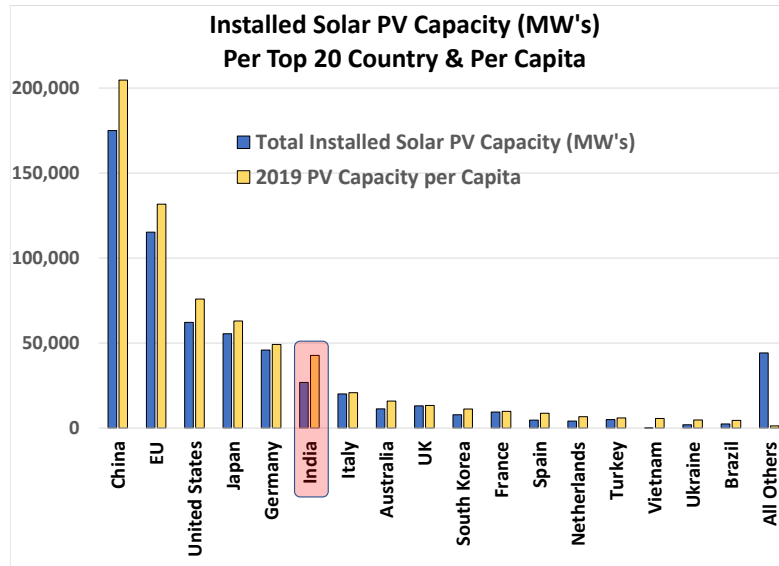


India's Solar PV Emerging Market and Opportunities With A Supporting Silver Eco-System

In 2010, India launched the renewable energy program- 'Jawaharlal Nehru National Solar Mission (JNNSM)', with an objective of deploying 20,000 MW of solar power by 2022, and revision in this target was made to 100,000 MW of which 60,000 MW has to be grid connected and 40,000 MW has to be rooftop solar.

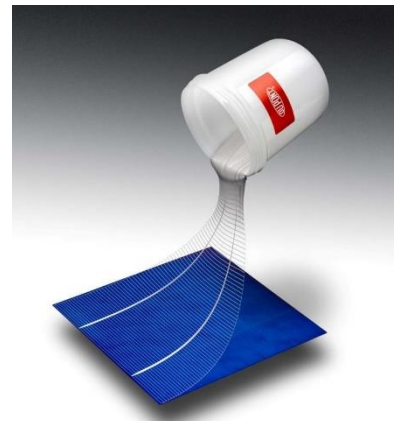
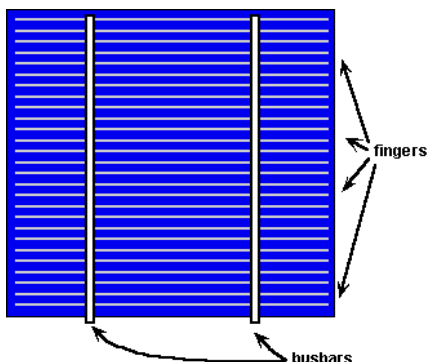
India's outlook for incremental Solar PV is strong. Already ranked #6 globally, both on aggregate installations and Solar PV per capita, India is looking to install still further installation to build out its power grid and distributed power networks. The data as presented is as of the end of 2019, and is set to grow each year for the next few decades. Jawaharlal Nehru National Solar Mission revised stated goals of achieving 100,000 MW of installations in India by 2022 is likely a bit out of reach.



Silver Products are an essential material to the efficient collection and transmission of the power generated (1) within the photovoltaic cells themselves, then (2) through the conductive stringing together of these cells, and then (3) through the assembled solar PV module. Silver acts as an efficient and durable conductive power transmission material enabling the energy to make its way through the entire module and into the modules which are daisy chain connected leading that power to the Solar PV sites power inverter, and finally into the distributed power system, energy storage device, and/or the power grid.

