2024International Union for Surface Finishing

Electroless Deposition Technology for Electrical Interconnections

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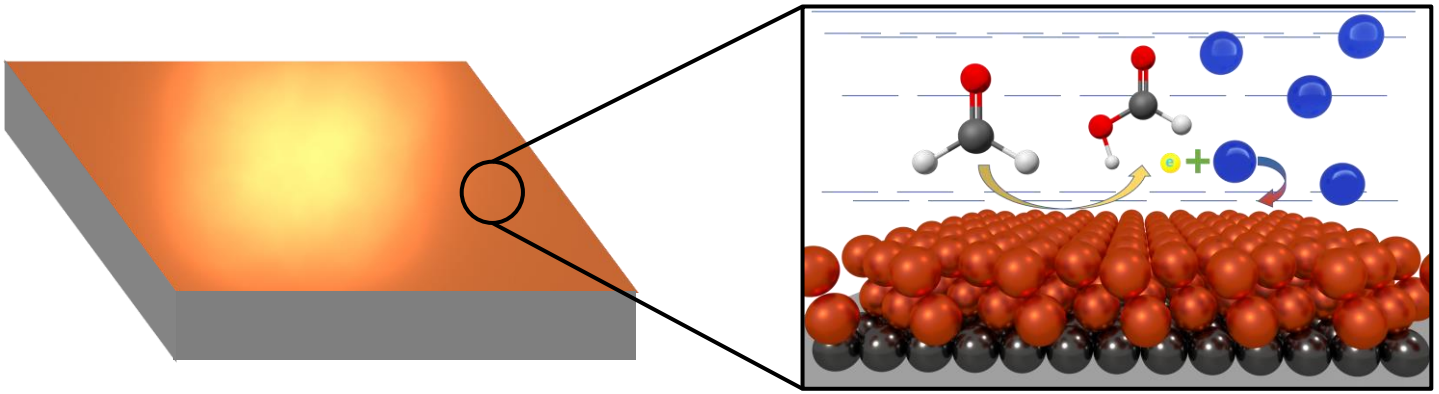
Electroless deposition-principle

Under the action of self catalysis, metal ions in the solution are reduced by reducing agents to form dense coatings on various material surfaces.



Electroless Cu deposition reaction

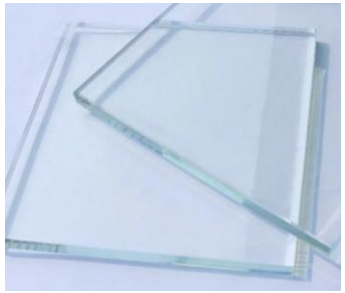
$$Cu^{2+} + 2HCHO + 4OH^- \xrightarrow[Cu]{Pd} Cu^0 + 2HCOO^- + 2H_2O + H_2$$

Electroless deposition-principle

Comparing to Electroplating:

Can be used for various substrates: polymer, ceramic, glass, semiconductor, conductor.






