140-6002  
Email: saleskorea@alfa-asia.com

## **ALFA AESAR INDIA**

(Johnson Matthey Chemicals India Pvt. Ltd.)  
3rd Floor, 108 Sir Theagaraya Road  
Survey No 195, 196, Kandlakoya Village  
Medchal Mandal, R R District  
Hyderabad 501401, India  
Tel: +91 8008 812424  
Fax: +91 8418 260060  
Email: India@alfa.com

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