Typical Solar PV Silver Products

- A. **Silver Front Side Metallization Screen Printed Pastes.** Screen printed onto the front of each individual solar PV cell is an alloy of metallic materials containing silver. The Silver composition in these pastes varies by application and vendor, but are typically below 40% as a cost savings strategy, while still maintaining excellent conductive properties and lifetime durability performance. Immediately after screen printing, the cells are fired



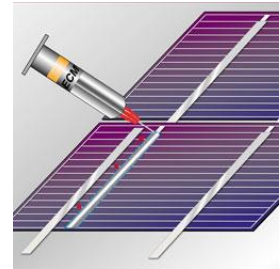
to cure the paste into place before further processing. The primary function of these very thin silver traces, often called fingers, that are screen printed in a very precise grid pattern is to collect and route the energy generated by the Solar PV cell to the edges of the cell where it can be collected with minimal solar irradiation blocking of the sun to the solar cells surface.



B. **Silver Containing Ribbon Interconnect Tab Materials** are then used at the ends of each cell to organized and transmit the collected energy from the cell, to strings of cells assembled next.

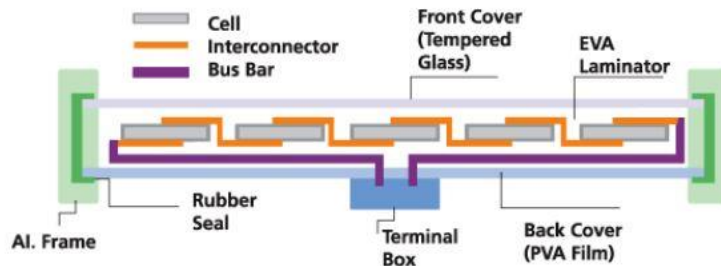
C. **Silver Containing Buss Bar** that used on the ends of the solar module to collect all of the energy from the respective strings of cells These strings are then laid out on a series of laminate backing plate materials four strings wide.

D. **Silver Conductive Adhesives** are used to conductively attach and glue these various ribbons and bus bars together.



Fundamental to all of these silver products is the management of particle size and metalizing, or alloying, with various other metallic materials to achieved the desired cost, conductive properties, and durability over the 25+ year expected lifetime of these solar modules. These products need to survive the constant bombardment by sunlight, the high temperatures generated on these

Solar PV cell surfaces during peak operation, and although encapsulated, have reasonable corrosion and mechanical durability features to survive and function for 25+ years with minimal gains in resistance.



As mentioned in the October 2020 The Silver Lining for Indian Economy webinar, having a solid precious metal refining and processing capability of refined silver flakes, grains, and salts is fundamental to each of these raw materials, and ensuring a continuity of supply to meet India’s growing Solar PV materials needs. This capability will obviously be of some assistance at the backend of the life of these systems, when recycle processes will be needed to keep this valuable mineral out of its landfills.

India needs to invest in the latest refining technologies and final stage processing equipment to stage itself as a self-supplier of any silver products, including those used with growing demand in Solar PV, or NEV vehicles electrification products, or even in the semiconductor and electronics packaging material markets. Being a cutting-edge technology refiner and raw material processor is the key. [Metalor Technologies](#), [Ames Goldsmith](#), and [Heraeus Photovoltaics](#) are all excellent existing Silver Refining and Silver Materials Processor business model examples to follow. Frankly, in the Solar PV world, both Henkel and Dupont (Dow) have razor thin gross margins in the screen-printed paste and electro-conductive

adhesive markets. These final products are an extremely mature industry, and entry at this late point in time would be extremely challenging.

In Solar PV products, complex alloying coupled with low cost processes for flakes with good particle size control topics dominate this Solar Paste technology. Key Solar PV Silver Paste producers globally include: [Heraeus Photovoltaics](#), [Dupont Photovoltaic Materials](#), [Rutech](#), [Leed-Ink](#), and others found on this [list](#).

