



High Performance Metal Solutions

High Performance Solutions in Thin Film Materials

H.C.Starck 

High Performance Metal Solutions

Introducing H.C. Starck Solutions

Refractory metals, ceramics, and electronic chemicals form the core of a product and service offering that secures our role in each of today's fastest growing industries. Offering outstanding expertise in high tech materials, H.C. Starck Solutions is your best choice for innovative, high value products. Our major production sites and branch locations in America, Asia, and Europe allow us to serve our international customer base.

Our products and services are in increasing demand among customers in growth sectors such as energy, electronics, aerospace, medical, chemical processing, automotive, and several other industries.

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1

Materials

We provide a unique range of high performance materials that are unsurpassed in quality and supply reliability.

2

Development

Our intensive R&D and application-oriented expertise makes us a driving force behind new products, technologies, applications and markets.

3

Solutions

We support our customers along the entire value chain – from inorganic chemicals to finished products – with innovative and customized solutions.

Materials – Development – Solutions Driving your Value Creation

Our high tech materials and technologies, creatively combined with the innovative power of H.C. Starck Solutions, produce value added solutions for the rapidly changing field of thin film materials and sputtering technology.

| Materials |

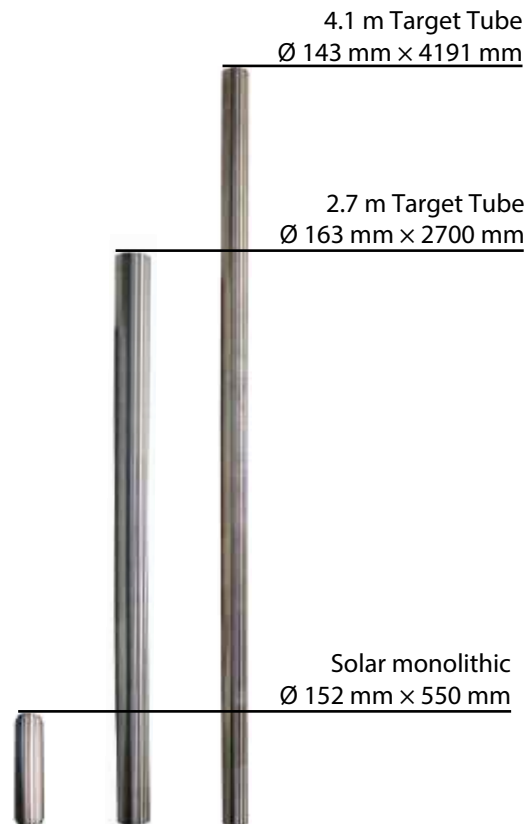
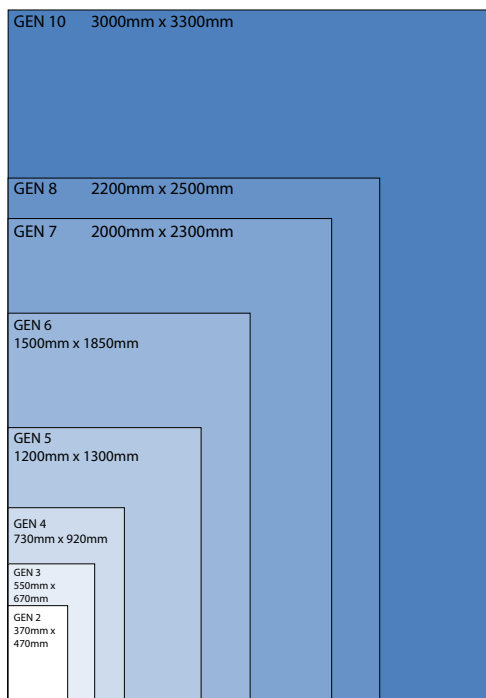
High Tech Materials for Thin Film Applications