Uniform coating thickness

Strong deep hole plating ability

Comparing to PVD, low cost and uniform/deep plating

Electroless deposition-Challenge

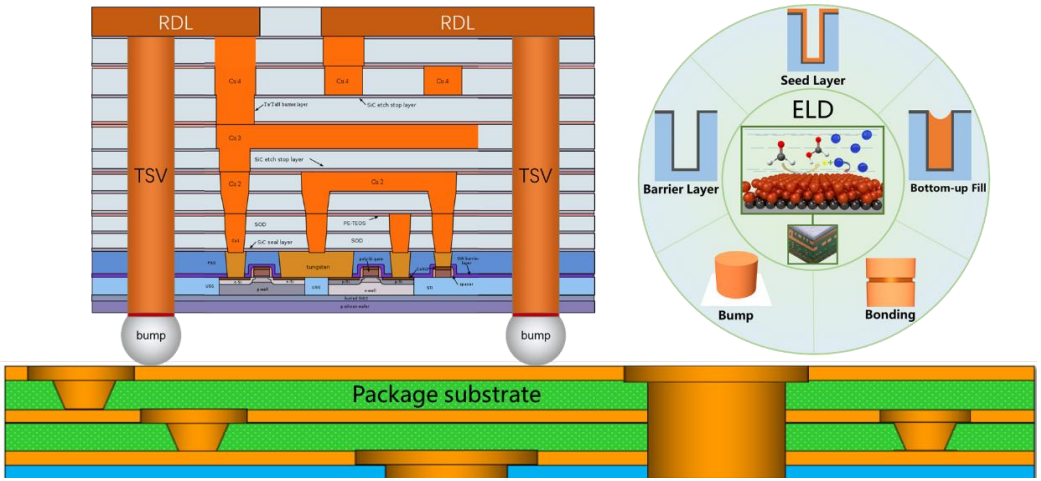
Complex pre-procedures

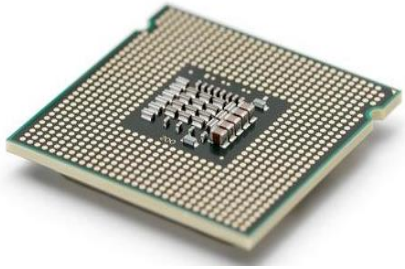
High cost of Pd catalyst

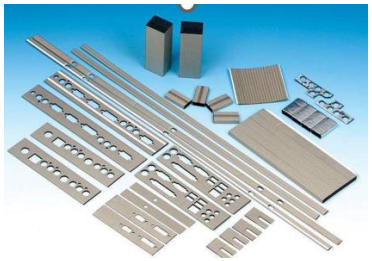
Low stability of plating solution

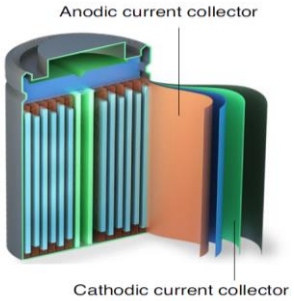
Not easy to control

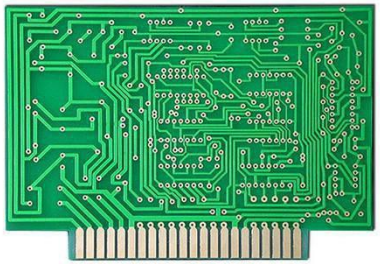
Electroless deposition-Applications in electronics

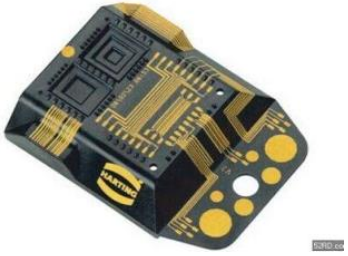


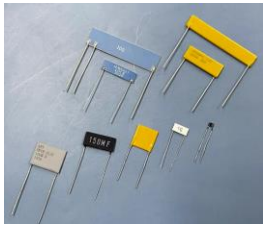












Interconnection

Protection

Electromagnetic shielding

Anti-corrosion

Heat dissipation

Magnetic material

Resistive material

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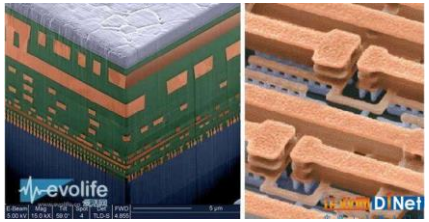
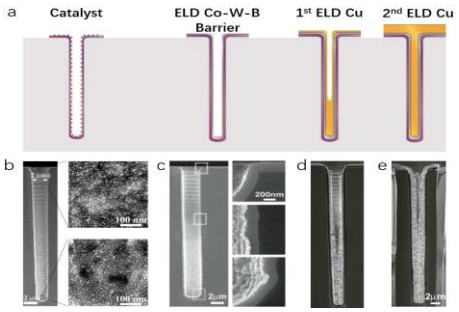
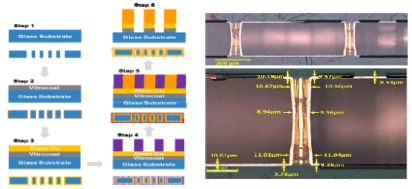
Electroless -Applications in interconnection



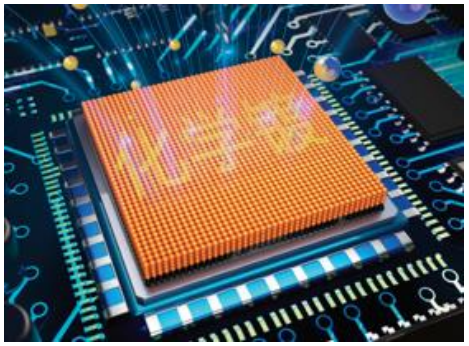
Damascus

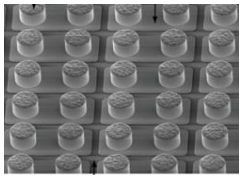


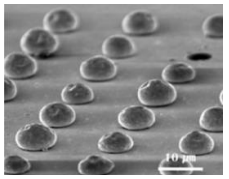
TSV



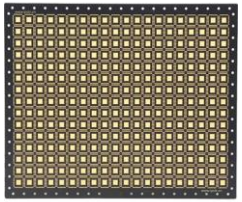
TGV



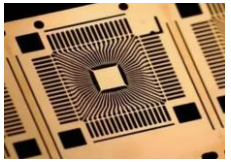


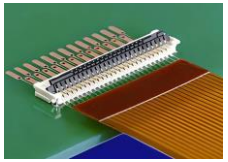


Bumping/UBM

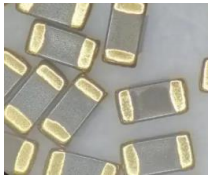


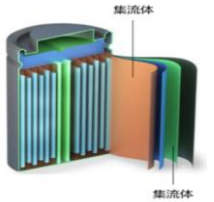
Substrate/PCB





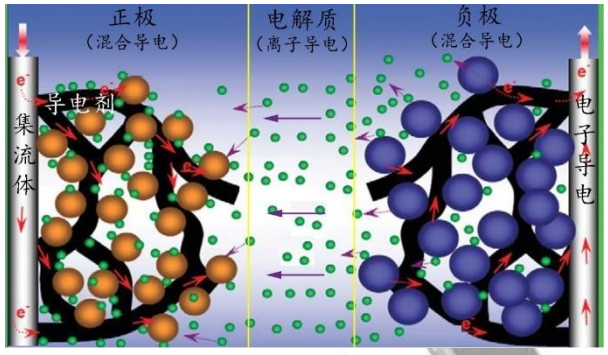
Lead frame/Connector

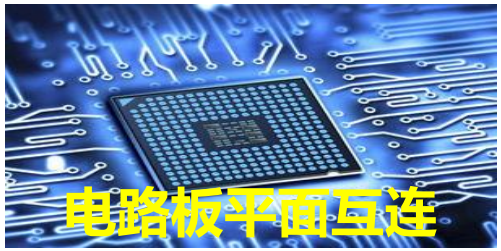