In Solar Silver Interconnect Tab and Ribbon products, again alloying technologies and or silver plating on copper capabilities are key, along with achieving a state of low oxidation and thus the good solderability of this noble metal. Key manufacturers in this market include: [Ulbrich Solar Technologies](#), [Targray](#), [Shenmao Technology Inc.](#), [Tamra Dhatu](#), [Luvata](#), [Bruker-Spaleck GmbH](#), [Sarkuysan](#), and [Sukriti Vidyut Udyog](#)

In the Silver Conductive Adhesive market, again alloying and particle size control, along with design features for wettability and low temperature curing dominate this space. [Henkel](#) and [Dupont](#) have historically dominated this market. Other producers include [H.B. Fuller](#), [Masterbond](#), [Panacol Elosol](#), and a number of smaller specialty firms including [Ferro](#), [ACI Materials](#), [Creative Materials](#).

Semiconductor/Electronics and Vehicle Electrification Markets Use Of Silver

In the electronics and semiconductor markets, silver is a key component in today's back-end packaging materials markets. In Semiconductor market alone, over \$900 million USD of Silver Material products spend occurs each year. Silver Solder, Silver Die Attach (conductive adhesive) materials, and Silver Bonding Wire are the three most prevalent products in use there.

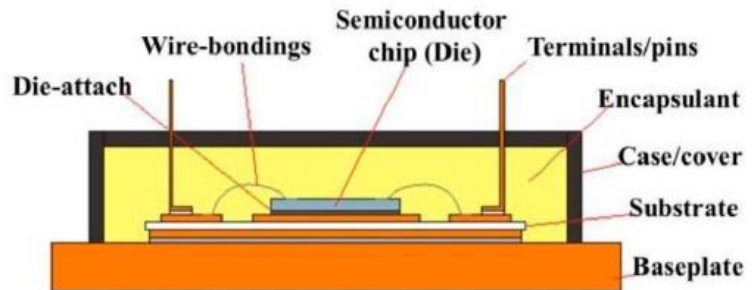
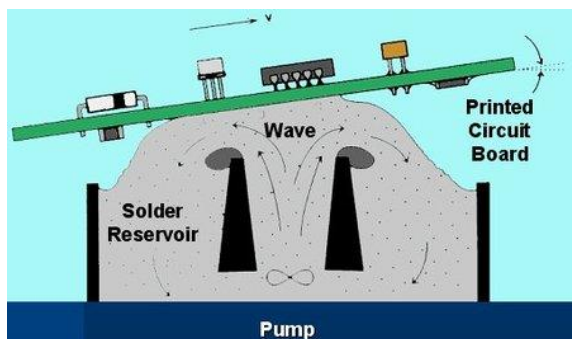


Figure 1. Typical power electronics package structure.



Silver Wave and Silver Solder Reflow

Also, as the world drives carbon emissions down in the electric vehicle market, look for more silver in electronics devices to be used in the NEV market arena. Effectively, electric vehicles will use more electronics, plain and simple. Even on conventional ICE vehicles today, approximately 50% of the vehicle cost is electronics. As we migrate into Plug-In Hybrid gas/Electric Vehicles (PHEV's), to full range Battery Electric Vehicles (BEV's), and ultimately into Fuel Cell Electric Vehicles (FCEV's), there is a progression of

more electronics with each step. More Integrated circuits and passive components, and circuit boards are needed to support the electronification of the vehicle.

Typical Semiconductor and EV Silver Products

For Silver in the Electric Vehicle Markets and in Semiconductor Markets key products include: Silver Conductive Adhesives (or often called Die Attach material), Silver Bonding Wire, Silver Solder Materials, and Silver based wet chemistries.

For Conductive adhesives, same discussion and list of key players above in Solar PV. You can also find [Kyocera](#), [Honeywell](#),

For Silver Bonding Wire, or Silver/Gold alloy Bonding Wire, the key to this technology is understanding the wire drawing process. A sequential progression in wire pulling dies, each with progressively smaller diameter are used. Understanding the full aspects of die maintenance and management is key. Tanaka Precious Metals has 5 bonding wire plants, the closest is in Singapore. They are one of the worlds biggest bonding wire producers for Gold, Silver, Palladium coated copper, and high purity copper bonding wire products that feed the semiconductor markets. The other key process management feature is understanding the wiring drawing progressions, and when full annealing steps and soaks are needed to relieve diameter reduction stresses, to then be able to once again complete a series of several diameter reductions down to the desired final product dimensions. Key players in this space include [Tanaka Precious Metals](#), [Heraeus](#), [MK Electron](#), [Sumitomo](#), [Amkor](#), and [Tatsuta](#),