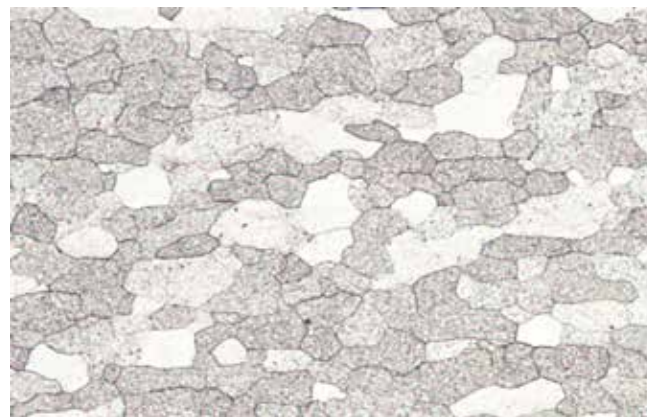
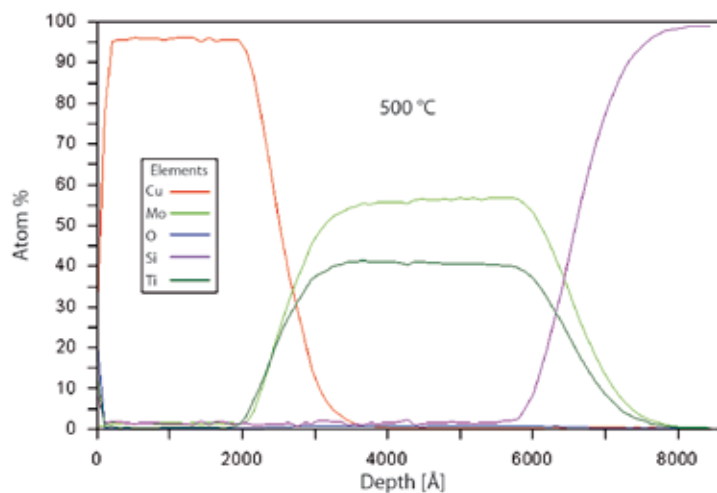
H.C. Starck Solutions a division of the H.C. Starck Group has decades of experience in the production of a unique combination of high performance materials – particularly the refractory metals molybdenum, tungsten, tantalum, niobium, rhenium and their alloys.

In thin film market applications, tantalum, tungsten and molybdenum are the most commonly used, but we also produce sputtering target materials from niobium, titanium, and alloys of copper, nickel, and molybdenum.

Common uses for refractory metal thin films include:

- > **Diffusion barriers:** Tantalum, molybdenum, and tungsten thin film layers can prevent inter diffusion between two materials in electronic devices.
- > **Optical coatings:** Reactively sputtered tantalum and niobium films have a desirably high refractive index and low absorption.
- > **Electrodes:** Molybdenum is chosen for its resistivity and good ohmic contact property.





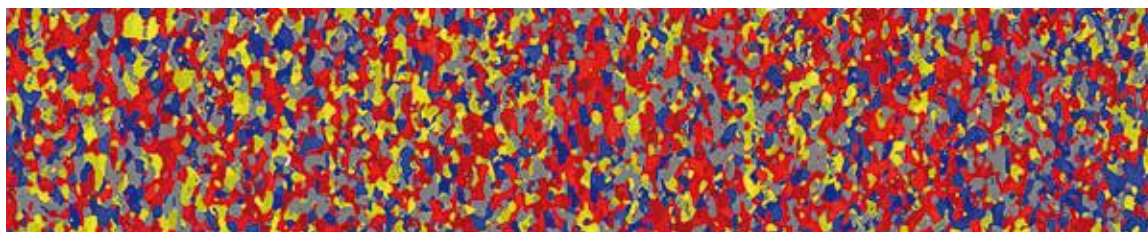
Mo Microstructure

Auger Spectroscopy is used to show that a Mo-Ti alloy barrier layer blocks inter diffusion during annealing, even at high temperature.

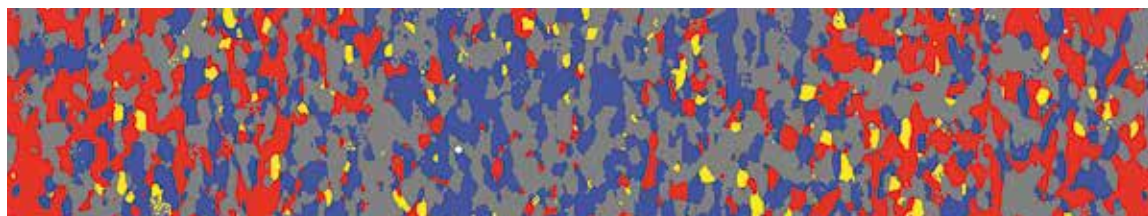
Refractory metals have special properties for thin film applications:

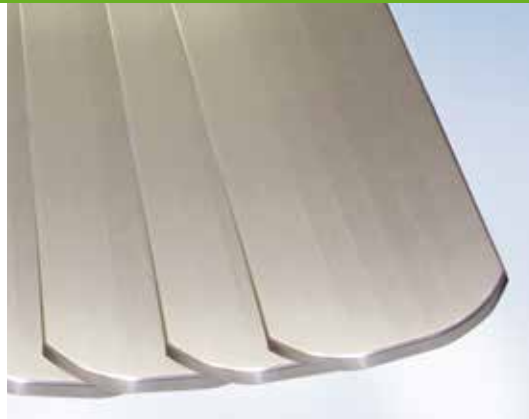
- > **Conductive but non magnetic and easily sputtered**
- > **Resistant to the harsh etchants used in device manufacturing**
- > **Good adhesion to substrates and subsequent layers**
- > **Resistant to the diffusion of impurities**
- > **Coefficients of thermal expansion that are similar to silicon sputter conditions**
- > **Low residual stress at optimum**

Mo Texture - EBSD



Ta Texture - EBSD





Security of Supply from Mine to Market

H.C. Starck Solutions is one of the world's largest producers of tungsten and tantalum metal, as well as of molybdenum metal powder. In the case of molybdenum unlike many of our competitors (who enter the supply chain much later in the process, typically after sublimation or reduction), we start with technical grade MoO_3 . By controlling the process of material production from the very beginning, we can control the physical properties of the materials we produce.

This integration of process and material control – unique to H.C. Starck Solutions – yields a superior final product.

High Tech Recycling of Refractory Metals

H.C. Starck Solutions is the only company worldwide able to extract any refractory metal by reclaiming it in a recycling process. Our recycled tungsten, tantalum and molybdenum, from spent sputter targets for example, provide the same high quality and purity as the raw material.

In the face of competition for raw materials the technically high developed recycling at H.C. Starck Solutions will continue to gain in importance. Moreover, it is a vital strategic component of a stable raw material supply. At the same time we save natural resources and minimize energy consumption.

Tantalum

H.C. Starck Solutions supplies more tantalum plate than all of our competitors combined. Our tantalum products, like all of our products, are characterized by their uniform, high density microstructure and controlled texture, which promotes uniform sputtering rates and generally superior sputtering behavior. Our tantalum processing starts with ore concentrate. We offer six different grades of tantalum, ranging from 99.95% purity to 99.995%, to meet the specific application requirements of our customers. In addition to its use in thin film PVD applications, tantalum is widely used in the chemical processing and pharmaceutical industries.

Tungsten

As one of the world's leading producers of tungsten, we supply tungsten in purity levels of up to 99.99%, in pure and alloy form. Tungsten possessing excellent properties such as extremely high density has become an essential material for applications in the thin film coating industry.

Like tantalum and tungsten – molybdenum, niobium and titanium are also transition metals that are widely used in the thin film materials industry. They also find use in a wide variety of other demanding applications.

Molybdenum

H.C. Starck Solutions as the world's largest producer of molybdenum metal powder also supplies molybdenum as finished parts. Molybdenum finds wide use in the sputtering target market for use in LCD displays, photovoltaic solar cells, and in integrated circuits. We also supply significant quantities of molybdenum to the medical equipment, aircraft, glass manufacturing, filaments, and furnace industries.

Niobium

Niobium thin film is used mostly for optical applications. Niobium, like tantalum, is highly resistant to corrosion and chemical attack.

Titanium

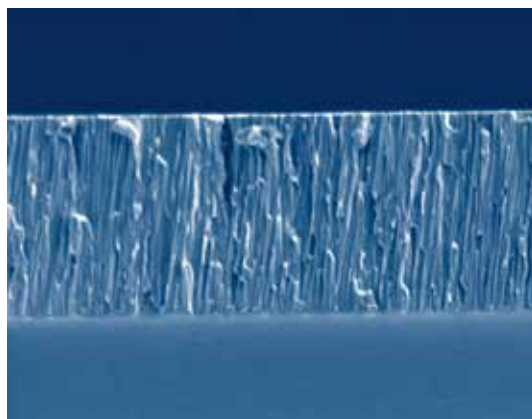
Titanium is also highly corrosion resistant, and has good electrical resistivity. It is used as a barrier layer, for LCDs, solar cells, and optical coatings.

Other Materials

H.C. Starck Solutions also supplies alloys such as:

- > MoTi (Molybdenum-Titanium)
- > MoNbZr (Molybdenum-Niobium-Zirconium)
- > MoW (Molybdenum-Tungsten)
- > NiCr (Nickel-Chromium)
- > NiV (Nickel-Vanadium)

As the PVD market continues its explosive growth, H.C. Starck Solutions is developing new alloys and other materials to meet the challenges of OEMs in every market segment.



The morphology of a thin film can only be seen in an electron microscope. Here, both a side view and a top view are shown.

| Development |

The Key to Customer Value

Development is the bridge that connects our material expertise with its practical application to our customers' products – our innovative solutions.

The number one goal of H.C. Starck Solutions is to manufacture materials for sputtering targets that produce high quality, uniform coatings while ensuring cost effective target utilization. Our focus at the Fabricated Products Group of H.C. Starck Solutions is to ensure that our R&D and product development activities are contributing to that effort. That's why all of our development activities, whether they are conducted in our laboratories or at our manufacturing plants, are always customer driven.

Because we are involved in several different thin film market sectors (LCD flat panel display, photovoltaic solar cells, integrated circuits, data storage, optical coating), we are a key player in the development of new products and technologies for the overall market. We are providing technology that improves quality and performance. We work closely with our customers, providing on site support that delivers superior, cost effective product solutions.



H.C. Starck Solutions' thin film laboratory is capable of sputtering experimental targets under a wide variety of conditions.

The Innovative Power of H.C. Starck Solutions

World class R&D, innovative application technology, and unparalleled laboratory services allow us to work on customers' projects with tremendous energy and focus, resulting in accelerated product development and reduced time to market.

By focusing our development activities on what is important to our customers, we can help them optimize product performance while minimizing costly materials. Our technical and sales personnel are constantly working with customers, not just to develop specific solutions to existing applications, but also to help them create innovative new products. For example, our work with the manufacturers of LCDs has resulted in the development of new barrier layer materials. In the area of integrated circuits we have developed processes to enhance Tantalum thin film characteristics.

The Driving Force Behind New Products

Innovation and research are key strengths at H.C. Starck Solutions. As a worldwide leader in refractory metals – from inorganic chemicals to finished products – we have state of the art laboratories where we are constantly refining and improving our products and materials.

The Fabricated Products Group boasts an R&D team of highly skilled professionals, including numerous Ph.D.'s and degreed engineers. This group conducts R&D programs that are shaped by constant dialogue with our customers. By listening to their needs and requirements, our R&D team helps customers develop new and innovative products for the future. Many of them work in our Thin Film Materials Lab, which is equipped with a full array of state of the art analytical equipment, including:

- > **Scanning Electron Microscopes (including both Electron Backscatter Diffraction and Energy Dispersive X-Ray Spectroscopy types)**
- > **4-Point Resistivity Probe**
- > **Spectrophotometer**
- > **Vacuum Annealing Equipment**
- > **Adhesion Tester**
- > **Film Stress Tester**
- > **Magnetron Sputtering Equipment**

This group is backed up by a Central Research and Development Division at corporate headquarters in Goslar, Germany, as well as by R&D facilities throughout Europe, North America and Asia, in order to support our customers around the world. Our state of the art labs routinely conduct tests for structure, porosity, microhardness, layer adhesion, diffusion, particle count, differential interference contrast, and many other tests.

