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The Duplex Dragon

Deep within the Tarim Basin of Xinjiang, China, pipelines transport natural gas as it is extracted and refined for distribution throughout the country. However, gas leakage has been a recurrent issue as a result of pipeline corrosion. Enter the 'Pipeline Dragon': constructed entirely of molybdenum-containing 2205 duplex stainless steel, a new pipeline promises to reduce gas leakage, preventing environmental disaster while conserving resources. At 4,500 tonnes, it is the largest single order of duplex stainless steel in China to date.

Some of the earliest uses of natural gas date back 500 BC, when the Chinese used hollow bamboo stalks to transport gas into stoves that boiled seawater for salt. Today, China's natural gas industry continues to grow as the country seeks to reduce its carbon footprint and move away from its dependence on coal. One of the largest domestic deposits of raw gas that supplies this industry is found in the Tarim Basin, which is estimated to contain over 200 trillion cubic feet of natural gas in underground reserves.

Gas production in the middle of nowhere

The Tarim Basin sits in a sparsely populated area of China's westernmost province. The production and transport of natural gas in this desert region is no small feat. The challenging, wind-swept terrain and the lack of access roads make the drilling of wells and especially the building of pipelines extremely difficult, time-consuming, and expensive.

The new pipeline is located in the Tarim Basin of China's Xinjiang Province, highlighted in orange.

From the wells, raw gas is transported through pipelines to nearby refineries for processing. Balancing gas input with refinery capacity is vital to maximize productivity. Therefore, a new pipeline, the Pipeline Dragon, connecting two refineries, has been started. When it is finished, the refineries will be able to route the flow of gas to optimize capacity utilization.

Eventually, the refined gas from the Tarim Basin feeds into the massive West-East Gas Pipeline for use across China.

Preventing gas leaks

The environmental conditions in the Tarim Basin pose several challenges to pipeline operation. The vast, Taklamakan desert is extremely dry. Summers are hot and winters are cold, and strong winds often form massive dust storms, making for extremely difficult working conditions. The soil in the area is classified as highly corrosive. It can contain significant concentrations of soluble salts, left behind by evaporating water over the millennia. Furthermore, the raw gas is high in carbon dioxide and contains up to 10% chlorides, increasing its corrosiveness. In this environment, only a highly corrosion resistant material can provide a permanent solution. ›

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International Molybdenum Association
454-458 Chiswick High Road
London W4 5TT, United Kingdom
www.imoa.info
info@imoa.info
+44 20 8747 6120

Editor in Chief:
Nicole Kinsman

Managing Editor:
Karlee Williston

Contributing Writers:
Rikki Li (RL), Michael Bold (MB), Martina Helzel (MH), Philip Mitchell (PM), Karlee Williston (KW)

Layout and Design:
circa drei, Martina Helzel

Cover photo:
The Pipeline Dragon is located in a remote desert area in western China. © Cheng Xingbao

Duplex stainless steel pipes awaiting installation in the field. © Wang Qinghai

Pipelines carrying corrosive raw gas here have typically been built from clad pipe, a carbon steel pipe that is internally lined with a thin layer of Type 316 stainless steel. Such a pipe can resist corrosion by the aggressive gas and is initially less expensive than a solid stainless steel pipe. However, welding clad pipe in the field is far more difficult than welding it in the controlled environment of a factory. The internal stainless steel weld bead can become diluted with carbon steel, lowering its corrosion resistance. Weld corrosion of clad pipe has been found to be a cause of frequent leaking in the Tarim Basin.

The ensuing environmental damage, loss of revenue and, in the worst case, explosions, mean that leaks must be fixed as quickly as possible. However, finding and repairing leaks is challenging, time-consuming and even dangerous in the desert sands of this difficult to access area. The gas company, therefore, sought a more robust pipe material for the new pipeline to prevent leaks from occurring in the first place.

Scales reinforced with molybdenum

The new pipeline connecting the two refineries is 3.3 kilometers long and has diameters of 325 and 406 millimeters, with wall thicknesses between seven and 17 millimeters. To completely avoid corrosion, the engineers chose a solid stainless steel solution rather than coated or clad carbon steel pipe. A literature study and testing concluded that 2205 duplex stainless steel would be able to resist the corrosive raw gas. With 3% molybdenum, this stainless steel grade has superior pitting and crevice corrosion resistance to Type 316 stainless steel.

To test whether 2205 duplex stainless steel would also be resistant enough to the salt-laden desert sand, a three-year corrosion study was conducted. Test samples, buried in the sand, were examined at yearly intervals with satisfactory results.

In addition to its corrosion resistance, duplex stainless steel provides other advantages to such projects: its superior strength enables thinner wall thicknesses and reduced weight of the finished pipe, facilitating transport, handling and installation, important considerations in the extreme weather of the Tarim Basin. The thinner wall thickness also reduces welding time and cost, without the complications associated with clad pipe.

These advantages translate to a long and maintenance-free service life, contributing to the protection of the

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Workers inspecting the new pipeline. © Cheng Xingbao

environment and the safety of the workforce. And despite a slightly higher initial cost compared to clad pipe, the duplex solution has a significant impact on lowering the overall cost of gas production.

An enduring solution

Life Cycle Costing (LLC), where material selection is based not just on initial installation costs, but also on cumulative costs of future maintenance and operations, is becoming more prevalent. Over time, a duplex stainless steel pipeline can pay for itself in avoiding gas loss and eliminating repair and replacement cost.

Xinjiang's 'Pipeline Dragon' not only optimizes natural gas production in western China but also spearheads the country's commitment to a more sustainable future in energy. The robust investment in a duplex stainless steel pipeline signifies a move away from less expensive construction to sustainable, long-lasting solutions. (RL)

Many thanks to Mr. Wang Qinghai and Ms. Wang Qiyan, at TISCO for their help in preparing this article.

No moly – no life!

Molybdenum is vital for keeping organisms fit and healthy. In fact, molybdenum is an 'essential trace element', which means human, animal and plant life could not survive without it. Its bio-essentiality derives from molybdenum-dependent enzymes that are required not only for human health, but also for the health of the ecosystem as a whole.

IMOA's website offers a comprehensive account of why molybdenum is essential for life. For example, the *Molybdenum Essentiality* video on IMOA's You Tube channel explains that "molybdenum is required for several important chemical reactions in humans and animals, including the metabolism of nitrogen and sulfur compounds as well as nitrogen fixation in plants. However, the body cannot make molybdenum compounds, so they have to come from external sources, including food".

Molybdenum is found in several foods, including cauliflower and walnuts.

Rich and varied sources of molybdenum

Molybdenum is found in combination with sulfur in the mineral molybdenite and with oxygen in naturally occurring molybdate in oceans, rivers, and soils. It is present in a range of everyday foods including cows' milk, lentils, nuts, whole grains, meat (particularly offal) and vegetables such as spinach, cauliflower and kale. Many over-the-counter multi-vitamin and mineral dietary supplements also contain molybdenum, typically providing around 50 micrograms per dosage.

50 micrograms are about what the human body needs every day to remain healthy. Molybdenum intake varies around the world and depends in part on the soil in which vegetables and other plants grow. It typically ranges from 20 micrograms per day in areas of poor diet or soil quality, up to 560 micrograms. For instance, an average daily diet in the USA contains roughly 90 micrograms. Excessive intake is highly unlikely in a person with a reasonably healthy lifestyle. Using homeostatic mechanisms, human bodies self-regulate the level of molybdenum and other essential elements to keep them within optimal ranges, excreting any excess.

Because it is normally sufficiently present in the diet, clinical molybdenum deficiency is extremely rare. One case in existing literature describes how a patient on an artificial diet, where calories and nutrients were delivered into a vein, received no molybdenum at all for 18 months. The patient developed symptoms of molybdenum deficiency, that were reversed by adding ammonium molybdate to the artificial diet.

Molybdenum's role in human metabolism

In humans, molybdenum is an essential constitutent of enzymes that help to digest food, produce energy and eliminate waste products. However, scientific research into the function and properties of molybdenum did not begin with its ›

Molybdenum is essential for healthy humans, animals and plants. © iStockphoto.com/vitranc

role in humans. Rather, molybdenum was first found to be essential for plants in the early 1930s, and subsequently in the 1940s and 1950s for bacteria, animals and humans. Over time, studies of the role of molybdenum have shown that it is required for the formation and activity of several enzymes in human bodies, with various vital body functions being reliant on these enzymes.

Molybdenum has an essential role in enabling the human body to use biological sulfur compounds. They are crucial for the structure of connective tissue. Optimal performance of the connective tissue relies on molybdenum, because it is indispensable in the activity of the sulfite oxidase enzyme. This enzyme converts toxic sulfite into sulfate, a stage in enabling the sulfur in the body to carry out its function by a reaction called sulfation. Furthermore, human livers cannot function properly if there is an excessive build-up of sulfites and an insufficient supply of sulfates. So, molybdenum supports liver detoxification, promotes connective tissue development, and contributes to the sulfur balance throughout the human body.

Molybdenum is likewise required in the functioning of the enzyme xanthine oxidase, which converts hypoxanthine and xanthine to uric acid. The latter contributes to plasma antioxidant capacity within the bloodstream. Finally, molybdenum also plays a role as a cofactor for the enzyme aldehyde oxidase, present at high levels in the liver and lung, and implicated in the detoxification of environmental pollutants and xenobiotics, such as drugs and food additives.

Continuing the learning process

Molybdenum is a crucial mineral nutrient, found in a wide range of foods, without which humans, animals and plants would not survive. Ongoing research continues to explore the full extent of molybdenum's role in the human body, especially in protecting the organism against neurological and other diseases, including cancer. However, it is clear that life on earth would not be possible without this life sustaining, bio-essential element.

For further information, explore the Health, Safety and Environment and Molybdenum for Life sections of the IMOA website at www.imoa.info and watch Dr Philip Mitchell on the essentiality of molybdenum on IMOA's YouTube channel. IMOA's regularly updated database *Database of Molybdenum in Human Health and the Environment* (https://www.imoa.info/HSE/environmental_data/database.php) is a searchable source of information on all aspects of molybdenum in biology and the environment. (MB)

Floating towards the future

Like a net frozen in mid-air, a striking footbridge in southern Germany is making a statement about minimalism. This gossamer structure is only possible thanks to the unique characteristics of 2205 duplex stainless steel.

At first glance, it resembles a giant piece of metallic silk. But this airy bridge offers more than just good looks; it represents new possibilities for sustainability and efficiency in structural design. The footbridge connects two production areas of the TRUMPF campus in Ditzingen near Stuttgart, Germany. International success and growth meant the only way to expand was to the other side of a busy country road. With the campus divided in two, getting from one part to the other was cumbersome. Besides crossing the road, checking in and out of security gates increased the amount of time taken. The new bridge not only provides employees and visitors with a way to move around their campus, but also serves as a showcase for what is now possible in laser-cutting technology – one of the main products of the company.

An elegant reduction

The 28-meter long and 10-meter wide footbridge was designed by schlaich bergermann partner. It consists of double curved stainless steel sheets just 20 millimeters thick. To reinforce the lightweight structure, all edges are folded downwards and twist towards the four base points to form triangular bearing points. No further bracing was required in the shell to support the 21-tonne bridge. To create the ethereal feel of the structure, holes corresponding to the flow of forces were cut into the shell with laser machines. Their size and placement were calculated to maximize airiness while maintaining structural integrity.

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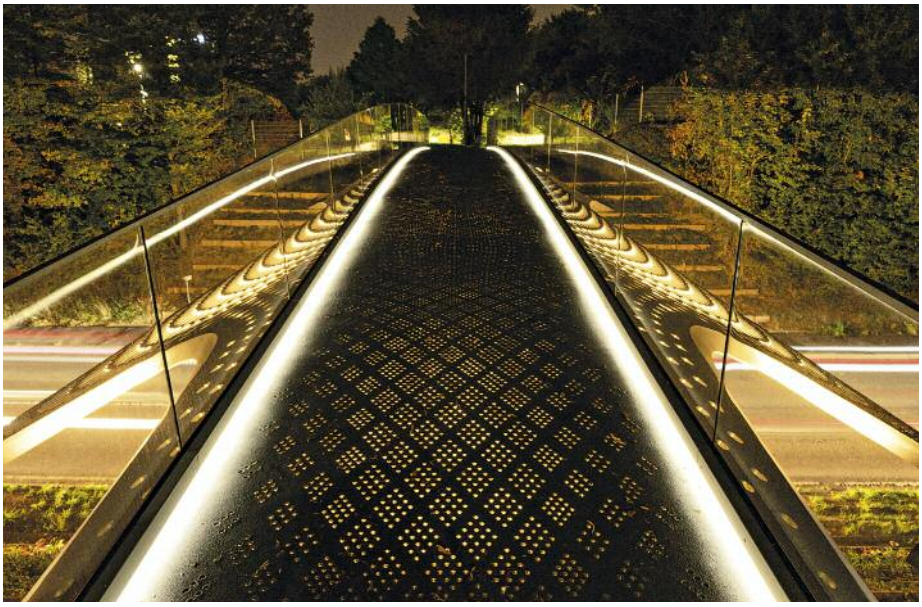
Pedestrians walk directly on the stainless steel shell, which is treated with a slip-resistant coating. The holes in this area are smaller but more numerous and filled with glass plugs. These bundle the daylight and increase the transparent appearance. During the night, the effect inverts; light from LED spotlights under the bridge shines through the glass fillings in the walking area and the lateral areas of the structure. Additionally, the lightness of the bridge is accented by anti-reflective, all-glass railings. The culmination of these effects is a bridge that appears not only to float, but also to softly glow as it hovers over the country road.

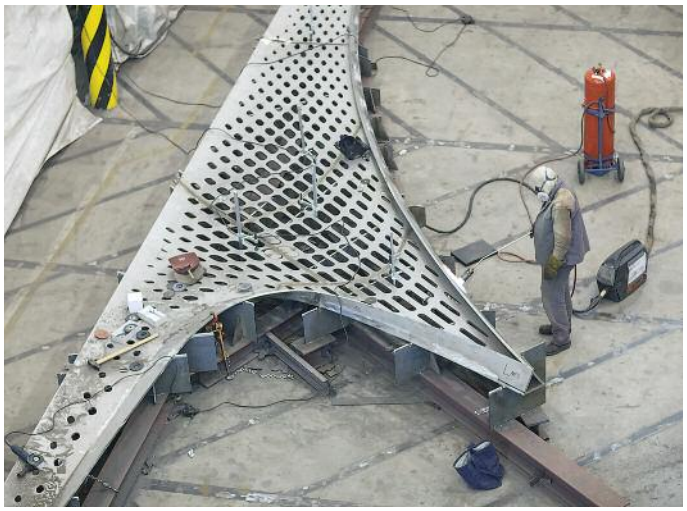
2205 Duplex: less is more

To realize the unique design of the bridge, 2205 duplex stainless steel was an ideal choice. With its 3% molybdenum content, it resists the corrosive environment ›



At night, LED lights illuminate the bridge on both sides of the walkway and from underneath. © sbp/Andreas Schnubel

Due to the optimized design, the bridge is so light, it appears to float over the road. © sbp/Andreas Schnubel



The lasered stainless steel sheets are formed three dimensionally on a heavy press (left). Afterwards these sheets are welded together into four quarters. The 'folded' edges that reinforce the lightweight shell construction are actually attached by welding. © Wilfried Dechau

created by deicing salts used both on, and under, the bridge. While a similar design may have been possible in carbon steel, it would not have been practical given the many perforations. Sealing all these surfaces with a protective coating would have been intricate work and therefore, expensive. Additionally, this process would have had to be repeated regularly as the coatings deteriorated, resulting in enormous maintenance costs. Finally, the bare stainless steel surface also affords the bridge a crisp and modern look.

Innovation meets tradition

The duplex stainless steel sheets were cut to shape and holed by modern laser technology. Nevertheless, forming the high-strength duplex stainless steel into double-curved shapes was not easy. Turning the 20-millimeter-thick flat sheets into the three-dimensional structures prescribed by the data model, required operator experience as well as a heavy press at a traditional shipbuilding firm. There they were also welded into seven larger pieces of the bridge. These parts were then transported to a field factory adjacent to the installation site and welded together. Lastly, a heavy-duty crane lifted the entire bridge into its final position. Due to the bridge's strength and light weight, the crane was able to lift it quickly and with minimal disruption to traffic.

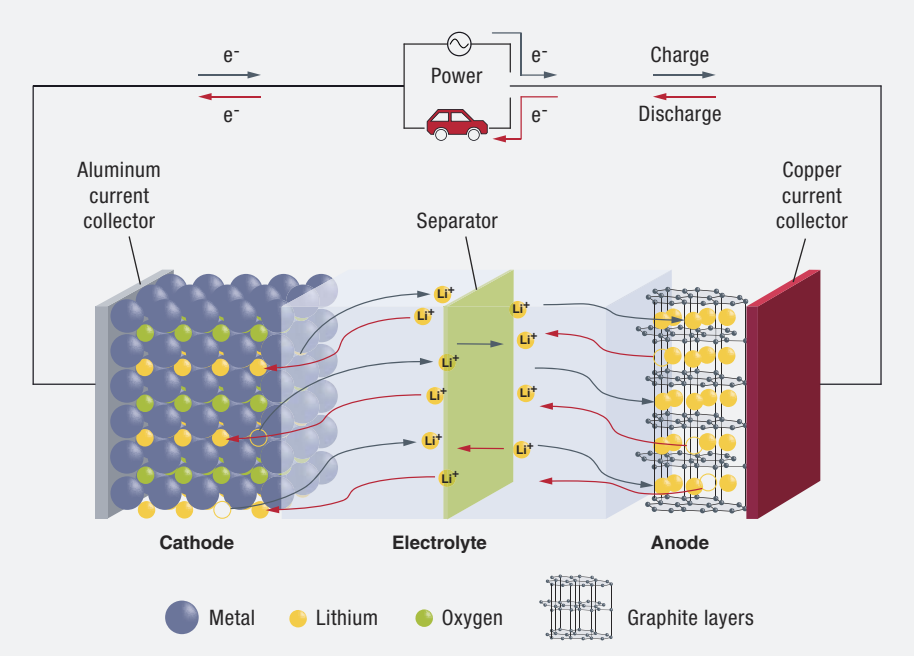
With its striking design and innovative use of material, the bridge sets new standards. The interplay between high strength, work hardening rate, and elongation means that duplex grades are particularly well suited to lightweight and cost-efficient applications with complex shapes. Due to the excellent weldability, structural components can be prefabricated in large sections and installed on site very quickly. The possibilities are endless. This beautiful, almost weightless bridge shows that sustainable, efficient architecture can also be high art. (MH)

The bridge being lowered into its final position by crane; it is only self-supporting once placed in this exact position. © schlaich bergermann partner

Moly to boost batteries?

When developing sustainable technologies such as renewable energy solutions and electric vehicles, power storage is as crucial as power generation. To this end, improving battery performance is an area of enormous scientific interest. Numerous studies show that molybdenum disulfide composites could play a key role in increasing batteries' electrical power, energy storage capacity, recharging speed and stability.

Laptops, mobile phones, electric scooters and a plethora of other rechargeable devices all depend on lithium-ion/graphite (LIB) batteries. But some scientists and urban planners imagine a future where batteries could do much more e.g. power airplanes or even entire cities. These promising ideas, as well as longer ranges for electric vehicles, remain limited by the relatively low storage capacity of the graphite anode in commercial LIBs. However, researchers may finally have a robust solution to this problem. Certain molybdenum disulfide (MoS_2) composite anodes have been found to have two to three times the storage capacity of graphite. Therefore, molybdenum-containing compounds in batteries could offer significant improvements over currently available energy storage capacity.



A lithium-ion battery cell with lithium-metal (Co, Ni, Mn, or Al) oxide cathode and graphite anode. During charging, electrons (e^-) travel from the cathode round the external circuit to the anode and lithium ions, Li^+ travel through the electrolyte. The opposite movement occurs when the battery is used to power a device. In a MoS_2 cell MoS_2 or a composite replaces the graphite anode. Re-drawn from Liang et al. 2018. Copyright 2018 Elsevier.

Molybdenum disulfide history in batteries

From electric shavers, to drones, to electric vehicles, batteries are ubiquitous; but, what *is* a battery, and how is molybdenum involved? A battery is a cell or set of connected cells that convert chemical energy to electrical energy. Each cell contains a negative terminal, the "anode," and a positive terminal, the "cathode." Both the anode and the cathode, known generically as "electrodes," are immersed in an electrolyte that conducts electricity. For example, sulfuric acid is the electrolyte in the traditional lead-acid battery installed in vehicles around the world. These batteries contain lead electrodes that are not only extremely heavy but also have other drawbacks, including low energy density and potential environmental exposure. These disadvantages spurred the development of new rechargeable-battery designs in the 1970s and 80s. An early example is the nickel metal hydride (NiMH) battery, which depends on an optimal exchange of hydrogen ions. 'Lithium-ion' batteries, which supplanted much of the market for NiMH batteries, provided improved life, greatly improved energy density and reduced life-cycle cost. As a result, lithium-ion batteries supply power to most laptops and other consumer devices today. ›

Lithium-ion/graphite batteries power most common, rechargeable devices. © shutterstock.com/DW2630

This is where molybdenum comes in. An early (1980s) lithium rechargeable battery design used a MoS_2 anode, delivering more energy, without memory effect, than the existing Ni-Cd battery, which was the standard rechargeable of the day. Unfortunately, the design's use of highly reactive lithium metal resulted in overheating and fires. And, the battery lost power after relatively few charge/discharge cycles as the Li-MoS_2 deteriorated, limiting its service life. Commercial interest in MoS_2 waned, but recent research suggests that it might provide the next breakthrough in energy storage.

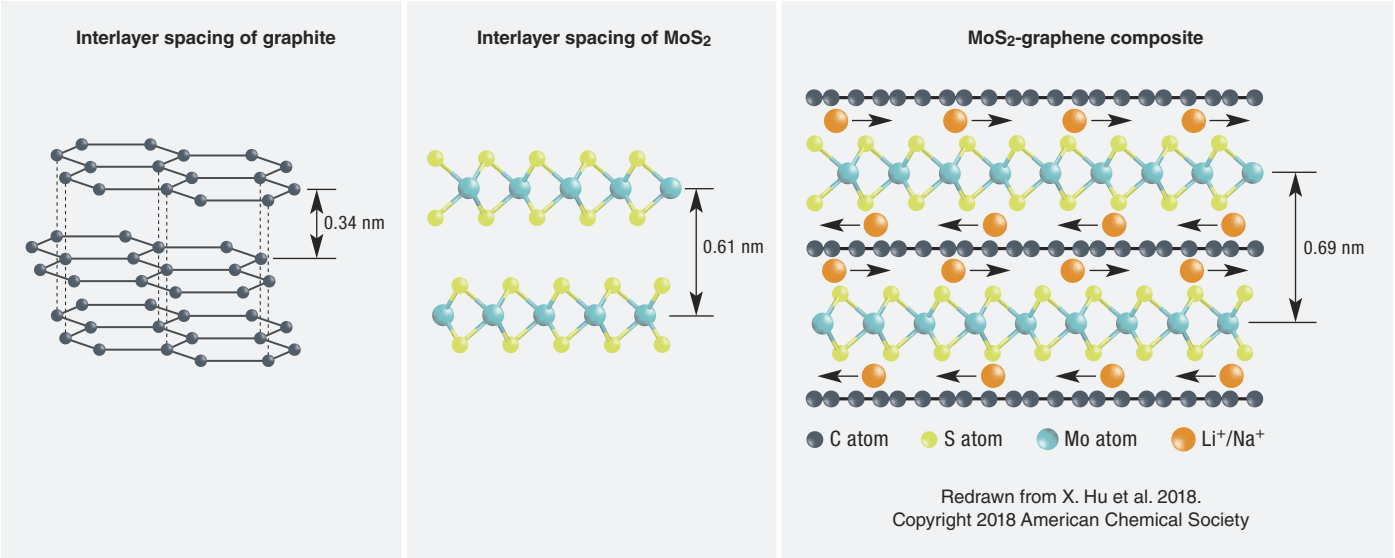
MoS_2 and carbon: better together

In the operation of a battery cell, the greater the number of ions stored, the larger its capacity. Moreover, the faster these ions travel, the more efficient the cell. Today, most LIBs have a lithium-metal (Co, Ni, Mn, or Al) oxide cathode and a graphite anode. Graphite, made of layers of carbon atoms, has better stability and conductivity than MoS_2, (also a layered material), but graphite cannot store as many lithium ions between its layers. The wider interlayer spacing of MoS_2 provides nearly twice graphite's storage capacity, as shown on the graphic below.

Rechargeable battery types

Feature	Lead-acid	LiCo	LiNiMnCo	$NiCoAl_2O_3$
Anode (-)	Pb	Graphite	Graphite	Graphite
Cathode (+)	PbO_2	$LiCoO_2$	$LiNiMnCoO_2$	$LiNiCoAlO_2$
Energy density (kwh/kg)	30 – 50	150 – 250	150 – 220	200 –260
Cycle life	200 – 300	500 – 1,000	1,000 – 2000	500
Applications	Automotive batteries	Dominant for laptops, cameras, mobile phones, but likely to be replaced by LiNiMnCo.	Electric vehicles, in the future also consumer electronics and stationary.	Electric vehicles, may also be replaced by LiNiMnCo in the future
Advantages	Inexpensive	Long tradition, good energy density	Low cost, safe, long life	Low cost, high energy density
Disadvantages	Low energy density, heavy, toxicity	High cost, limited availability, toxicity	Lower energy density	Less safe

When MoS_2 layers are stacked together with layers of highly conductive nano-materials such as graphene or carbon nanotubes the anode performance further improves. These 'composite' electrodes are superior to electrodes made of either material separately. They combine the desirable properties of both and more: the larger Li^+ storage ability and fast ion transport of MoS_2, and the exceptional electrical conductivity of graphene, without the accelerated degradation of ›



Redrawn from X. Hu et al. 2018.

Layer structures and interlayer spacing of graphite, MoS_2, and a MoS_2-graphene composite. The gap between layers, which can accommodate ('intercalate') lithium or sodium ions, is almost twice as wide for MoS_2 as for graphite. A composite further improves the capacity for Li^+ ion storage.

Batteries containing MoS_2 could one day help to increase the range of electric vehicles and maybe power entire cities.
© iStockphoto.com/urbancow

the early MoS_2 batteries. In fact, lithium-ion composite battery technology can provide *twice* the initial capacity of a corresponding MoS_2 battery, according to the data on the right, and the composite has exceptional cycling capabilities as shown in the figure below.

Developing technologies: lithium-air and sodium-ion batteries

New research suggests MoS_2 may also play a role in developing battery technologies, including Li-O_2 (air) and sodium-ion batteries. While these technologies are not yet commercial, electrodes using both MoS_2 or MoS_2/graphene composite have demonstrated excellent performance in laboratory trials. In Na^+ batteries, MoS_2's wider interlayer spacing compared to graphite is essential to accommodate the bigger Na^+ ion (0.10 nm radius, cf. Li^+ 0.076 nm). Furthermore, the storage capacity of a sodium-ion cell with the composite electrode is greater than the sum of capacities for cells with individual MoS_2 and graphene electrodes, as shown by Xie et al. (2015).

Summary of electrochemical performance data for various LIB anode materials (Data compiled by T. Stephenson et al. 2014)

Anode materials	Theoretical specific capacity mAh/g	First discharge capacity mAh/g	First charge capacity mAh/g	Reversible capacity after (n) cycles mAh/g
MoS_2	669	1062	917	907 (50)
MoS_2-GNS*	669 – 1675	1300	2200	1290 (50)
Graphene	372 – 1116	945	650	460 (100)
Graphite	372	320	320	240 (20)

* MoS_2-Graphene nanosheet composite

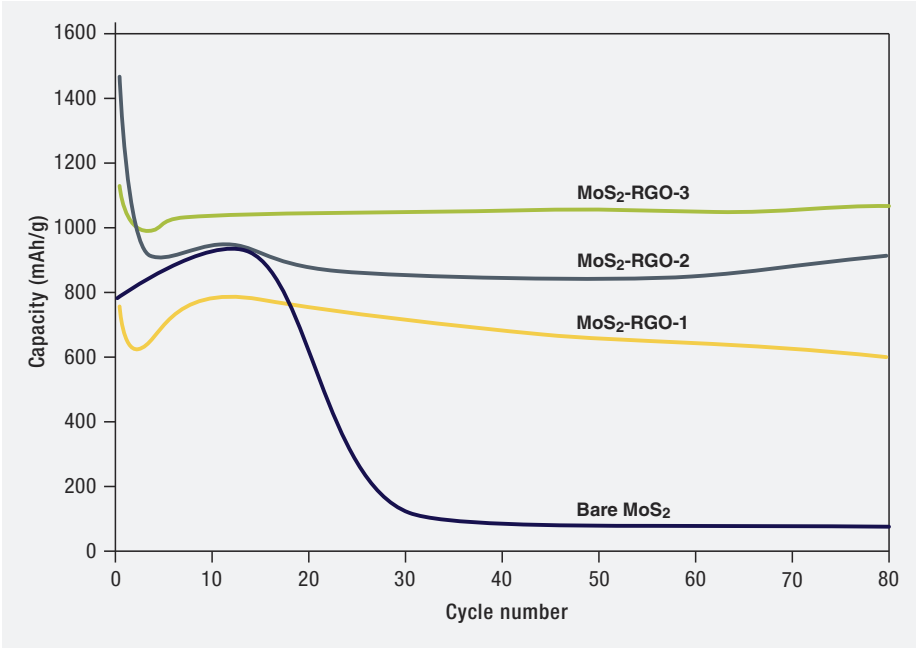
From the laboratory to production

Sustainability is an important consideration in the development of new technologies. Life Cycle Inventory datasets, shown on page 16 for molybdenum, support assessment tools such as Life Cycle Costing (LCC) and Life Cycle Assessment (LCA). LCC measures the differing total life cycle costs between battery technologies performing similar functions. Likewise, LCA evaluates environmental impacts of batteries on a life cycle basis over production, distribution, use and end-of-life. Outcomes of such assessments are increasingly important in decisions to upscale to commercial production.

Moving from the laboratory into the up-scaled commercial world is challenging for new technologies – especially for those that use nanomaterials like the atom-thick layers required here. The processes to make composite sheets of nanoscale graphite and MoS_2 combined are different from those used to make sheets of graphite and MoS_2 individually.

Considering the potential economic impact of these composite electrodes when commercialized, many routes for scalability are being explored in laboratory studies. For example, composites consisting of stacked MoS_2 nanosheets embedded in a matrix of amorphous carbon, were prepared hydrothermally by mixing aqueous solutions of the MoS_2-precursor ammonium tetrathiomolybdate and a carbon source (resorcinol, formaldehyde and sodium carbonate) followed by autoclaving and calcination by Das et al. (2012).

In an ingenious one-step procedure, a mixture of glucose and ammonium tetrathiomolybdate was thermally decomposed, thereby creating glucose bubbles and, ultimately, MoS_2 nanoflakes in graphene by Fei et al. (2018). Other approaches use carbon nanotubes or graphene as "seeds" on which to grow MoS_2. Each of these approaches has ›



The capacity development with increasing number of charge and discharge cycles for MoS_2-RGO (reduced graphene oxide) anodes and a bare MoS_2 anode. While the bare MoS_2 anode loses much of its initial capacity in this test after 15 to 20 cycles, the composite anodes are much more stable. Re-drawn from Choi et al. 2017. Copyright 2017 Elsevier

produced impressive results, and all have the potential for process scalability.

Unlocking future potential

The challenge is a battery technology able to store ever more electricity, provide ever more power, and recharge ever more quickly. Promising laboratory results indicate that MoS_2 could play a role in a future battery-based economy. To satisfy the energy demands of rising populations and growing cities, while reducing the amount of carbon released to the atmosphere, means that more efficient and environmentally friendly ways to generate and store energy are needed. With commercial scalability, MoS_2 composite electrodes could play an important role in meeting these energy-storage challenges. (PM)

Full references and permissions can be found in the PDF online version of this article at www.imoa.info.

Stainless in Seattle

Type 316 stainless steel adorns the face of a new Seattle infrastructure project: an electrical substation that doubles as a public park. As cities grow and global energy demand continues to rise, the new Denny Substation is a welcome glimpse into what a future powered by accessible, sustainable infrastructure might look like.

Regardless of the necessity of electricity in modern life, most people do not give much thought to their local electrical substation. Despite the vital service they provide, electrical substations are mostly eyesores: unattractive clusters of wire and blinking grey surfaces, peripheral to the communities they serve. But for some, the rapid growth of 21st-century cities provides an opportunity to improve and reimagine public infrastructure. In this spirit, a new Seattle utility project, the Denny Substation, designed by Seattle architecture firm NBBJ, was destined not for the city outskirts, but the heart of one of its busiest neighborhoods. A glass and stainless steel façade, adjoining green space, and art installations transform the alien-like hive of wire and knobs into a sleek, inviting space. In its double life as both a public utility and park, the Denny Substation aims not only to illuminate Seattle's South Lake Union neighborhood, but also the community's understanding of sustainable energy consumption.

An aerial view of the substation prior to opening to the public in July 2019. © Seattle City Light

A utility and an amenity

The Denny Substation is more than just a power provider; it is an integrated, community space. The architects and urban planners behind the substation wanted to highlight the idea of growth with both sustainability and neighborhood welfare in mind. A commitment to accessibility, open space, and energy efficiency is reflected in the substation's design, which offers over 4,000 square meters of public area and energy-neutral facilities. The campus surrounding the substation includes an elevated walkway, an outdoor event space, art installations, solar panels, and – last but not least – an off-leash area for dogs.

These features pander to 10-meter high stainless steel walls that slope inward to form a trapezoidal structure, disguising the substation's unseemly, electrical organs. For curious visitors, the elevated walkway, which extends for 400 meters, allows for a stroll above the walls to peer inside at the substation's innards through glass panels. While on the walking path, the public can engage with interactive art installations like the 'Switchwall,' which changes color as ›

Type 316 stainless steel panels offer a modern aesthetic to an often overlooked public utility. © Samuel Sproule

the wind blows past. The inward sloping angle of the substation's walls allows for enough sunlight to nourish gardens of local, low-maintenance plants. Around the Denny Substation campus, various other elements such as informative sign plaques, seating, and window frames all integrate stainless steel for its low maintenance requirements and its sleek finish. The substation opened to the public on July 20th of 2019.

Sustainable solutions to growth

As of 2015, Seattle had not constructed a new electrical substation in nearly 40 years. Over those four decades, the city's population exploded. The influx of tech and service giants ushered in scores of new residents, with many more expected to arrive in the coming years. For some of the fastest growing neighborhoods, such as South Lake Union, public utilities were beginning to fall short of capacity. To meet demand pressures, Seattle City Light began construction on the Denny Substation and underground distribution network in the spring of 2016. A derelict bus maintenance facility and its adjacent alley were chosen for the site. A 'street vacation,' which grants a private entity control of a public right-of-way, allowed the substation to be built over the street. This street vacation provided enough room for key aesthetic and sustainability features such as the sloping, pentagonal design and local plant life. The rest is history, as dogs, food trucks, and performance artists now frequent the Denny Substation campus.

Although the initial phase of the project is now completed, an expanded subterranean distribution network is planned for 2020 to increase capacity beyond South Lake Union, into other Seattle neighborhoods, sustaining future population growth.

Bringing urban lighting out of the shadows

The designers of the Denny Substation wanted to highlight sustainability by building net-zero energy facilities, meaning all buildings on site generate the entirety of their own power. Indeed, the substation itself contains on-site solar power, and a heat recycling system that provides 100% of the facility's heat. This pledge to energy-neutrality was no easy feat in a densely populated, ›

Visitors take a look inside the substation through windows. © Curtis Kovach

city neighborhood. Typically, it is difficult for a small, low-lying area in a high-rise, urban environment to receive enough direct sunlight for solar power and plant life. That is where the Denny Substation's molybdenum-containing stainless steel walls come in. By sloping inward at an angle, the reflective surface of the stainless steel-clad panels allows enough sunlight to reach the public areas and support plant growth. Furthermore, the use of Type 316 stainless steel itself contributes to sustainability through material longevity, as its corrosion resistance, thanks to the addition of 2% molybdenum, helps protect against both marine and de-icing salts endemic to Seattle. For these reasons, stainless steel is essential to the sustainable design features at the Denny Substation.

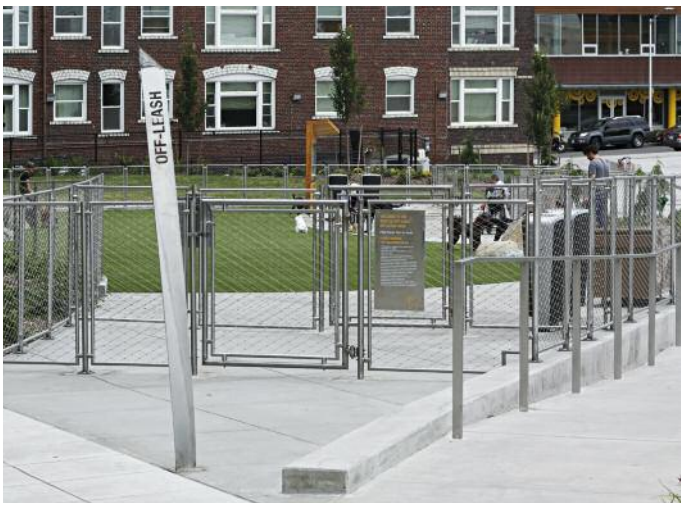
A closer look at the substation's stainless steel panels. © Seattle City Light

Furthering the commitment to sustainability, the plants chosen for the substation's gardens are native to the Pacific Northwest, require very little water, and encourage proper drainage. Because the Denny Substation rests on a former bus maintenance facility, before construction the soil of the site was shallow and polluted, and contaminated debris frequently drained into storm sewers. The site was cleaned, the debris removed, the soil deepened, and a bioretention planter placed to treat stormwater, removing contaminants around the station. In concert with solar power capacity and heat recycling, these measures make the Denny Substation a sustainable facility.

In an age when citizens are increasingly distant from the processes that sustain life, the Denny Substation facilitates awareness of energy consumption while highlighting the promise of sustainable growth. Seattle's decision to invite the public to enjoy an ordinarily obscure utility indicates an innovative future for urban infrastructure. By highlighting the unique properties of Type 316 stainless steel, the Denny Substation also signals the centrality of molybdenum to a future of sustainable, community-centered urban growth. (KW)

Sculptures near the entrance of the walkway incorporate stainless steel. © Seattle City Light

The off-leash area for dogs also uses sleek, stainless steel elements. © Samuel Sproule



IMOA news

De-regulation from Toxic-Free Kids Act

IMOA's Health, Safety and Environment Committee work is focused on ensuring that the regulation of molybdenum across the globe is protective of the environment and human health and based on sound science. Generating the robust scientific data required for regulatory purposes, either to fill data-gaps or as weight-of-evidence against existing poor-quality data, is key to that goal.

In January 2019, Oregon Health Authority in the U.S. de-regulated molybdenum and compounds from its legislation known as the 'Toxic-Free Kids Act'. De-regulation was a result of a triennial review of substances on their Chemicals of High Concern to Children list, during which IMOA made a technical submission that shared and advocated more recent toxicological and risk assessment data than had been available when the substances were first listed in 2011. IMOA's responsible product stewardship approach meant the submitted data was drawn from studies conducted by independent laboratories, in accordance with stringent OECD protocols, to foster international regulatory confidence in the generated data.

This decision by Oregon State followed a similar decision the previous year, in which an IMOA submission resulted in the de-listing of molybdenum and compounds from Washington State's Children's Product Safety Rule in October 2017.

Life Cycle inventory update now available

Life cycle costs and environmental impacts of materials are sustainability considerations that are routinely factored into business assessments both about material selection and scalability of commercial production levels. A pre-requisite for generating an accurate assessment is the availability of reliable life cycle inventory datasets.

Following a two-year project, the Life Cycle Inventory dataset for molybdenum products for metallurgical applications was published in December 2018. Products assessed were roasted molybdenite concentrates in powder and briquette forms, and ferromolybdenum.

An LCI is an inventory of flows from and to nature – including inputs of water, energy, and raw materials and releases to air, land and water – for a product system. LCI datasets help companies operating in many different sectors to assess the green credentials of their own and competing products.

In line with best practice, the Life Cycle Inventory dataset for molybdenum products for metallurgical applications will be supported with a program of five-year updates to satisfy the assessment needs of LCI practitioners.

Commenting on the newly published datasets for molybdenum products for metallurgical applications, Sandra Carey of IMOA's HSE Committee said: "Visibility and ease of access are key factors to ensure the three updated LCI datasets will be widely used. We are working to make access to the newly published datasets as easy as possible, which is why we have widened dissemination compared to previous years. As well as being available via enquiry (https://www.imoa.info/HSE/LCI/onlineform/online_form.php) to the IMOA website, the peer-reviewed datasets are also embedded in Gabi (http://tiny.cc/GABI), which is one of the most frequently used LCI software programs. The LCI datasets will also be publicly available on the International Reference Life Cycle Data System (ILCD)."