Silver Solder and Plating Materials are used extensively to bond components to printed circuit boards, and in creating conductive joining other electrical components. [Dupont](#) again is a main player in this segment, along with [Heraeus](#), [AIM](#), [Indium Corporation](#), [Capling](#), [Honeywell](#), and [MacDermid](#) is dominates the wet chemistry electronics markets

Silver Eco-System Policy Needs

Recycle ... Recycle ... Recycle

For the solar PV market, I cannot stress enough the need for legislation to mandate, not encourage, Solar PV module recycle. The key discussion of on the value chain in recycle is that approximately \$3 USD per module of recovery in Aluminum Framing, Glass, and Copper wiring from harnesses and inverters is accomplished with typical Solar PV Recycling. Silver's value has been negligible, although we need to recover from a global sustainability perspective. The overall cost of recycle unfortunately is typically \$12-\$14 per module. Legislation to force a \$10 per panel recycle fee deposit at the time of purchase could be used to make the recycle eco-system whole and cost effective.

Cd/Te and CIGS Recycle Needs To Be Mandatory

Key to Solar PV recycle, of the many types of technologies out there is the mandatory recycling of Cd/Te and CIGS based Solar PV systems. These globally represent approximately 10% of the global installed Solar PV base. These contain Cadmium, Selenium and other materials that can be very harmful to the environment. These types of Solar PV should not enter India's landfills.

Do Not Let India Become The World's Dumping Ground

Lastly, do not let India become the world's Lithium Battery, E-Waste and Solar PV Dumping Grounds.

On Lithium Batteries, I understand there is a national discussion about using aged BEV and Li-batteries for grid level storage, and effectively extending their life while getting some productive use out of the battery as it ages and its storage performance folds over. This is fine, as long as the economics are there to get 100% of the LiB's recycled. Cobalt, Nickel, Lithium, Vanadium, and Graphite are all going to be stressed mineral markets as the world electrifies transportation, and the value of these minerals is very likely to dramatically increase, which may help ensure the recycle and recovery of same.

Recycle Technology Partnerships

Look to partners like Umicore for LiB Recycle technology, and provide financial incentives for their building recycle capacity and factories in India. As part of the deal, learn from them about how to recycle and the processes involved. There are a number of new greener recycle technologies that are being developed to compete with conventional pyro and hydro technologies. Encourage and fund research into all of these recycle technologies. The cheapest path to the minerals you will need is always through recycle. This is true in auto catalyst with PGM's, with e-Waste for precious metals, and will be for Lithium Batteries as well.

Learn The Finer Skills Around Flakes, Grains, Salts and Materials That Make All The Products

Then, like I said before, the best Silver metal processors extend their refining excellence just a little bit further into the value-add chain to focus on their skills for makings salts, grains, pellets, powders and flakes, all with precise controls on different physical features to meet technological requirements for wettability, segregation, curing, electrical properties, etc. Ames Goldsmith, Metalor Technology, and Heraeus Photovoltaic are the best examples I can point you to on same. Arrange for visits to these firms and see what they do close up. Create relationships with them. Get them to invest in plants in India.

These are the best suggestions for India I can make. I hope this make sense. I, like many in the US, am pulling for India to continue to prosper and remain independent and strong in a volatile region of the world. We share so many values with you, and need you to succeed in this century where Clean Energy and Minerals Constraints will be a dominant theme. Best Wishes.

Matthew Watson

Precious Metals Commodity Management LLC, Sole Proprietor

mattwatson@preciousmetalscommoditymanagement.com

+1 (925) 321-2686

1694 Cairo St., Livermore, CA 94550-6039, USA

<https://www.preciousmetalscommoditymanagement.com/>

44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver
76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold