High Performance Metal Solutions

High Performance Solutions for the LED Industry

H.C.Starck

High Performance Metal Solutions

Our Commitment to Engineering Excellence

H.C. Starck Solutions delivers superior quality with material consistency and product reliability. H.C. Starck Solutions achieves world class quality through continuous research of new products, development of engineering solutions, and applying them in H.C. Starck Solutions' manufacturing environment to deliver premium products for the most challenging applications.

Nearly 100 years of powder metallurgical experience is the cornerstone of H.C. Starck Solutions' success in producing advanced technology metals for fast growing industries including aerospace, chemical processing, electronics, industrial, medical, and energy. As one of the world's leading suppliers of molybdenum, tungsten, tantalum, niobium, and their alloys, H.C. Starck Solutions is at the forefront of creating solutions with next-generation materials and fabricating engineered components for a diverse spectrum of markets.

- > **Product Quality and Service**
- > **Manufacturing Excellence**
- > **Research and Development**
- > **Reclamation and Recycling**






Strategic Advantages of Working with H.C. Starck Solutions

H.C. Starck Solutions understands market trends and the latest cutting-edge technologies providing us the opportunity to create value-added solutions for complex applications. In addition, our robust and sustainable vertically integrated supply chain enables us to deliver high performance materials and products seamlessly to the marketplace.

A recognized leader in refractory metal technology, H.C. Starck Solutions' knowledge and technical expertise benefit customers through joint collaborations with our dedicated team of research engineers. This collaborative effort facilitates new and improved product designs through a study of the product's life-cycle. Extensive in-house state-of-the-art laboratory facilities with the latest in analytical tools, testing equipment, modeling and simulation software assist engineers in evaluating product performance. Innovative material solutions provide texture control thus enhancing the uniformity and performance consistency.

With over 30 locations worldwide including Asia, Europe, and the Americas, H.C. Starck Solutions offers exceptional customer care with local sales and technical support. Our local presence coupled with multiple global manufacturing sites permits us to effectively respond to our customer's requests.

LED – the Next Generation in Solid State Lighting

Solid state lighting has seen rapid adoption in the electronics industry as backlighting for flat panel display applications, and the automotive industry. The next wave of innovation will be in the general lighting industry for interior designs, architectural, municipal, and home lighting, which will drive tremendous growth in white LEDs.

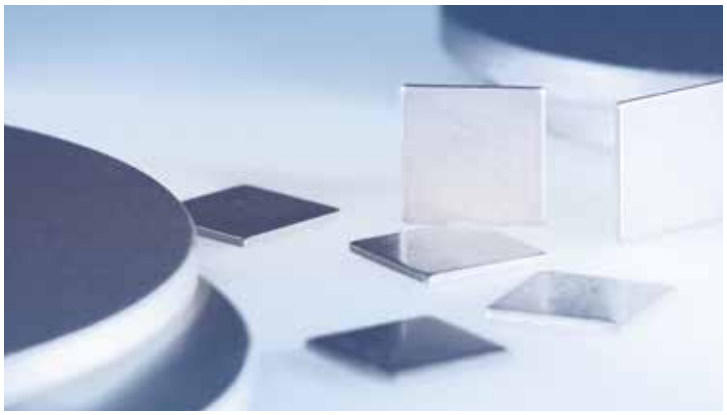
The most attractive features of LEDs are their high energy efficiency, miniature size, environmentally friendly and longer service life. H.C. Starck Solutions' engineered product solutions support the LED market with products critical to the success of the sapphire crystal-growing industry's high temperature furnaces. LED cutting-edge technology requires refractory materials – molybdenum and tungsten that do not contaminate molten alumina during the crystal growth process.

H.C. Starck Solutions' molybdenum crucibles for sapphire crystal growth are pressed, sintered, and formed to a customer's required specification. The tungsten crucibles are pressed, sintered, and precision machined to achieve both the shape and required surface finish needed for easier release of the sapphire boule from the crucible at the end of its growth cycle.






Sapphire Crystal Growth in High Temperature Furnaces



The furnace industry has seen remarkable growth in the production of custom-made, high temperature vacuum or argon atmosphere furnaces for growing sapphire crystals used in the production of LEDs. These furnaces have unique and demanding hot zone designs for melting alumina in crucibles for precise, highly controlled crystal growth.

Whether by KY, EFG, CZ, or HEM-like methods (GTAT, CHES, and VHGF), H.C. Starck Solutions is well versed in these different sapphire crystal growth methods and supplies engineered product solutions for all technology platforms.

The hot zones in sapphire growing furnaces use H.C. Starck Solutions' molybdenum and tungsten products for furnace components and fixtures. These high temperature materials are characterized by their high thermal and electrical conductivity, low coefficient of thermal expansion, and excellent strength and stability at temperatures above 2000 °C.

Customer specific furnace components and fixtures for high temperature furnaces are uniquely designed and supplied by H.C. Starck Solutions. We machine and fabricate products from molybdenum and tungsten rod, plate, sheet, and foil:

- **Seed Holders**
- **Hot Zones**
- **Heating Element Materials**
- **Other Support Components**

Contributing to the LED Manufacturing Process

Beyond the critical sapphire growth process, H.C. Starck Solutions offers engineered product solutions for all the other critical process steps in the manufacturing of LEDs.

In the production of phosphors, H.C. Starck Solutions' molybdenum and tungsten crucibles and boats are either pressed and sintered, or made from formed flat rolled material. Moreover, H.C. Starck Solutions' hot zones and furnace components are uniquely designed for phosphor production furnaces and are machined or fabricated to meet specific temperature requirements.

MOCVD equipment plays an important role in the LED manufacturing process. H.C. Starck Solutions' product solutions are fabricated from molybdenum and tungsten materials for complex assembly configurations:

- **Collector rings**
- **Heaters**
- **Wafer carriers**
- **Heat sinks**

Additionally, we offer molybdenum and Mo-Cu clads materials for base plates and heat spreaders for heat dissipation in LED devices.

H.C. Starck Solutions' engineered components and fabricated products manufactured from molybdenum, tungsten, and their alloys are used in products for LED applications:

Crucibles and Hot Zones

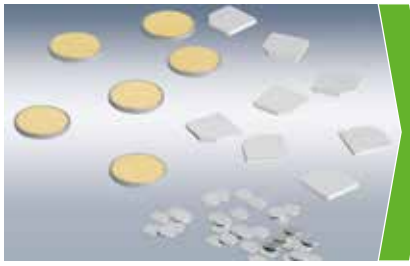
Sapphire Crystal and Wafers

Substrate for Heat Sinks

Heat Dissipation

Hot Zones and Furnace Components

Phosphor Production



Substrate for Heat Sinks

LED Lamp

H.C. Starck Solutions‘ Products for the LED Market

H.C. Starck Solutions Materials	H.C. Starck Solutions Products	End Product	Applications
Mo, W, Mo-La, Mo-W	> Crucibles > Hot Zones > Furnace Components	Crystal Growth Furnaces	Sapphire Crystal Growth
Mo, W	> Collector Ring > Heater > Wafer Carriers > Heat Sinks	MOCVD Equipment	Epitaxial Growth
Mo, W, Mo-La, Mo-W	> Crucibles > Hot Zones > Furnace Components	Furnaces	Phosphor Production
Mo, Mo-Cu	> Base Plates > Heat Spreaders	LED Devices	Heat Dissipation
Ceramic Powders			
Si_3N_4, AlN	Nitride powders	Phosphor powders	Phosphor powders & coatings
AlN	AlN powders	Substrate materials	Thermal management in LED-packaging

High Purity Nitrides for LED Phosphors

H.C. Starck Solutions supplies non-oxide ceramics for high-purity requirements of LED phosphor products. Our Silicon nitride (Si_3N_4) and Aluminum nitride (AlN) powders are used as matrix materials for (oxy-) nitride based phosphor formulations.

In general, the advantages of nitrides are excellent durability and thermal stability. Furthermore, high purity nitrides enable a broader range of color combinations.

There is a strong demand for white LED-light for the indoor lighting market that is still in the early phase of competition with current technologies for indoor lighting like CFL’s and standard light bulbs.

Nitrides of H.C. Starck Solutions support the development and production of new (red) phosphors to allow LED manufacturers to produce new LED-lighting devices that will address the needs of the indoor lighting market of the future.

H.C. Starck Solutions' Secure Material Supply Chain

H.C. Starck Solutions' Responsible Supply Chain Management System (RSCM) contributes to its reliable and secure supply chain through the procurement of raw materials that ensures efficient and competitive purchasing. RSCM helps to avoid sourcing from conflict regions in the world or from suppliers that do not act in line with environmental and social sustainability. The RSCM system fulfills all requirements of a management system standard required by ISO and has been confirmed by the external auditor, Bureau Veritas.

H.C. Starck Solutions is one of the first companies to pass a second consecutive audit under the Conflict-Free Smelter (CFS) Validation Program introduced in 2010. The program, created and driven by the electronics industry, is being recognized and adapted by many metal industries determined to eliminate unethical sources of raw material from their supply chains. The term "conflict minerals" applies to minerals (including tantalum, tin, tungsten and gold) that have originated in conflict regions where production and trade is closely connected with ongoing abuse of human rights.

In addition to the securing a conflict-free raw material supply chain, H.C. Starck Solutions reclaims spent materials for our customers. A recognized leader in Green Technology, H.C. Starck Solutions is a founding member of the Center for Resource Recovery and Recycling (CR3) coalition. H.C. Starck Solutions was also awarded the Sony "Green Partner" certification, one of the best established programs of its kind, and is a gold standard of the electronics industry. H.C. Starck Solutions' treats sound environmental standards, robust supply chain, energy efficiency and recycling as foundational pieces of our strategy.

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