Rapid Response Team

One innovation we're particularly proud of is our Technical Liaison and Rapid Response Team. They're prepared to continuously improve quality, and they are ready to address and resolve problems. Our experts provide on site customer technical support and consultation – and always with a one day response time.



Ultrasonic testing of thin film materials.

| Solutions |

Value Added Solutions for Growing Markets

The Fabricated Products Group of H.C. Starck Solutions uses its expertise in molybdenum, tungsten, tantalum, niobium, and specialized alloys to produce high performance thin film materials for a number of significant, growing markets.



Source: Infineon Technologies AG



Flat Panel Displays – Thin is In

LCD flat screen monitors are getting thinner – with higher resolution – every day.

H.C. Starck Solutions' ultra pure materials serve as an electrode, adhesion, or diffusion layer in coatings used for TFT-LCDs found in TV screens, computer monitors, cell phones, GPS systems, and other displays. We supply sputtering target materials to all the major display manufacturers around the world. They value the high purity, density, and uniform microstructure of our materials, as well as their low resistivity, high power density, and generally superior sputtering performance.

Faster, Smaller, Better – Electronics & Data Storage

We also supply sputtering target materials to the manufacturers of integrated circuits and optical data storage devices such as CDs and DVDs. The fast changing landscape of the data storage market (higher storage capacities, recordable and re-writeable discs) is putting increased demands on sputtering target materials. Integrated circuit manufacturers value the properties of our ultra pure materials and their consistent performance.

The Sun is Shining on the Solar Energy Market

The solar energy market has come of age. As the costs of fossil fuels skyrocket, the photovoltaic (PV) solar energy industry is poised to enter a period of explosive growth. Experts in the field predict that larger and more efficient PV panels will be the norm as solar energy producers strive to reduce production costs. Thin film PV, which up until a few years ago was a much smaller segment of the PV industry, is now one of the most vibrant areas of the market.

H.C. Starck Solutions continues to play a significant role in this market. We manufacture rotary and planar sputtering target materials made of high purity molybdenum for CdTe and CIGS based solar cells, and rotary NiV targets used for Si thin film solar cells. We also produce target materials from titanium, niobium, and other materials. As the PV solar cell market changes, H.C. Starck Solutions will continue to be a leader. We conduct active research into new solar cell technologies and we continue to expand our capabilities to produce planar and rotary configurations for ever larger targets.

Large Area Coating - A Smooth Future

Over the past few decades, the glass industry has used advanced coating technologies to produce value added products that meet the growing needs of its markets. Among others, the architectural, automotive, and display industries have driven the demand for products that provide improved aesthetics and functional comfort. H.C. Starck Solutions has helped facilitate this growth with materials that meet the stringent technical requirements of the industry.

For example, a major challenge in large area coating applications is to increase coater throughput while simultaneously maintaining all aspects of layer quality. The purity and uniformity of H.C. Starck Solutions rotary target materials helps coaters achieve excellent control of each separate deposition process, including optical, electrical, and mechanical layer properties. This results in the ability to coat very large area substrates while still obtaining high precision results.



By any Standard, our Quality Measures up

Customers in the computer, photovoltaic solar cell, integrated circuit, data storage and optical coating industries set high standards for the quality of their products – and ours. Because of our experience in these industries and also in the medical, aerospace, and other markets which we serve, we're used to exacting quality assurance standards. H.C. Starck Solutions products meet not only the requirements of our individual customers (we routinely achieve Preferred Supplier Status), but also all international quality management standards such as EFQM, ISO 9001:2000, RoHS, and ISO 14000 environmental management standards.

Our Quality Assurance Labs are staffed with certified quality engineers and technicians using sophisticated measuring and state of the art analytical equipment.

Adding Value at every Level

Complementing our material expertise, R&D, and application technology is our broad range of value added operations. Our extensive precision machining capability allows us to manufacture finished products to extremely tight specifications for fit, surface finish, and other characteristics.

Finally, the synergy between the Fabricated Products Group and other H.C. Starck Solutions business units allows us to bring unique resources to bear on customers' application challenges that our competitors cannot match.

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