THE SILVERINSTITUTE

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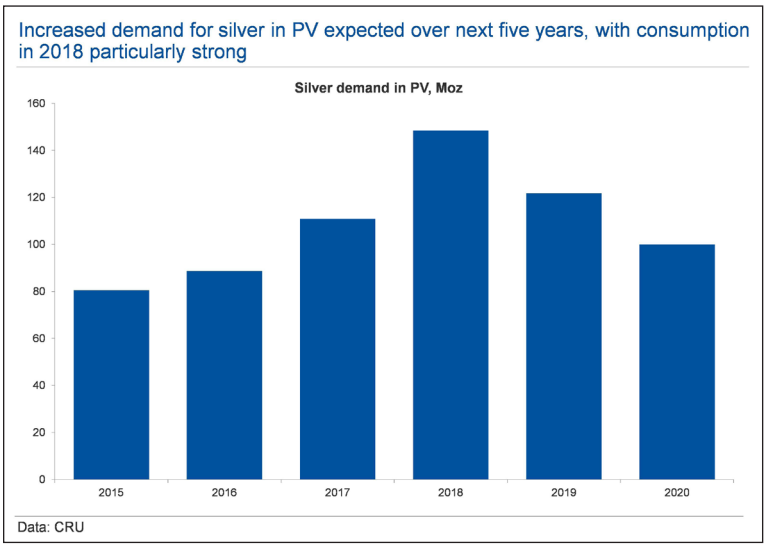
Silver News

Six Hundred Million Ounces of Silver to be Consumed in Photovoltaics and Ethylene Oxide Production Through 2020



PROSPECTS FOR SILVER DEMAND IN ETHYLENE OXIDE AND PHOTOVOLTAICS

"… the decrease in silver usage does not necessarily lead to a decrease in total silver consumption from the PV industry. The predicted significant increase in PV capacity… will more than offset the negative effect of thrifting."

The use of silver in photovoltaic (PV) cells and as a catalyst to produce ethylene oxide will together account for 120 million ounces per year of consumption on average from 2016 to 2020, an increase of 32% over 2015 levels, according to a report issued by The Silver Institute in December.

The report notes: "On average, we expect that the PV industry will consume 114 million ounces of silver annually during the next five years." The consumption of silver for ethylene oxide will average almost 6 million ounces annually. For both photovoltaics and ethylene oxide together consumption is expected to reach almost 600 million ounces through 2020, according to CRU Consulting, a global commodities consultancy, which produced the 26-page report for the Silver Institute.

Photovoltaic demand for silver in 2018 is expected to be about 75% greater than in 2015. This increase is due in part to stricter government emissions standards and the increasing efficiency of PV electricity generation compared to fossil fuels. "The increase in renewable sources of energy, especially solar power, will lead to an increasing demand for silver," the report notes. "Silver is consumed in the manufacturing of solar panels for the photovoltaic (PV) generation of power from the sun's energy. A high silver content layer is pasted on the front side of a silicon solar cell, as well as a lower silver content layer on the rear side."

The increasing consumption of silver for solar power generation is somewhat paradoxical because solar cells are using less silver per cell each year due to manufacturing efficiencies. "The amount of silver needed per watt has consequently decreased substantially (called 'thrifting') over the past 10 years with the amount of silver used in solar cells declining by an average annual rate of 7%." The report adds: "However, the decrease in silver usage does not necessarily lead to a decrease in total

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silver consumption from the PV industry. The predicted significant increase in PV capacity… will more than offset the negative effect of thrifting. According to our medium-term forecast, silver consumption from the PV industry peaks in 2018 at 148 million ounces, which is almost double the level seen in 2015 (80 million ounces)."

Ethylene oxide is a raw material used in many plastic and chemical goods. The main products that rely on ethylene oxide as a precursor are ethylene glycol used in the production of antifreeze, and polyethylene terephthalate (PET), a polyester resin used in clothing fibers, plastic bottles, food containers and other items. Antifreeze use is expected to rise worldwide as vehicle usage increases through 2020, with China adding the most vehicles. Europe and North America are projected to maintain their current high vehicle rates. The combination of PET packaging and automotive use is expected to hit 30 million ounces of silver demand in 2020.

Another factor in silver consumption in ethylene oxide manufacturing is the replacement of spent catalysts used during production. Silver-based catalysts generally have a lifespan of five years. They can be recycled, but are eventually discarded as the catalytic process causes 'sintering,' a condition in which overheating causes silver nanoparticles to accumulate, reducing the catalyst's surface area and therefore its chemical activity. The silver catalyst can also be contaminated by other chemicals. This acts to reduce the quantity of silver available to catalyze the reaction, lowering efficiency. Once the catalyst is spent, it is removed from the reactor and replaced with fresh material. "Around 10% of silver used to produce ethylene oxide in industry is as replacements for deactivated catalysts," the report notes. "Therefore, our forecast combines the growth in silver demand from the EO industry into two parts, new catalysts required by new production capacity, and replacement material required by existing production capacity."

The report *Prospects For Silver Demand in Ethylene Oxide and Photovoltaics* can be downloaded here.

Origami and Silver Solve Tiny Satellite's Temperature Problem

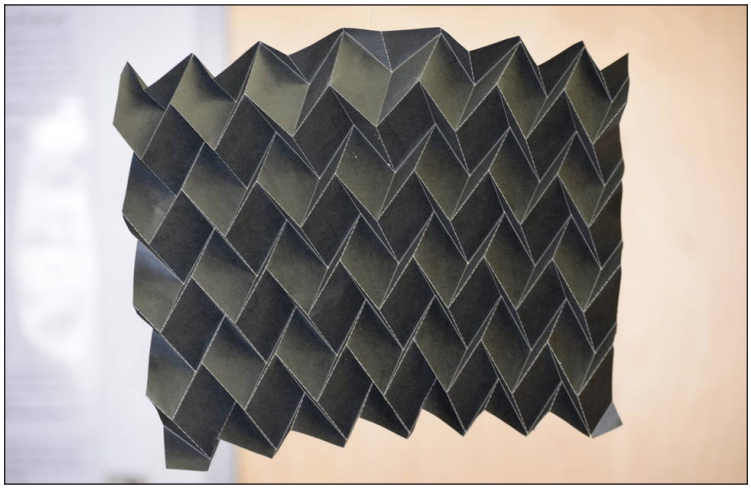
Keeping satellites cool in direct sunlight or warm when in the sun's shadow is a challenge for 'CubeSats,' a type of miniaturized satellite for space research. Because of their small size, large fins or radiators used to keep internal temperatures relatively stable on larger satellites are impossible to employ. They would be larger than the satellites themselves and add additional weight.

The answer, according to Brigham Young University researchers in concert with scientists from the U.S. National Aeronautics and Space Administration (NASA), is origami, vanadium-oxide and silver. The partnership is experimenting with intricate designs with hundreds of folds and lots of surface area, like Japanese origami shapes.

The deeper the folds the greater the heat absorption or the greater the cooling effect. The origami material is composed of vanadium-oxide which is coated with silver and titanium. Silver is one of the world's best conductors of heat. The silver and titanium are applied in a very thin film using a sputtering technique called atomic layer deposition that can evenly coat even the most intricate and complex shapes.

In addition, once in orbit the origami radiator can be programmed to open, like a blooming flower, or close tightly, depending upon the heating or cooling required to keep the satellite at a stable temperature.

"This approach has the potential to be a game changer in thermal design," said Vivek Dwivedi, PhD. a technologist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "Our goal is to replace traditional radiators with dynamic ones, period."



BRIGHAM YOUNG UNIVERSITY

The ancient Japanese art of origami is the inspiration for a foldable radiator that uses silver to help cool or warm tiny satellites known as CubeSats.

NASA

CubeSats are satellites that measure only a few inches across. Because of their small size, they need equally small but efficient cooling fins.

3D Printing Makes Waves In The Electronics Sector

By Trevor Keel, Technical Consultant to The Silver Institute

3D printing is an evolving branch of technology which holds the promise to revolutionize manufacturing in a broad range of industries. Silver has been a material long associated with 3D printing given the availability of high-quality printable inks. In June 2016, *Silver News* reported on work by Harvard University researchers on 3D printing silver (3D Printing in Mid-Air Allows Intricate Designs from Silver Ink) which has a potential impact in a number of industries.

One of the sectors which has most to gain from the improvements being made in 3D printing is electronics. Silver has long been a critical material in the electronics industry with practically all electrical devices we take for granted on a day-to-day basis relying on silver's conductivity for their operation. The metal is used in the form of wires and contacts, but is increasingly 'printed' onto circuit boards to create highly-conductive electrical pathways. This is a cost-effective way to ensure reliability using the most conductive metal available. According to the GFMS team at Thompson Reuters, 2015 saw almost 250 million ounces of silver used in the electrical and electronics sectors worldwide, which represents a significant source of demand for the metal.

How can 3D printing and silver inks combine to benefit the electronics industry? Recent announcements by two start-up companies focus on their technology's capability to fabricate complex electronic components in a single pass within specially designed 3D printers. The first, Israel-based Nano Dimension Technologies, has developed the *Dragonfly 2020* system which enables the use of silver nanoparticle inks for ultra-rapid prototyping of complex, high-performance multilayer circuit boards.

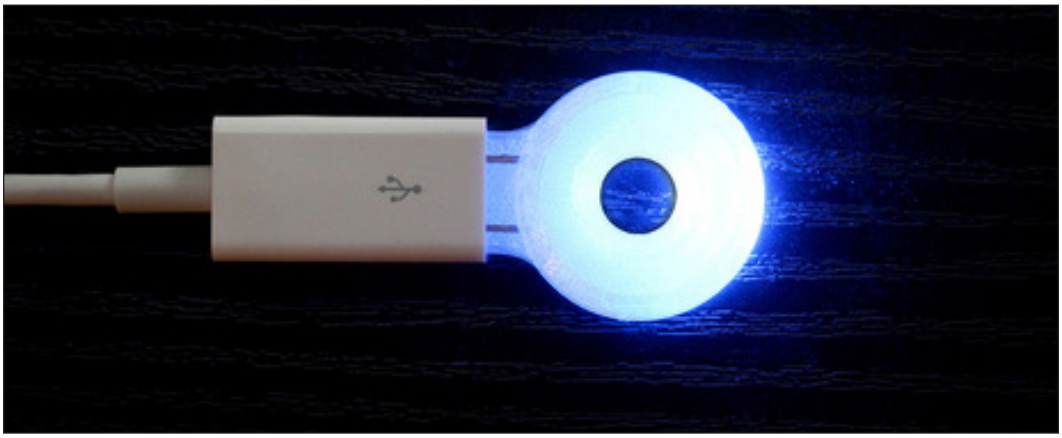
The company has recently announced a successful proof of concept of Printed Circuit Board (PCB) inkjet printing, in which electrical components were produced during the printing process. According to Nano Dimension Technologies' officials the system offers a number of advantages to companies involved in the design and development of PCBs, and they are in the process of patenting the system in the United States of America.

The second start-up company operating in the space is Voxel8, a company spun out of the Harvard University laboratory responsible for the intricate silver designs highlighted in the February, 2015 edition of *Silver News* (3-D Printer Prints Plastic and Silver Inks on Same Object; U.S. Government-Sponsored Project in Progress.)

Voxel8 has a slightly different approach to Nano Dimension Technologies in that they utilize a pneumatic printhead to deposit silver inks while a plastic extruder prints plastic filament onto a substrate. The system can be paused at any time to manually insert certain electronic components. The Voxel8 printer is capable of laying out precise circuits in three dimensions, forming wires that can be as narrow as 50 microns (0.05mm) thick, according to the company's co-founder.

The first 3D printing material to be developed by Voxel8 was a silver nanoparticle ink. There are a number of reasons for this. First, the material has a bulk electrical resistivity below 5.0x10-7 ohms per meter. Additionally, it is 20,000 times more conductive than conductive filled-thermoplastic filaments and over 5,000 times more conductive than carbon-based inks, making it suitable for 3D printed electronics with large operating currents. According to company officials, the ink is self-supporting and dries quickly at room temperature, yielding highly-conductive electrode traces and interconnects without requiring thermal annealing. The formulation of the ink is specially designed for pneumatic deposition through a 250 micron nozzle. To showcase the capabilities of their printer Voxel8 gives away 3D printed Light Emitting Diodes powered by their conductive silver ink.

3D printing technologies continue to improve at a startling rate, and the potential impact on a wide range of manufacturing industries is considerable. The electronics sector has much to gain from these advances, and silver is likely to be at the heart of breakthroughs in the field given its position as one of the most reliable conductive inks available.



Voxel8's 3D printed LED, complete with conductive silver tracks.

Silver Helps Detect A Single Bacterium Before it Grows Into Deadly Infection

What if doctors could detect a single bacterium in patients before it grew into a life-threatening infection?

Balaprasad Ankamwar, Phd., associate professor at the Savitribai Phule Pune University in India, offers a method that uses nanosilver to detect infections like those found in the urinary tract, even as small as a single bacterium. The technique uses silver nanoparticles which have been 'biosynthesized' (produced in a living organism) in *Neolamarckia Cadamba* leaf extract (from the kadam tree) as the source of stabilizing molecules and silver nitrate as the chemical compound from which the nanosilver particles are extracted. When the resulting mixture is exposed to a Raman laser, a process called Surface Enhanced Raman Scattering (SERS) Spectroscopy, signals that indicate the presence of bacteria are enhanced more than 100 times their size and thus are easier to detect.

Chinese scientists report using similar techniques to speed up blood tests in patients. (See *Silver-Coated Chip Offers Faster Blood Tests; Silver News,* June, 2015.)

The main advantage of Ankamwar's method is that test results can be obtained immediately. There is no need for growing cultures, which can take days or weeks in some slower-building bacteria. His team is developing a cost-efficient kit for commercial use along with a data bank of major disease-causing bacteria to compare to the test results.

The original research paper was published last year in Analytical Methods, a journal published by The Royal Society of Chemistry, U.K. *SERS Study Of Bacteria Using Biosynthesized Silver Nanoparticles as The SERS Substrate* was one of the top 25 accessed research works last year in that journal.

Silver Catalysts Shows Promise to Rid Air of Pollutants

Chemists at Tomsk State University in Russia have created a new silver catalyst they say can purify air by decomposing carbon monoxide formaldehyde and other harmful substances.

"Silver catalysts are less studied than other catalysts made with particles of precious metals like gold, platinum and palladium," according to Gregory Mamontov, senior researcher at the Laboratory of Catalytic Research. "However, they can be just as effective in the oxidation of harmful volatile substances and cheaper by a factor of ten."

The catalyst is prepared using nanotubes composed of silicon dioxide. Inside the tubes are silver particles and cerium oxide particles smaller than 3 nanometers. Once the structure is stabilized, it becomes a catalyst that provides oxidation of harmful substances. Mamontov suggests that the catalyst might be placed in air filters deployed in homes, offices and industrial settings. Unlike many catalysts that require heat to work, this catalyst is active at room temperature.

"First of all, such a catalyst will be in demand in industrial areas and cities to fight industrial emissions and smog from forest fires, which also contains a large amount of carbon monoxide. In addition, the catalyst can be adapted to neutralize the gas discharges of chemical plants and the exhaust systems of automobiles," said Mamontov.

VW Offers Silver-Film Windshield That Heats and Cools

The standard in defogging car windshields is the little wires that look like the lines on an American football field. While this method works well, some drivers complain about being distracted by the filament wires, especially when heading into a setting sun.

Now, Volkswagen has come up with a silver-based system that eliminates in-the-glass wires while controlling fog and ice on windshields.

The wire-free method relies on a thin film of silver within the laminated glass that is heated, consuming 400 to 500 watts of power. The silver is invisible.

In warm weather, the silver reflects sunlight, keeping the car cooler. Volkswagen officials say that it reflects up to 60% of the summer heat, resulting in a cooler car and less work for the air conditioner.

Some wire filaments remain in the windshield, however. The bottom of the glass contains traditional heating wires to keep wiper blades from freezing to the glass.

Volkswagen is offering the wire-free heated and infrared-reflecting windscreen as an optional extra for the Golf, Golf Sportsvan, Tiguan, Sharan, Passat and Passat Variant models. Prices start at US$360, depending on model. The company would not divulge how much silver this new application would consume, citing competitive reasons.

VW

This heated, wire-free windshield available to order in Europe for selected Volkswagen models uses silver to keep it fog and ice free.

Silver In Medicine – Past, Present And Future: A New Backgrounder from The Silver Institute

From the founder of modern medicine, Hippocrates, who wrote around 400 BCE of using silver to improve wound care, to the turn of the 19th century, when surgeons used silver sutures to prevent infections, and continuing to the present day, when silver is added to many consumer products such as smartphones and clothing to keep bacteria at bay, the metal's history is intertwined with protecting human health.

Much of modern medical research focuses on silver's bacteria-killing powers in an age when antibiotics are becoming ineffectual due to overuse. Because of its unique atomic structure, silver ions have the ability to destroy life-threatening bacteria, including the deadly MRSA microbe (*Methicillin*-resistant *Staphylococcus aureus*). MRSA, often found in hospitals, is caused by a type of staph bacteria that's become resistant to many of the antibiotics used to treat ordinary staph infections. Silver has the ability to destroy germs without allowing the targeted bacteria to grow resistant and without harming mammalian cells.

Recent breakthroughs center on using nanosilver particles to fight disease as well as using silver in concert with traditional antibiotics, allowing them to kill a larger range of microbes with greater efficiency.

The current amount of silver used in the silver antimicrobial coating market (which includes medical devices, textiles and wound dressings as main application areas) is estimated to be between 3 and 10 million ounces annually. Compared to other silver-based applications this is relatively low but this number is expected to grow at a double-digit pace over the next five to ten years.

To read the complete backgrounder click here: *Silver In Medicine – Past, Present And Future.*

University of California, Los Angeles (UCLA), Hosts Indian Jewelry Exhibit

A new silver jewelry exhibition highlighting designs of the Thar Desert region of India is now on display at the Fowler Museum at UCLA. The 160-work exhibit titled *Enduring Splendor: Jewelry of India's Thar Desert* will be on display until June 18, 2017, and offers visitors a view of the 5,000-year tradition of jewelry making in the Indian subcontinent.

In addition to older pieces, the museum also commissioned new silver works from four contemporary smiths whose designs reflect traditional designs and manufacturing techniques.

The exhibition has three sections, starting with an introduction to jewelry traditions seen in the region. These include sculptures and paintings of jewelry (from 200 B.C.E. to 1,000 C.E.) worn in ancient times, such as Hindu gods wearing jewelry and Mughal miniature watercolor paintings from the 17th to 19th centuries depicting elaborate ornaments worn by maharajas and empresses.

The second section shows 19th and 20th-century jewelry from the Ronald and Maxine Linde Collection that focuses on India's northwest Thar Desert region located on India's western border. For many years, it was considered the gateway to India, allowing passage of Genghis Khan, Alexander the Great and early European visitors.

The third section focuses on the commissioned works of smiths from the city of Jaisalmer: B.D. Soni, Dharmendra Soni, Hanuman Soni and Roopkishor Soni. The display includes videos showing each working with traditional tools and techniques.

RONALD AND MAXINE LINDE COLLECTION

A pair of early 19th-century anklets, crafted in silver. Artist unknown.

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