

Silver - The Cultural Pride of India

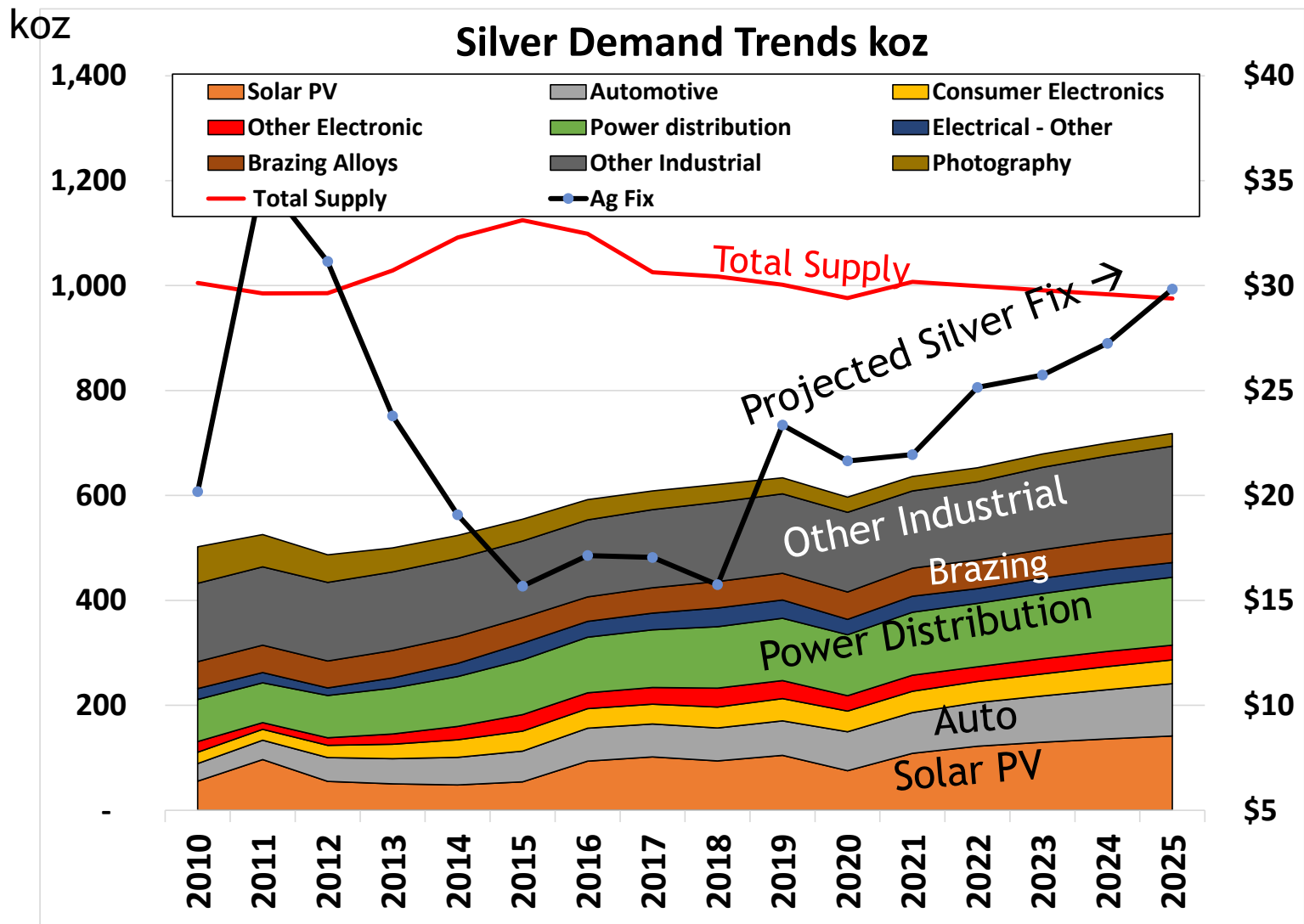
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44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682
76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 192.217	79 Au Gold 196.9666

October, 2020

By: Precious Metals Commodity Management LLC
Prepared for The Silver Institute

Silver Industrial Demand Trends



Total supply is mined plus recycle silver.

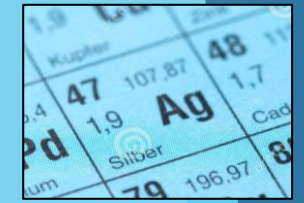
Industrial silver demand is approaching 60% today, greater than 70% by 2025

Ru	Rh	Pd	Ag
Ruthenium	Rhodium	Palladium	Silver
44	45	46	47
101.07	102.905	106.42	107.8652
Os	Ir	Pt	Au
Osmium	Iridium	Platinum	Gold
76	77	78	79
190.23	192.22	195.08	196.9665

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Sept. 29, 2020

5 Areas Of Industrial Demand Focus



1. Semiconductor and Electronics Demand

- Understand the silver products and develop the materials supply chain accordingly.
- Silver Conductive Joining Technologies: ECA / Die Attach, Pastes, Solder Materials, Bonding Wire

2. 5G Wireless Deployment - a Silver Force Multiplier

- 2 decades of steady 5G deployment - slow rise
- IoT (Internet of Things) explosion in the number of connected devices

3. Automotive Electronics - already > \$1.1 trillion dollar market already and growing

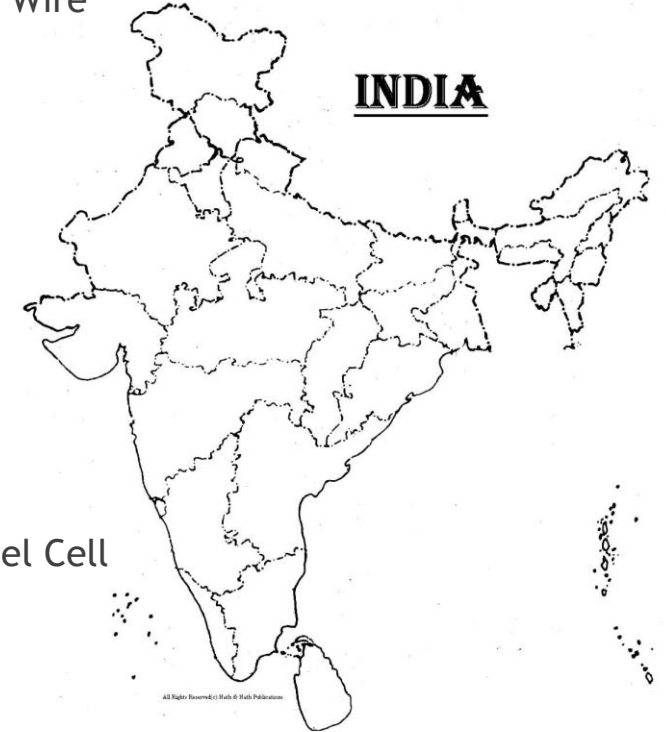
- Today >40% of a vehicles cost is now electronics, >50% by 2030
- Infotainment, Safety Systems, Auto Body, Powertrain, Chassis & Engine Control

4. Auto & Trucking Electrification

- NEV Types: Hybrid gas/electric, PHEV Plug-in Hybrid Electric, BEV Battery Electric, FCEV Fuel Cell Electric Vehicles.
- More electronics and logic devices come with each wave of electrification

5. Solar PV - Undeniable market growth continues

- 2019 saw 9% of silver supply consumed in Solar PV, 2020 is a down year
- 2021-25 will be growth years



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Legislative Suggestions



1. Electronics - If you can compete in Semiconductor (\$433B), you can compete in Auto Electronics (\$1.1T) and Consumer Electronics (\$1.9T) markets

- Develop your respective supply chains in these products
- Flakes and powders is a key component, but also nano-materials ← supreme refining is the backbone
- Recycle ... recycle ... recycle - Don't just throw in a landfill
- Don't become the world's e-waste bucket. Be selective in any imports of e-waste. Mobile phones, data center waste, and IC/Logic devices and PCB's have the highest precious metals content.

2. Li-Batteries - vehicle electrification and energy storage

- Advocate for responsible mining in Nickel, Cobalt, and Lithium
- Nickel Mine Tailings directly dumping into our oceans. Indonesia and Papua New Guinea have some of the worst offending miners.
- Regarding Solar PV Storage deployments - Be careful on repurposing Li-batteries. Don't become the LiB dumping grounds.
- LiB Recycle - absolutely develop this recycle industry. Umicore would be a good corporate partner.

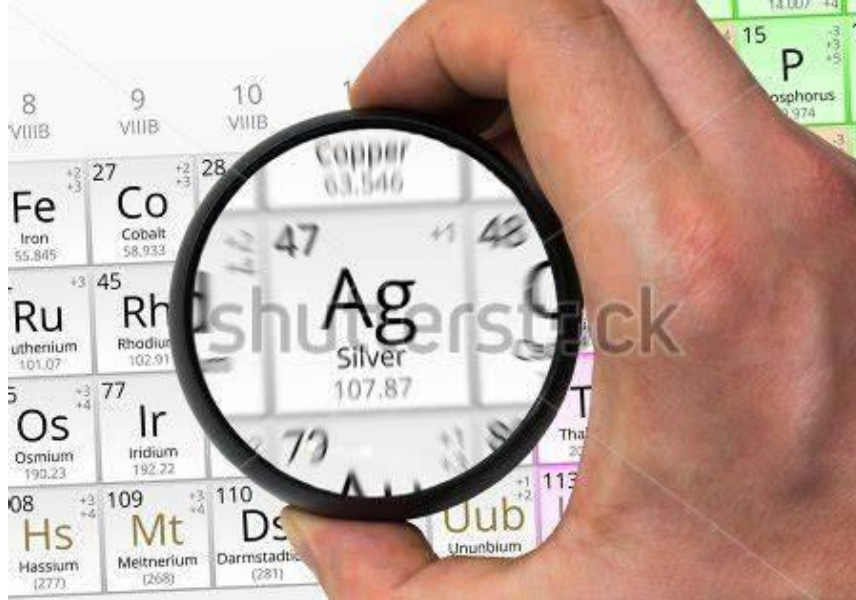
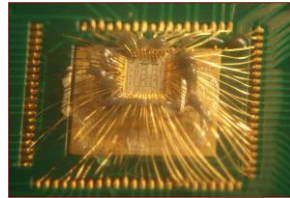
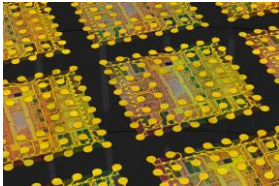
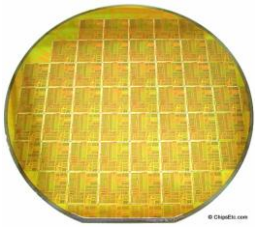
3. Solar PV - Undeniable market growth continues

- Develop your respective supply chain of materials to support this segment.
- Again, develop a recycle capability.
- Consider an upfront Solar PV panel disposal fee. Solar panel recycle costs in USA \$12-14 per 60-cell panel, yet only \$3 of Aluminum, Copper and Silver are recovered.
- Beware of CdTe (Cadmium/Tellurium) and CIGS panels (10% of the PV market) - Very toxic materials

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Semiconductor Silver Demand

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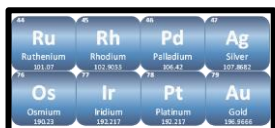
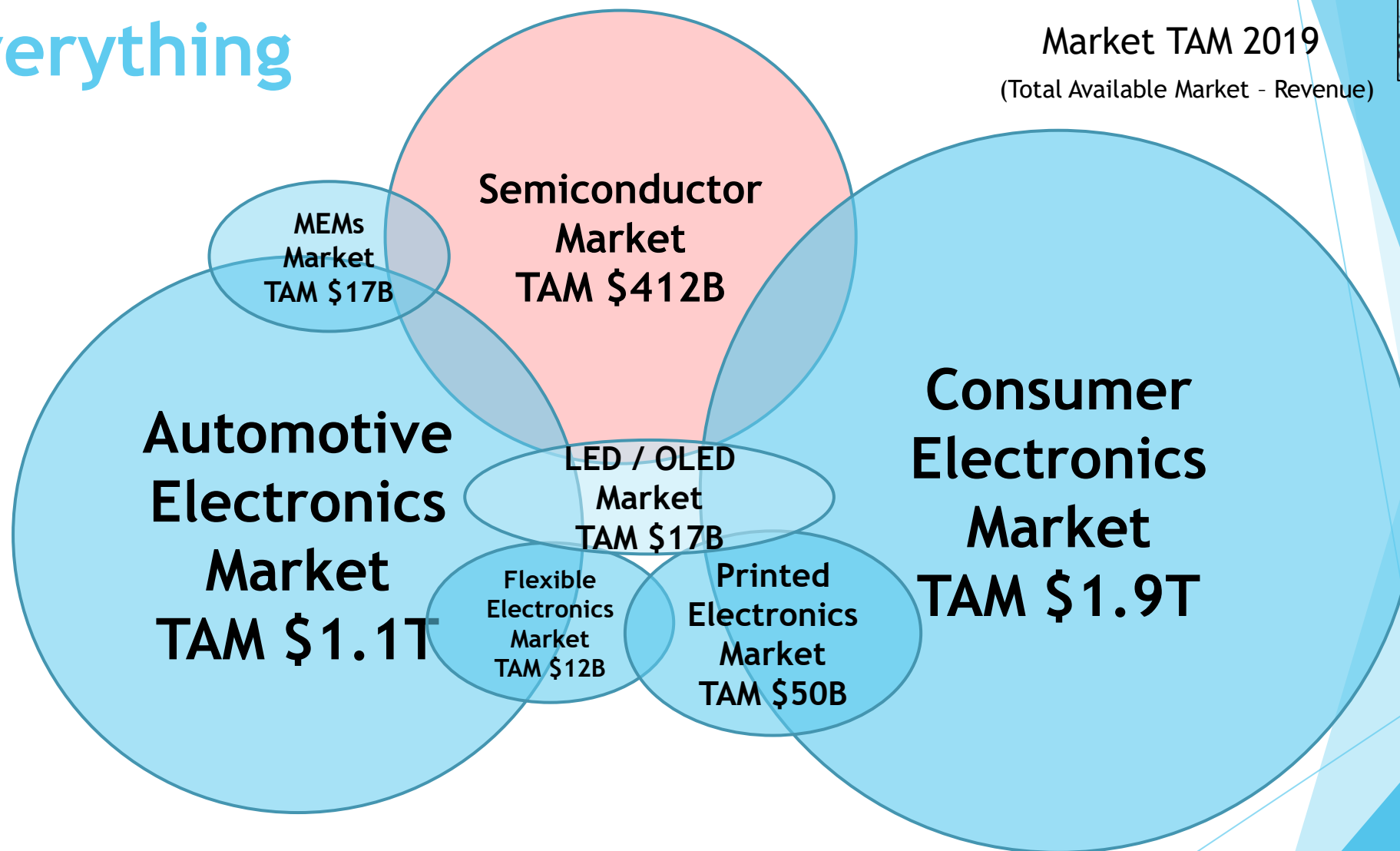
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Electronic Markets - Classification Is Everything

Market TAM 2019
(Total Available Market - Revenue)



47	107.87	48
Pd	Ag	Cd
106.42	107.8682	112.411

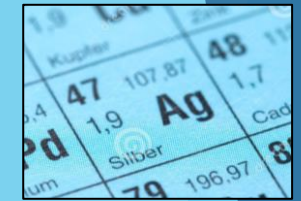


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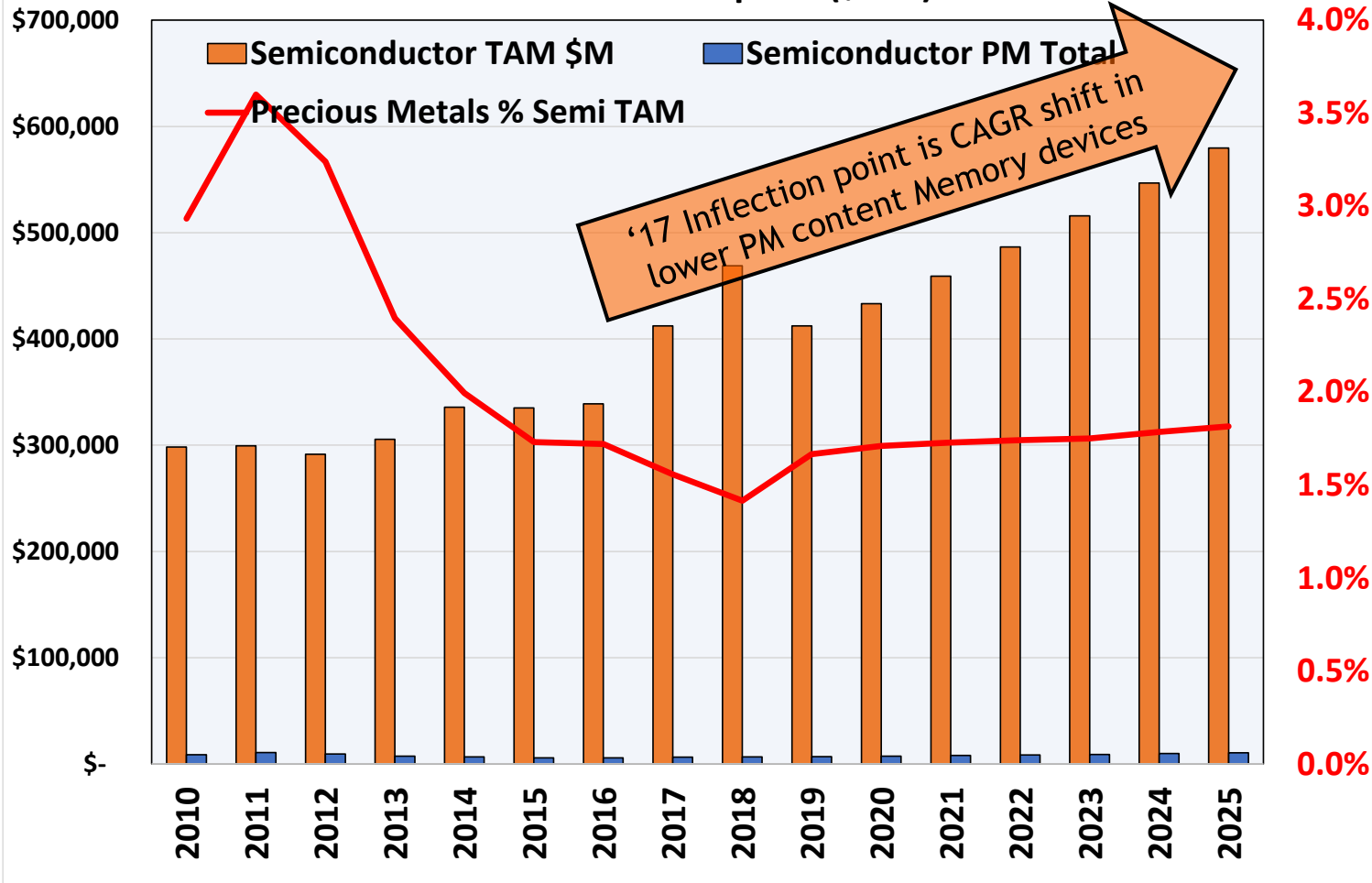
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Semiconductor Silver Demand



Semi Revenue (\$M's)

Semiconductor Revenue TAM &
Precious Metals Spend (\$M's)



Little precious metals in NAND/DRAM memory, but close to 2% of revenue in Integrated Circuits precious metals materials spend.

Metals content creeps up with each tighter pitch/node

2018: Memory shortage and pricing 3x inflated Semi TAM.

Ru Ruthenium 44 101.07	Rh Rhodium 45 102.91	Pd Palladium 46 106.42	Ag Silver 47 107.87
Os Osmium 76 190.23	Ir Iridium 77 192.22	Pt Platinum 78 195.08	Au Gold 79 196.97

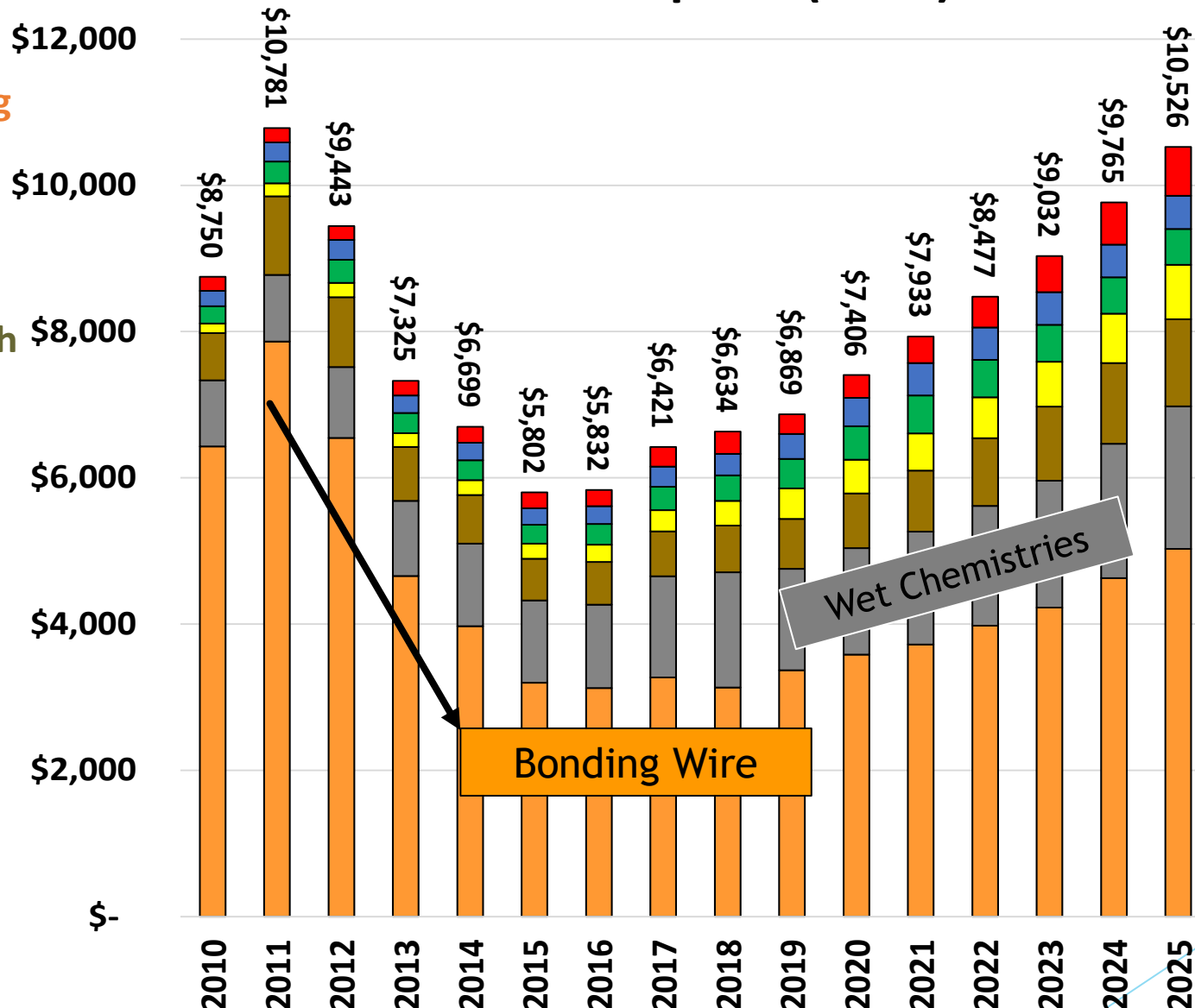
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Semiconductor Precious Metals Spend (\$M's)

#1
#2
#3
#4
#5
#6
#7

- Bonding / Bumping Wire
- Wet Chemistries
- Ag ECA / Die Attach / Paste / Solder
- MEMS Lids (Au)
- ALD / CVD / MOCVD Mtrls
- PVD Targets - Precious Metals
- Preforms (All Au, AuGe, AuSn)



Ag Die Attach, ECA, Paste & Solder Materials

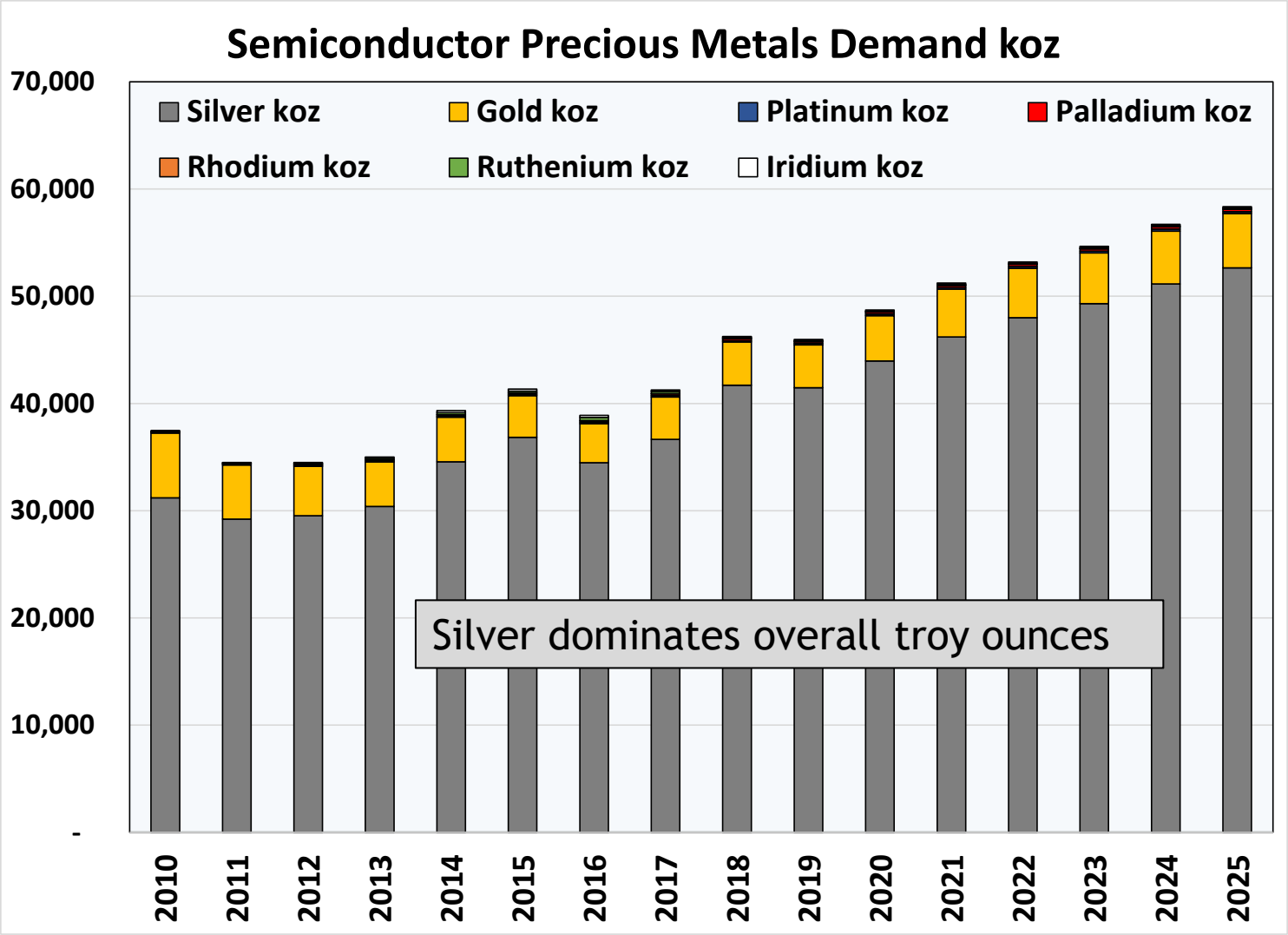
Wet Chemistries

Bonding Wire

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Semiconductor Precious Metals Demand

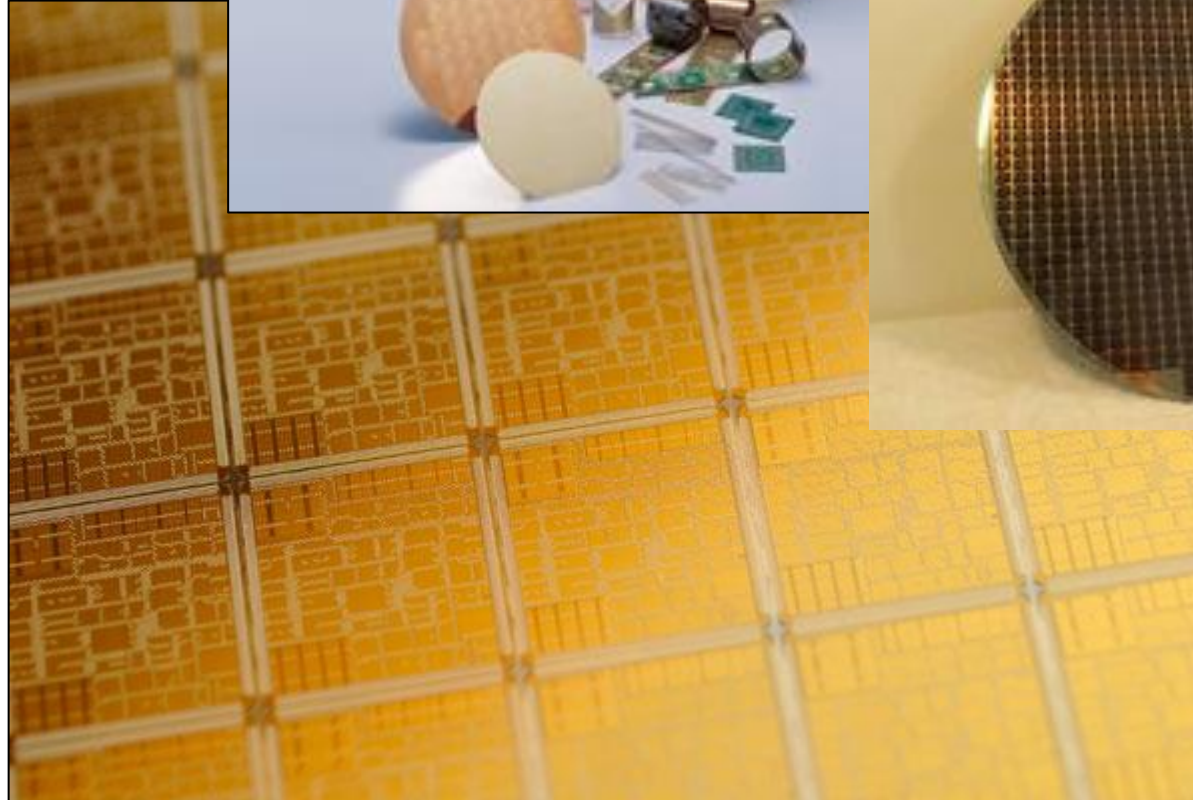


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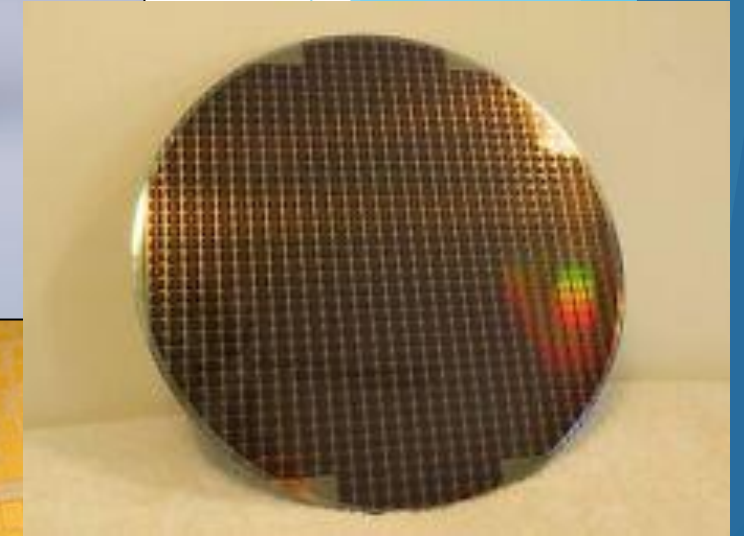
Wet Chemistries

#2 PM Spend Category

- ▶ Gold is > 90% of the plated materials
- ▶ Gold electroplating
- ▶ Gold alloy electroplating
- ▶ Gold strike plating
- ▶ Electro-less gold plating
- ▶ **Silver plating**
- ▶ Platinum group
- ▶ Rhodium plating
- ▶ Ruthenium plating

A partial periodic table showing elements Pd (47), Ag (48), and Au (79). The element Ag is highlighted with a blue circle. The table includes atomic numbers, element symbols, and names in German (Silber for Silver, Gold for Gold).

47	107.87	48
Pd	Ag	Cd
Silber		
79	196.97	80
Au		

A small periodic table showing elements Ru (44), Rh (45), Pd (46), Ag (47), Os (76), Ir (77), Pt (78), and Au (79). The element Ag is highlighted with a blue circle.

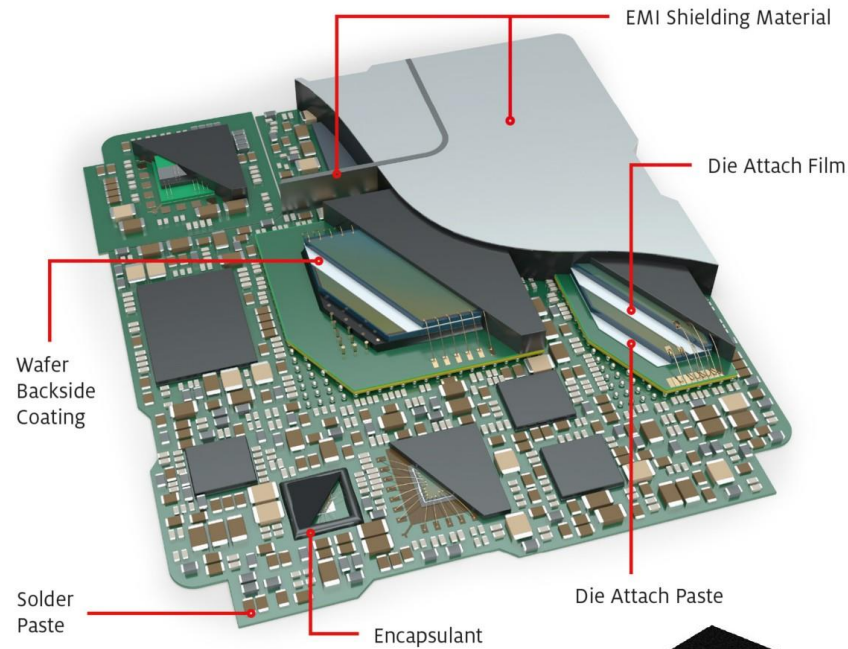
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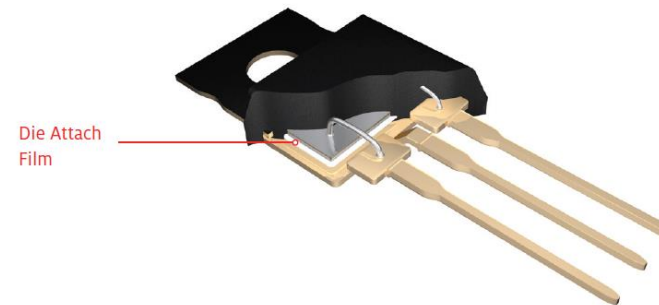
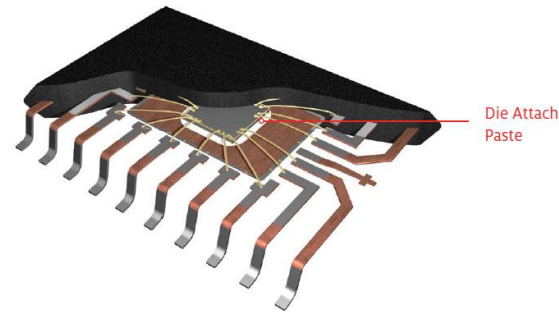
Ag Joining Technologies: Brazing Materials, ECA, Die Attach Materials

#3 PM Spend Category



ELECTRICALLY CONDUCTIVE DIE ATTACH PASTES (DAP)

PRODUCT	DESCRIPTION	KEY ATTRIBUTES	DIE SIZE (mm)	SUBSTRATE FINISH	MOISTURE SENSITIVITY LEVEL, MSL	VOLUME RESISTIVITY (Ohm·cm)	THERMAL CONDUCTIVITY (W/m·K)	RECOMMENDED CURE
LOCTITE ABLESTIK 2000	Ag-filled die attach adhesive	<ul style="list-style-type: none"> Low bleed Low stress Ultra-low moisture absorption Fast oven cure with no voids 	≤ 12 x 12	Solder mask or Au	L2 260°C capable	5.0 x 10 ⁻⁴	1.2	30 min. ramp and 15 min. hold at 175°C
LOCTITE ABLESTIK 2100A	Ag-filled die attach adhesive	<ul style="list-style-type: none"> Low bleed Low stress Oven cure 	≤ 12 x 12	Solder mask or Au	L2 260°C capable	5.0 x 10 ⁻²	1.2	30 min. ramp and 15 min. hold at 175°C
LOCTITE ABLESTIK 2300	Ag-filled die attach adhesive	<ul style="list-style-type: none"> Low bleed Low stress Excellent dispensability Low voiding Oven cure 	≤ 8 x 8	Solder mask or Au	L2 260°C capable	5.0 x 10 ⁻²	0.6	30 min. ramp and 15 min. hold at 175°C
LOCTITE ABLESTIK 2700HT	Ag-filled die attach adhesive	<ul style="list-style-type: none"> Excellent bleed performance Long work life Strong hot/wet adhesion to Au Ideal for small needle dispensing Oven cure 	≤ 3 x 3	Solder mask, Ag or Au	L3 260°C capable	3.0 x 10 ⁻⁴	11.0	30 min. ramp and 30 min. hold at 175°C in nitrogen
LOCTITE ABLESTIK ABP 20305CR	Ag-filled die attach adhesive	<ul style="list-style-type: none"> Low stress Compatible with dam & fill encapsulants Excellent dispensing performance for high throughput application Snap cure 	≤ 10 x 10	Solder mask, Ag, Au or plastics	L3 260°C capable	2.0 x 10 ⁻⁴	2.0	120 sec. at 120°C
LOCTITE ABLESTIK ABP 2032S	Ag-filled, epoxy die attach adhesive	<ul style="list-style-type: none"> Good adhesion to a variety of substrates Good dispensing characteristics Low temperature oven cure 	≤ 10 x 10	Solder mask, Ag, Au, steel or plastics	L3 260°C capable	2.0 x 10 ⁻⁴	1.0	60 min. at 80°C



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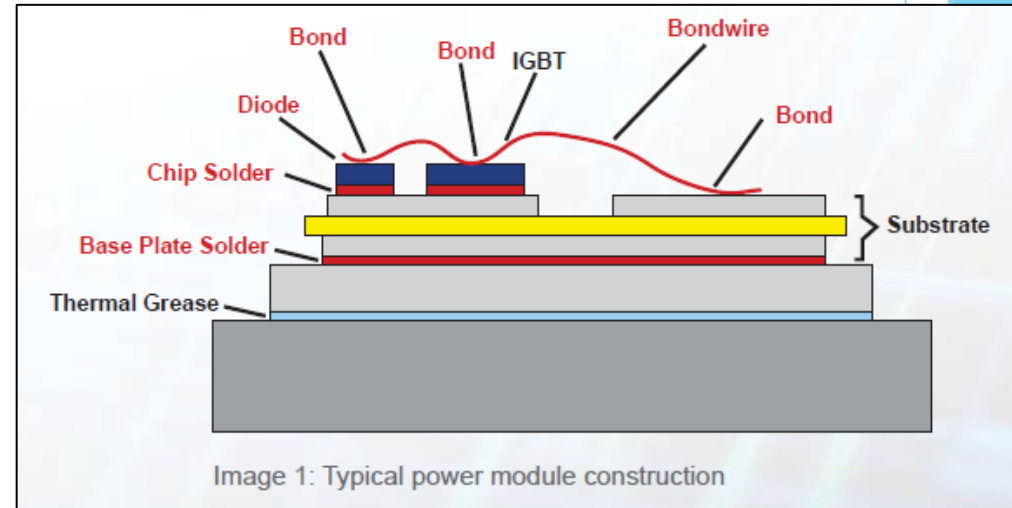
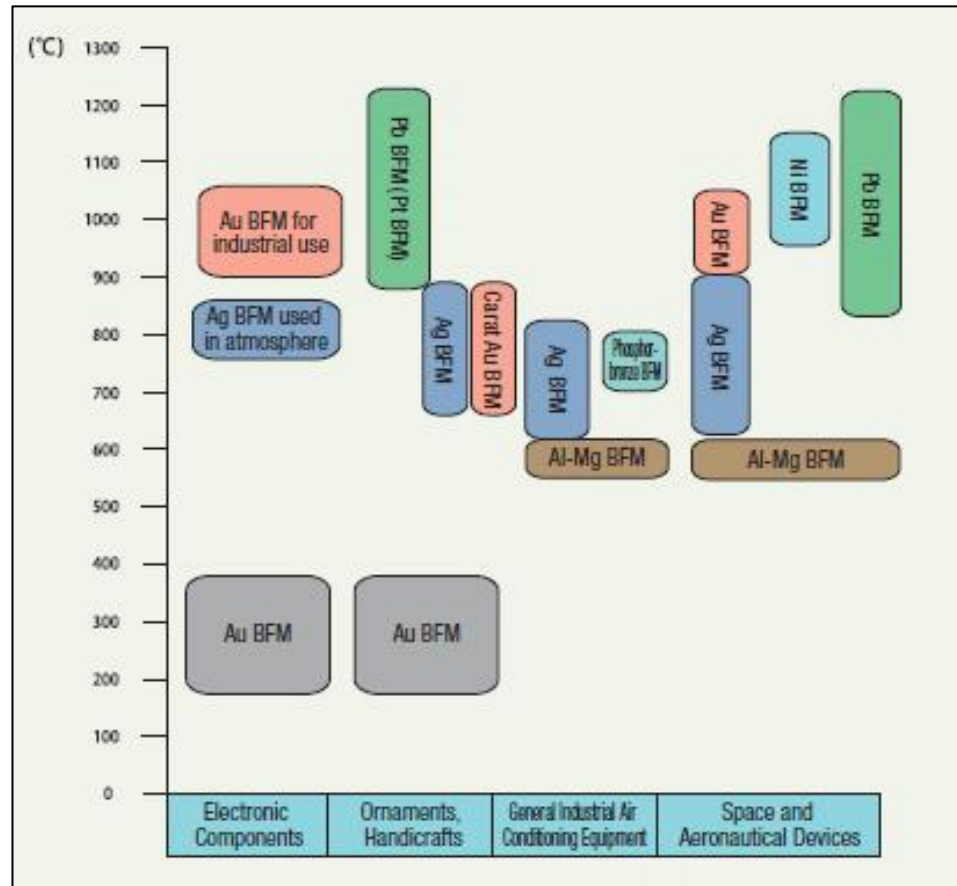
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Ag Solder / Brazing Materials

#3 PM Spend Category

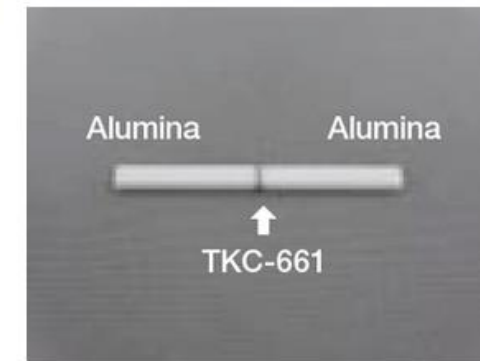
Melting Points of various BFM - Brazing Filler Materials



Exterior of active brazing filler metal



Exterior after active brazing filler metal has been brazed



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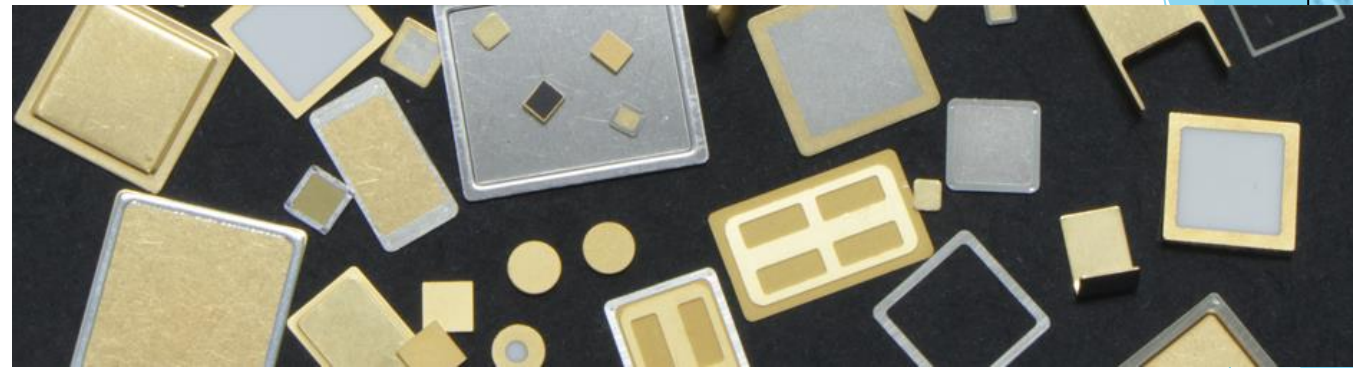
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MEMS Lid's

#4 Semi Precious Metals Send Category



Microelectronic Packaging Comparison Chart

Packaging Products	Applications	Illustrations	Lid Material	Preform
Combo-Lids™ (Flat)	High reliability hermetic packaging		Kovar or Alloy 42	Gold-Tin or other alloys
Combo-Lids™ (Drawn)	High reliability hermetic packaging where die height is higher than package cavity depth		Kovar or Alloy 42	Gold-Tin or other alloys
Non-magnetic Metal Combo-Lids™	Medical Imaging and signal noise control		Mo, CuW, Bronze, Cu	Gold-Tin or other alloys
Non-magnetic Metal Combo-Lids™	High Purity non-magnetic combo lids, does not contain Nickel or platinum		Mo, CuW, Bronze, Cu	Gold-Tin or other alloys
Non-magnetic BeCu Combo-Lids™	High Purity non-magnetic combo lids, does not contain Nickel or platinum		BeCu	Gold-Tin or other alloys
Nozzle Combo-Lids™	MEMS, Automotive and High reliability hermetic package sealing		Kovar	Gold-Tin
Ceramic Combo-Lids™ with edge metallization	Non-magnetic applications		Al ₂ O ₃	Gold-Tin or other alloys
Tack welding services for Ceramic Lids	Non-magnetic applications		Al ₂ O ₃	Gold-Tin or other alloys

Selectively plated Combo-Lids™	High reliability hermetic package sealing		Kovar or Al ₂ O ₃	Gold-Tin or other alloys
Getter Tack welded Combo-Lids™	High reliability hermetic package sealing		Kovar	Gold-Tin or other alloys
Palladium Combo-Lids™	High reliability hermetic package sealing		Kovar with Palladium	Gold-Tin or other alloys
Seam Seal-Lids™	Hermetic package sealing without preform		Kovar	-
Special Shaped Combo-Lids™	High reliability hermetic package sealing		Kovar	Gold-Tin
Eco-Lids™	Ceramic Lid for non-hermetic packages including CuPacks™		Al ₂ O ₃	MEG-150 or MEG-165 Epoxy
Ceramic Air Cavity Packages	Wireless Applications - Si, GaAs and GaN RF power transistors		Alloy 42 plated with Ni, NiCo, Au	Alumina ring frames
Etch Lids for AR Coated Glass	Double preform attached lid for Visi-Lid™ application		Kovar	Gold-Tin or other alloys

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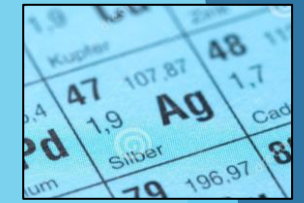
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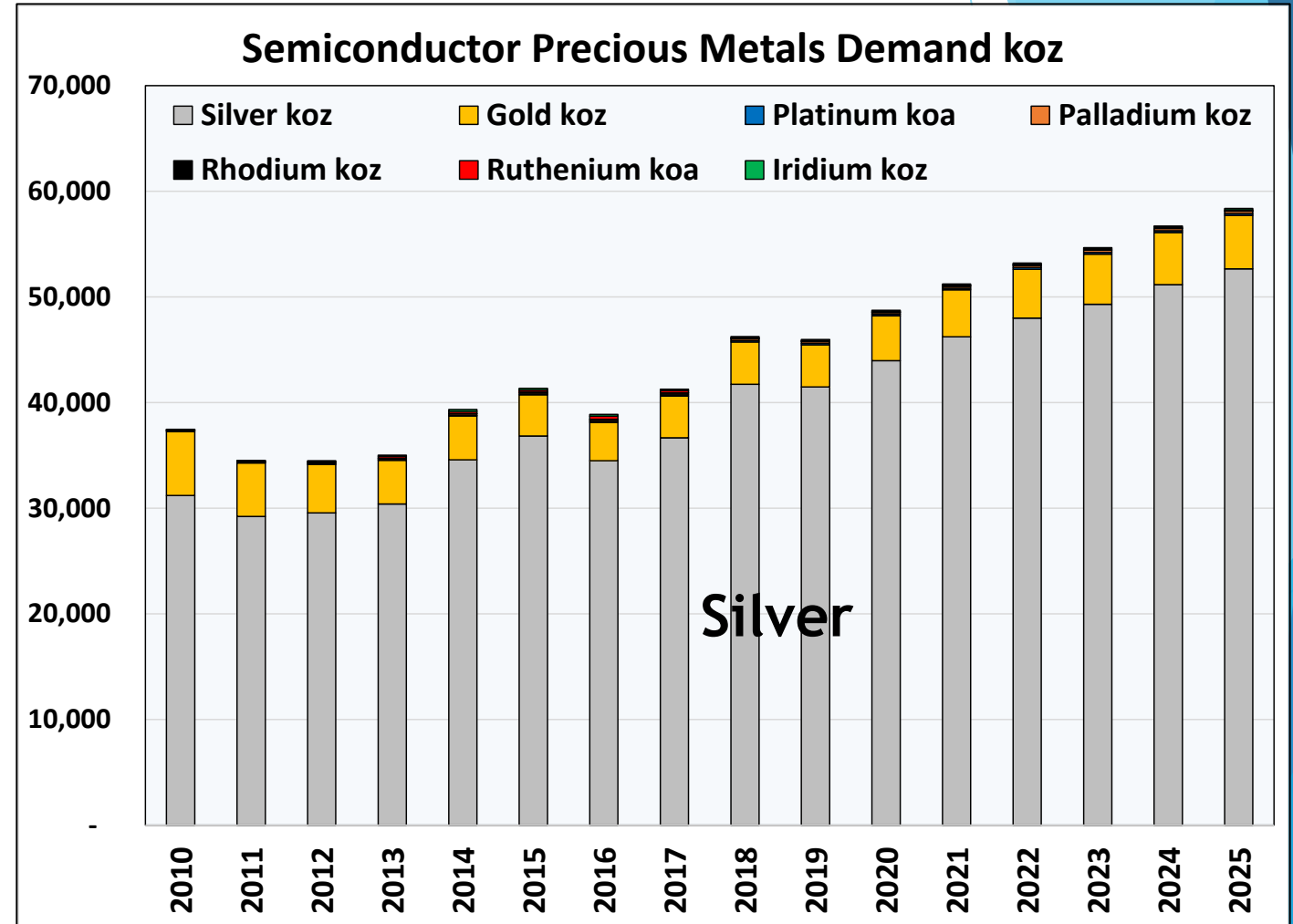
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Silver Use in Semiconductor Is Growing

Summary: PM Demand in Semi



- ▶ Flip Chip and WLP (Wafer Level Processing) is creating additional demands for conductive adhesives
- ▶ Surface mount of packages, and device in device mounting and electrical connection are increasing the use of conductive adhesives in all areas.
- ▶ Modest demand growth from Silver bonding wire. Linear meters are growing, while thrifting is achieved with less pure gold and smaller diameter wire,



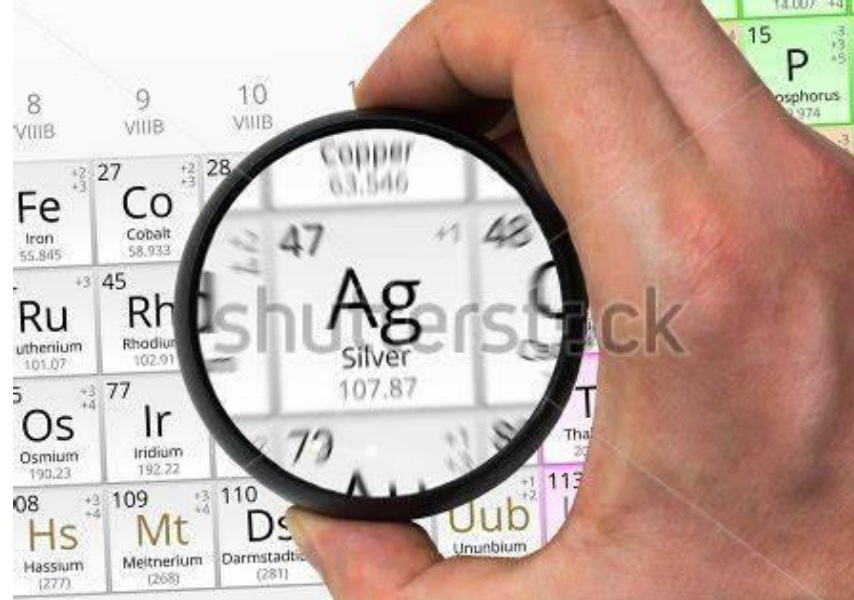
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Automotive

- Auto Semiconductor
- Auto Electronics
- Spark Plugs
- 10% of these categories
 - Contacts & Materials
 - Electrical Connectors



Automotive Silver Demand

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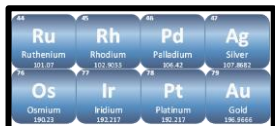
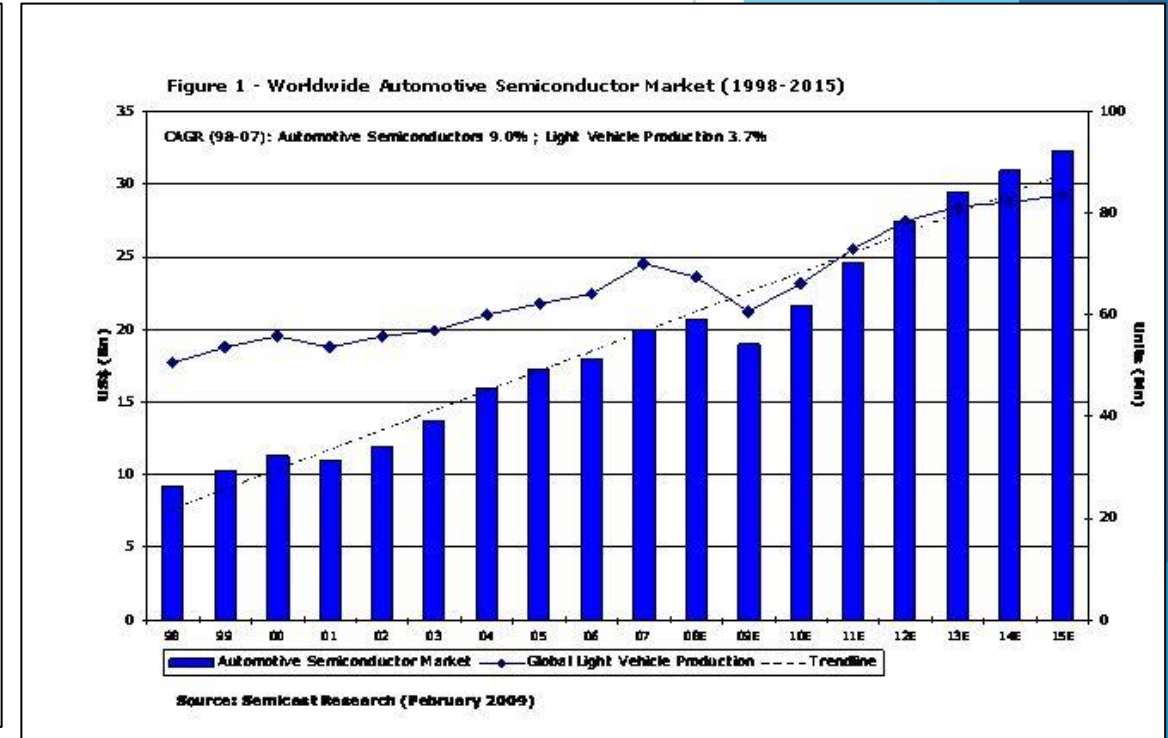
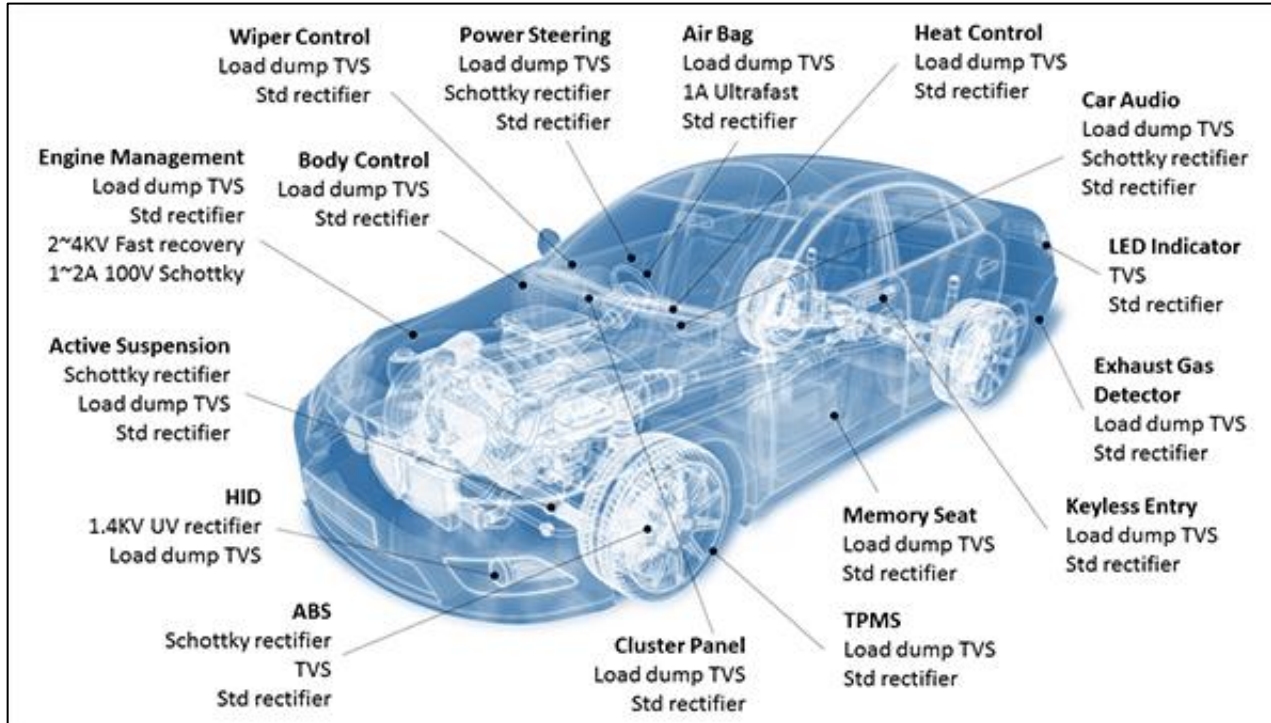
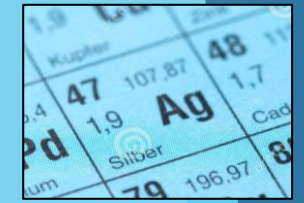
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Automotive Electronics Market Growth

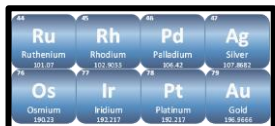
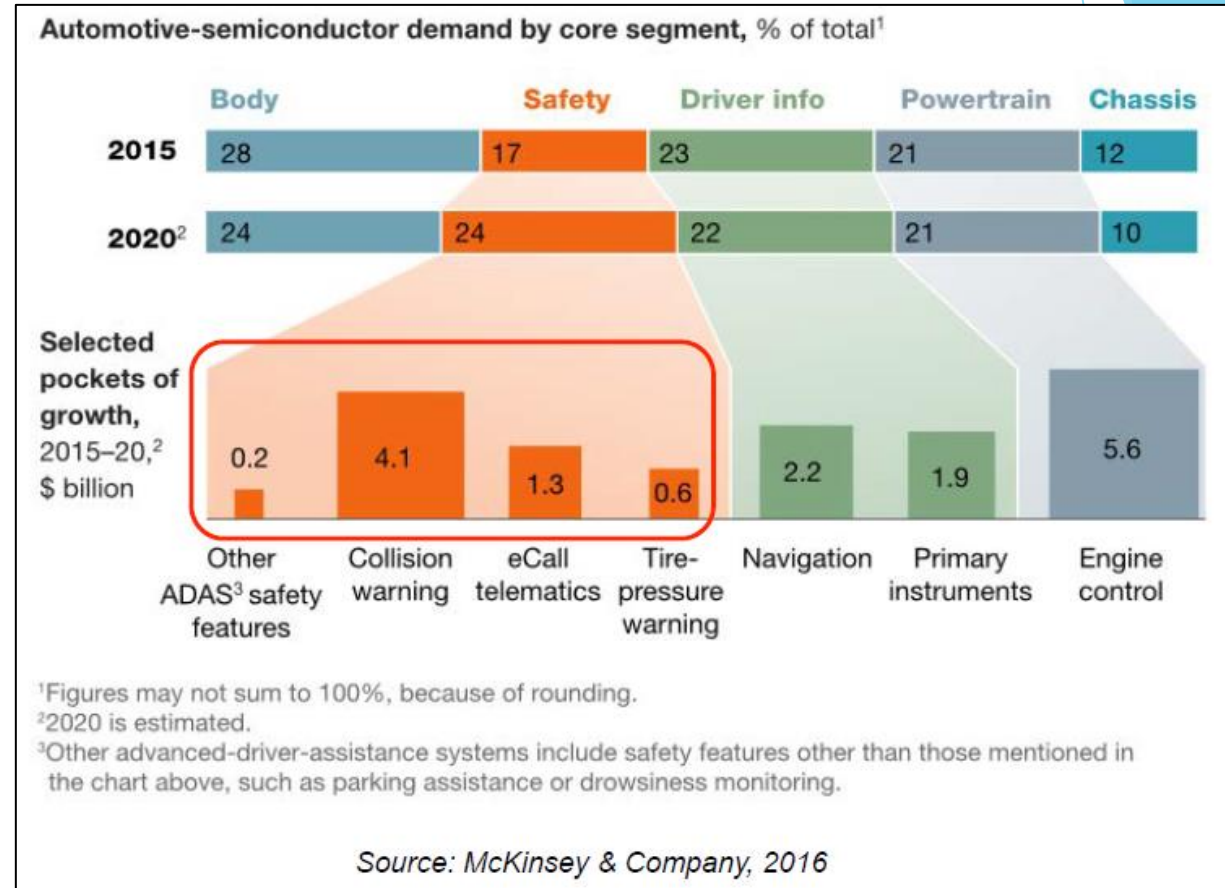


Automotive Electronics Main Spend Areas

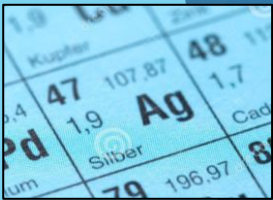
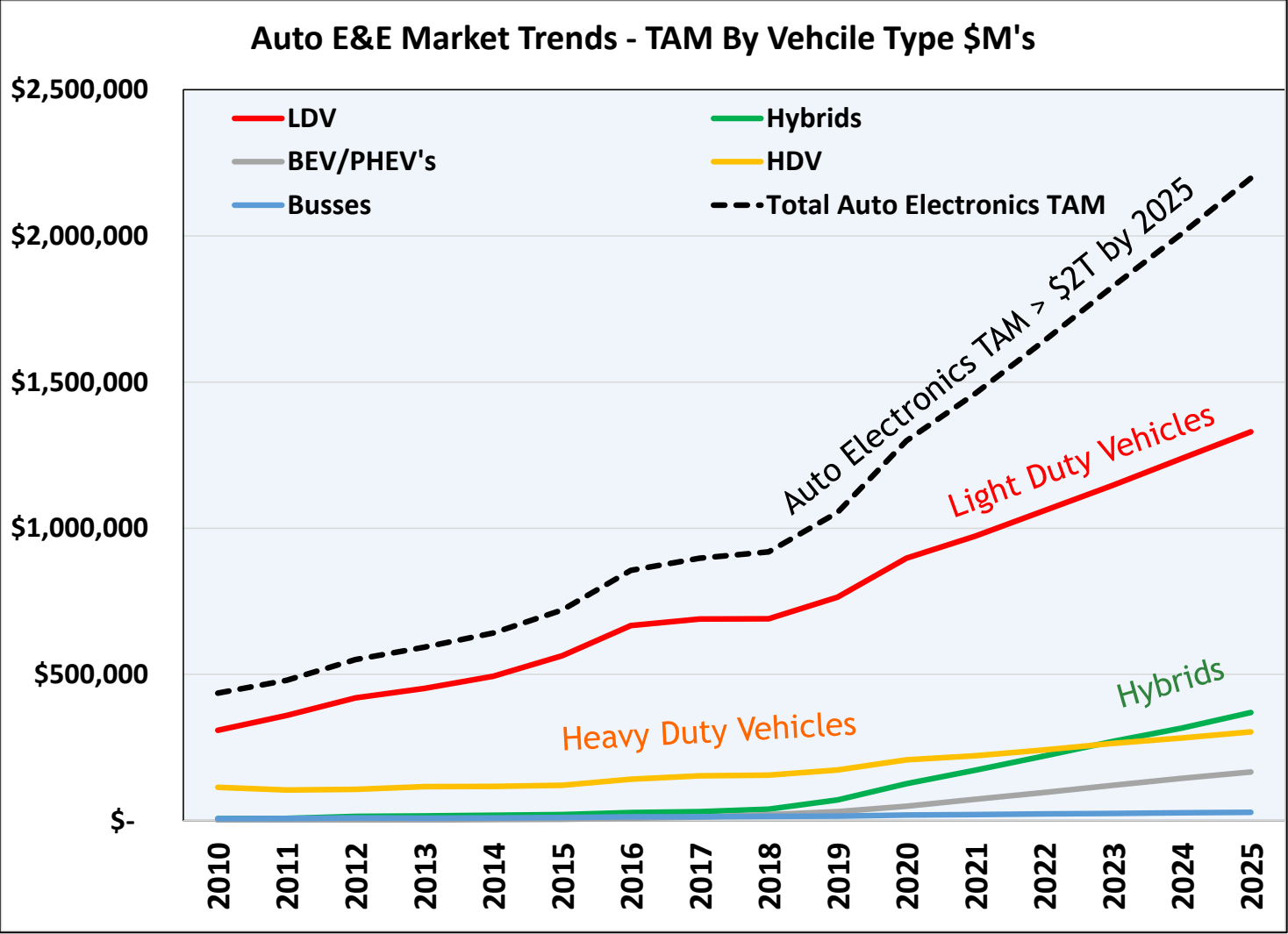
5 Main Categories:

- 1) Body
- 2) Safety Systems
- 3) Driver Information / Infotainment
- 4) Powertrain
- 5) Chassis & Engine Control

❑ Future: BEV/PHEV/FCEV
Related Electronics

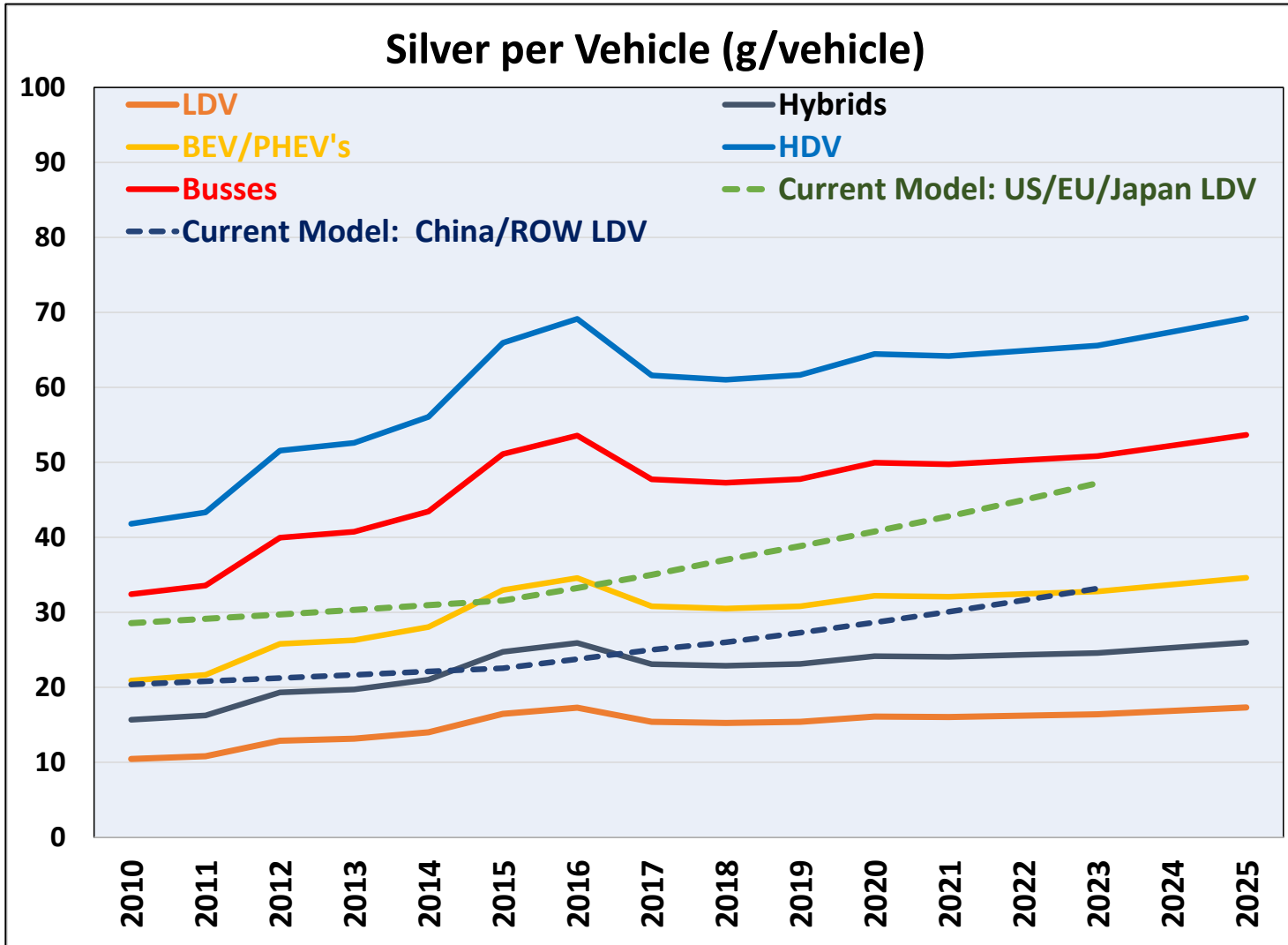


Auto Silver Demand By Vehicle Category



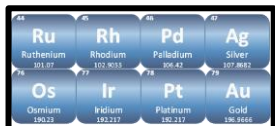
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Automotive Silver Demand

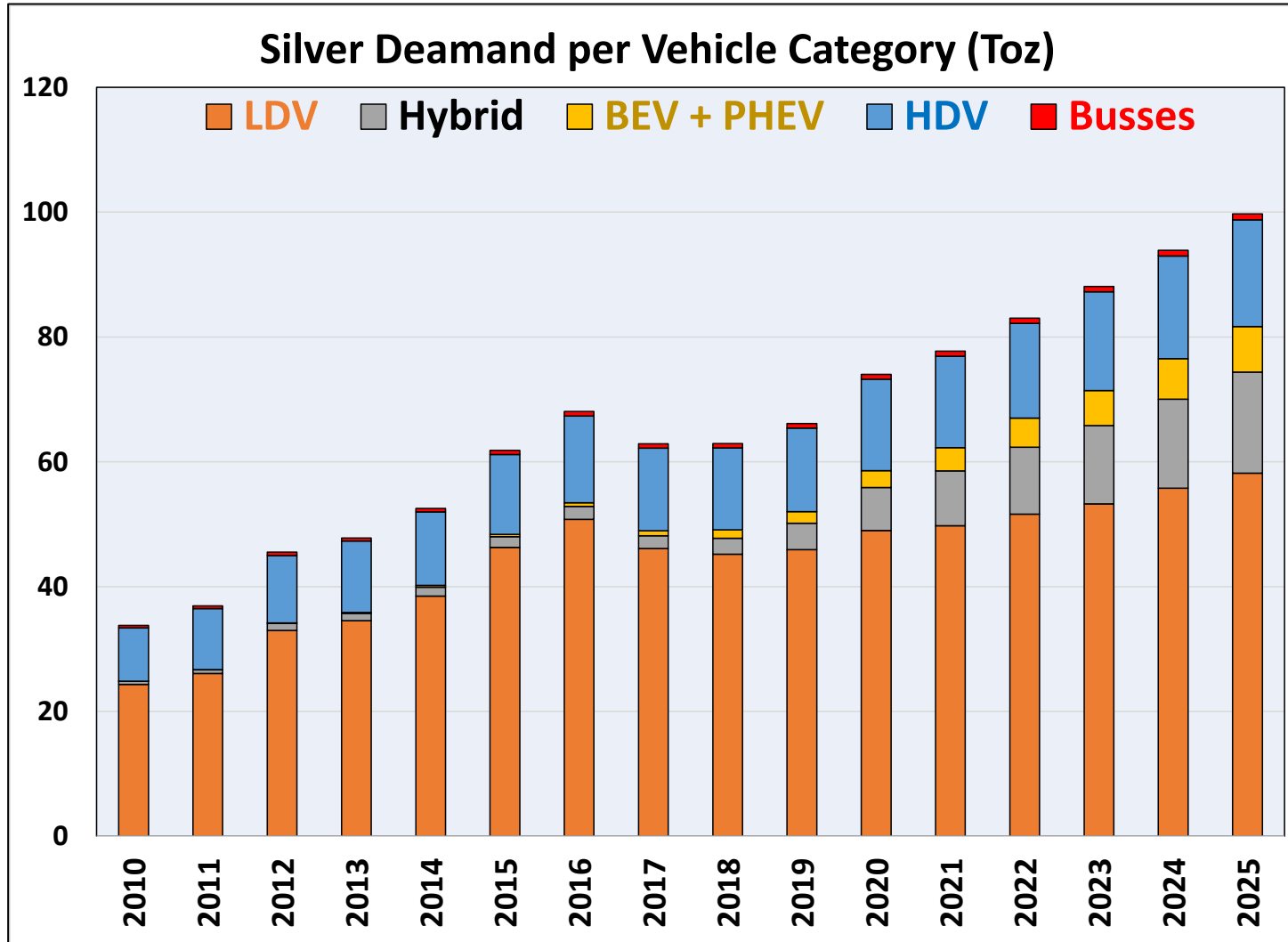


The shift in vehicle mix more than the increase in electronics loading over time will increase the silver auto demand the most.

Hybrids and BEV/PHEV's use 1.5x to 2x the loadings.

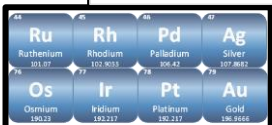


Total Automotive Silver Demand



Automotive

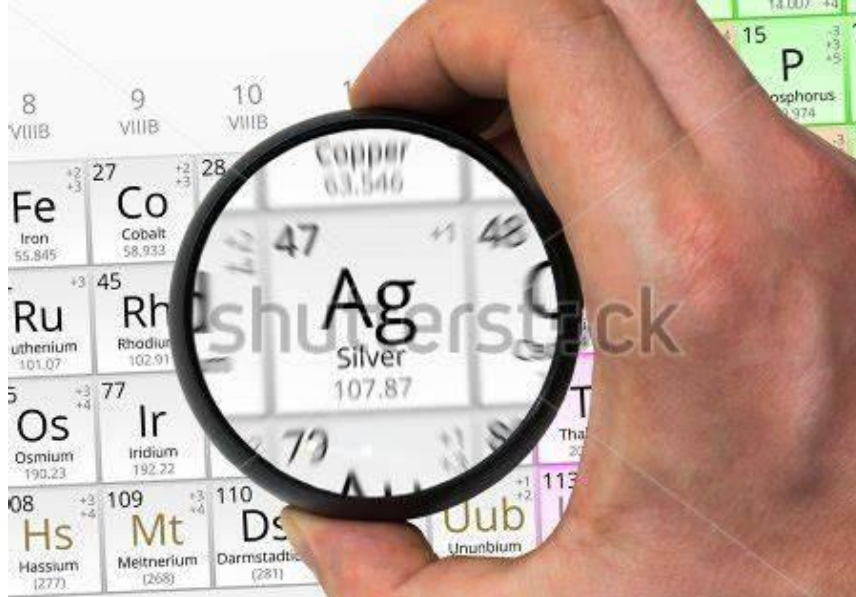
- Auto Semiconductor
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Solar PV Silver Demand

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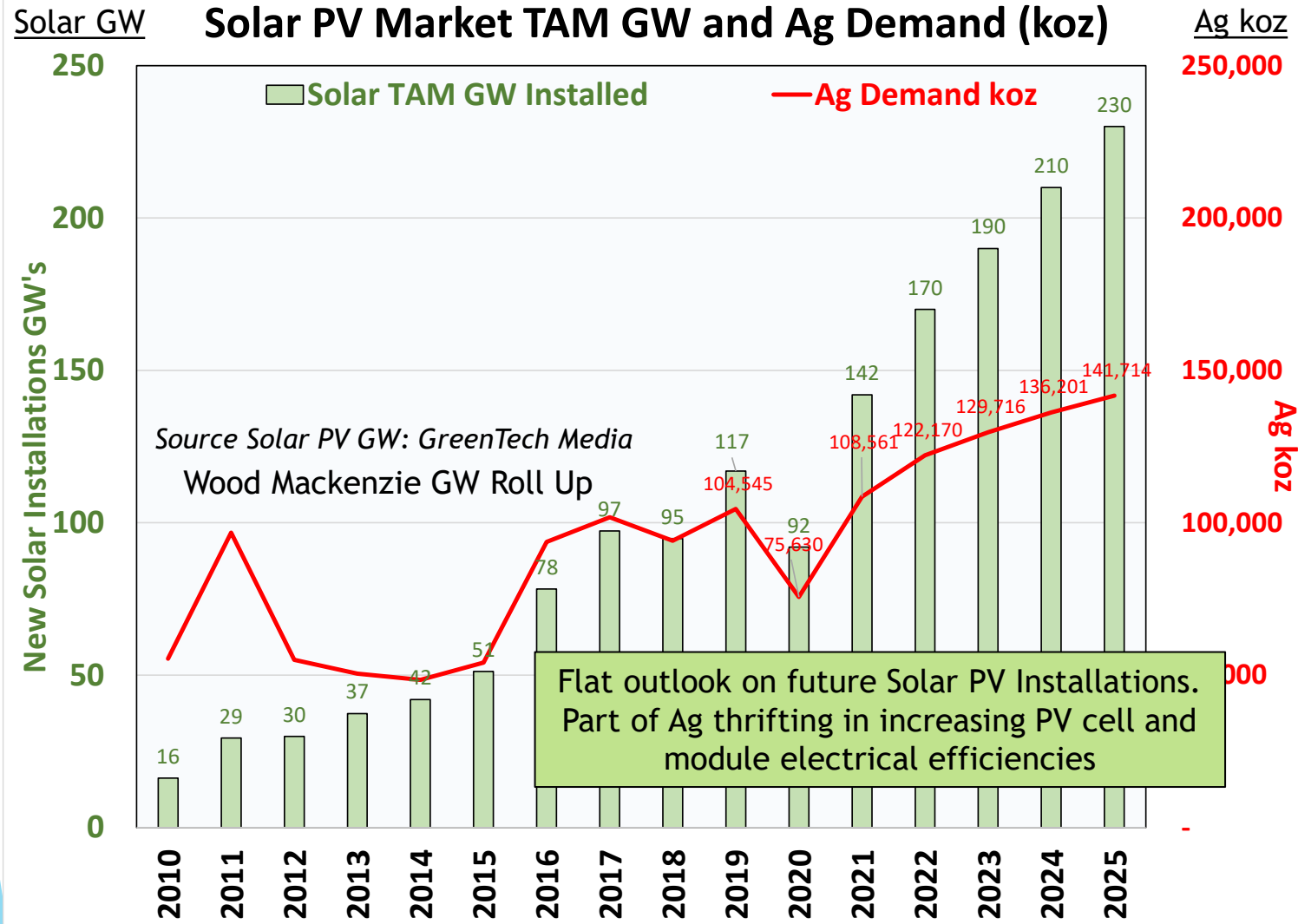
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Solar PV Market & Ag Demand (koz)

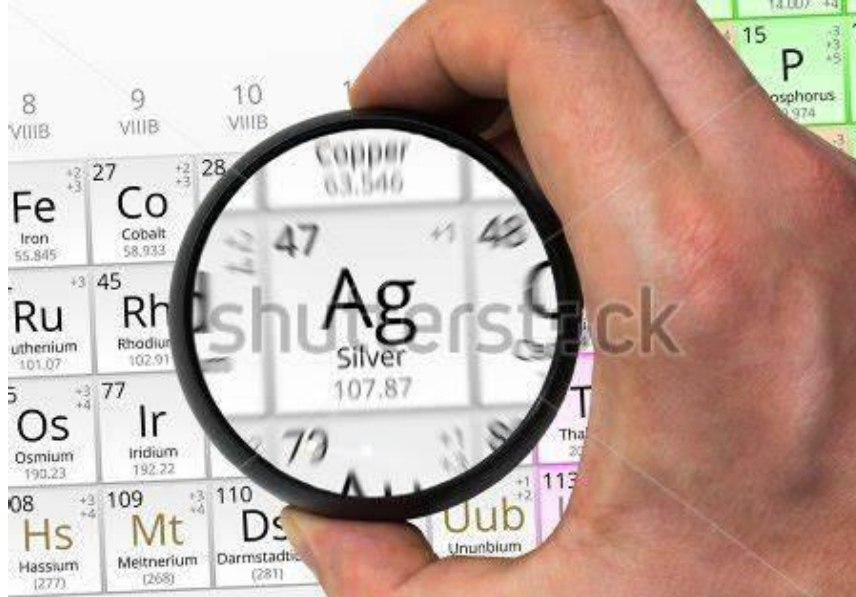
1.9	48
Kupfer	107.87
47	1.7
1.9	Ag
Silber	196.97
79	8



Getting Wood Mackenzie GW Forecast in November. Using PV Magazine Solar Power EU reference data until then.

Design thriving historical used to forecast thriving going forward.

Ru	Rh	Pd	Ag
Ruthenium	Rhodium	Palladium	Silver
101.07	102.905	106.42	107.87
Os	Ir	Pt	Au
Osmium	Iridium	Platinum	Gold
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Thank You

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