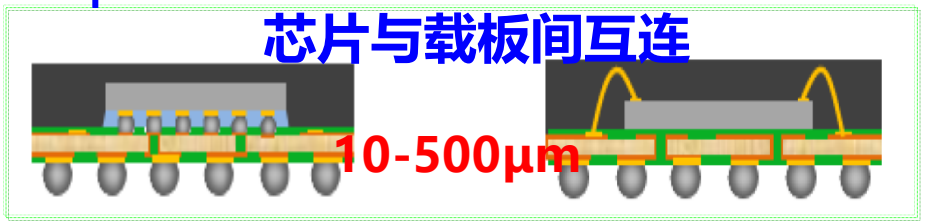
Electrode /
Current collector

Conductive Interconnection

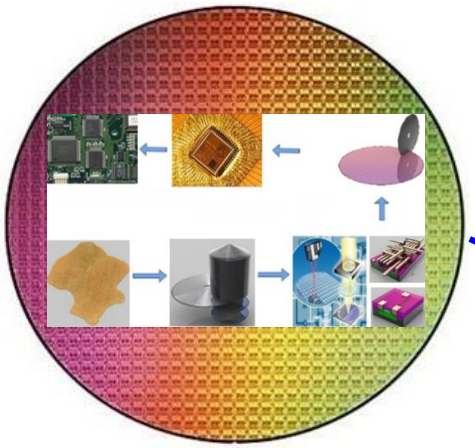


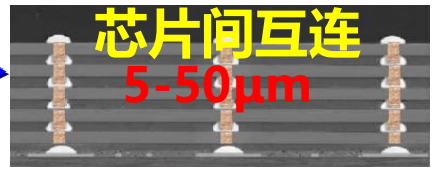


PCB



IC





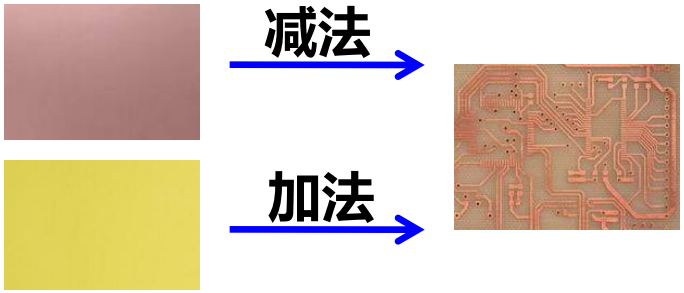
Conductive interconnection enables the transmission of electrical energy and signals, which is fundamental to the functioning of devices

Conductive Materials

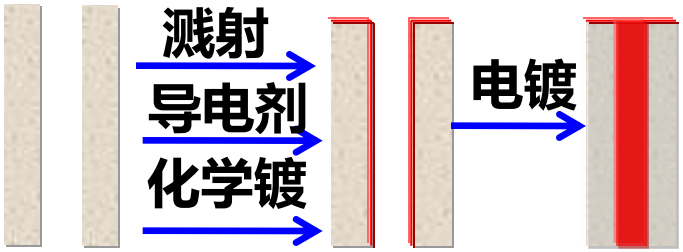
Materials	Ag	Cu	Al	Sn	Au	Ni	Pd	Graphite
ρ(×10⁻⁸Ω·m)	1.65	1.75	2.83	11.3	2.4	6.84	10.8	800-1800

Conductive Interconnection Process

Flat interconnection

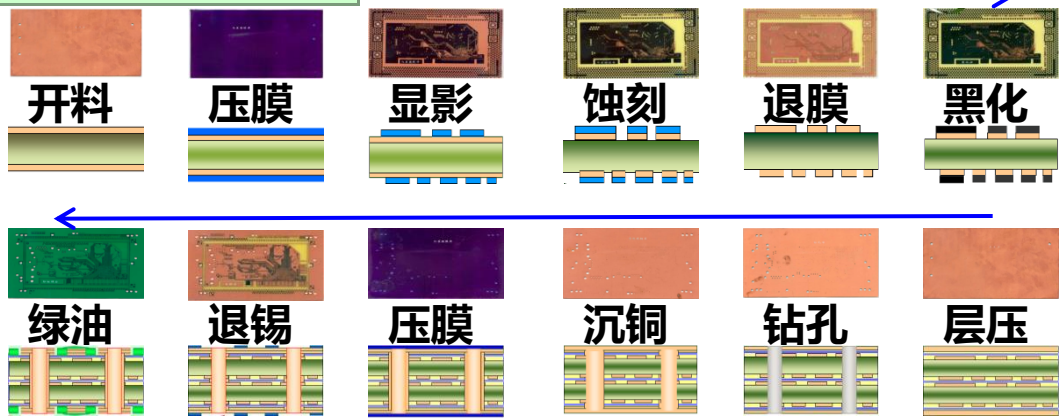


Vertical interconnection

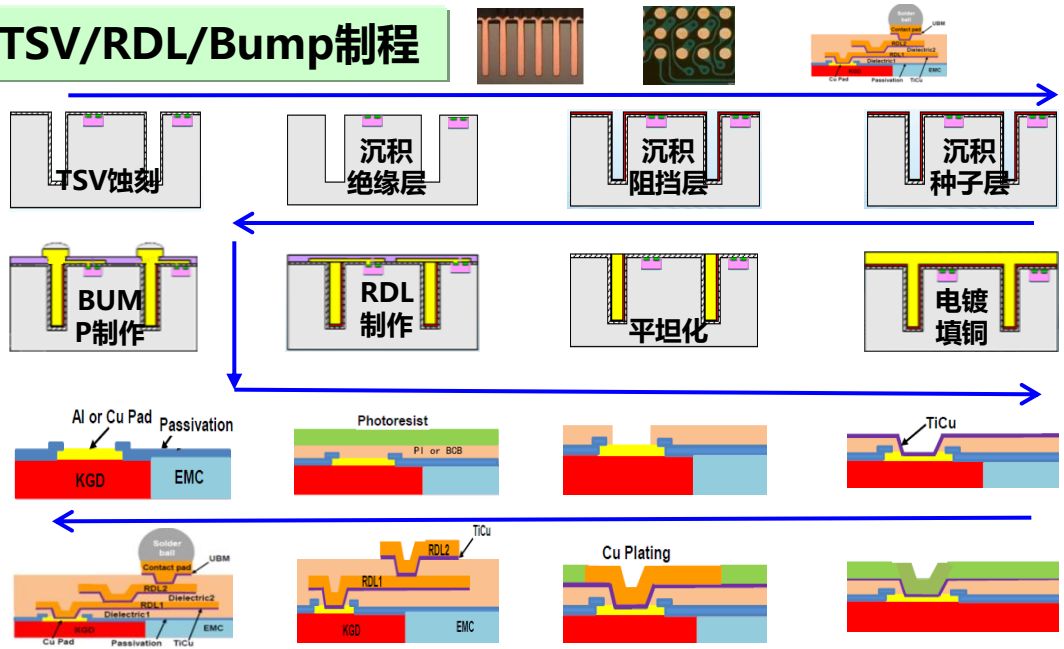


Realizing a conductive layer (metallization) with good adhesion on the surface of insulating substrate is a prerequisite for conductive interconnection

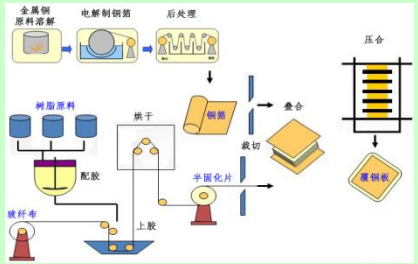
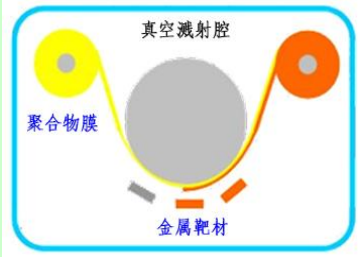
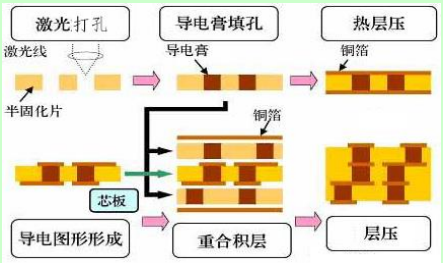
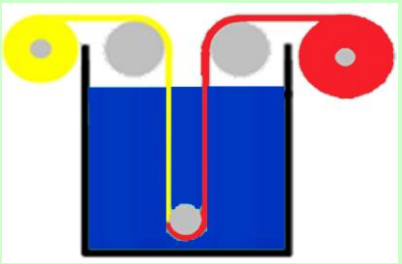
多层PCB制程



TSV/RDL/Bump制程

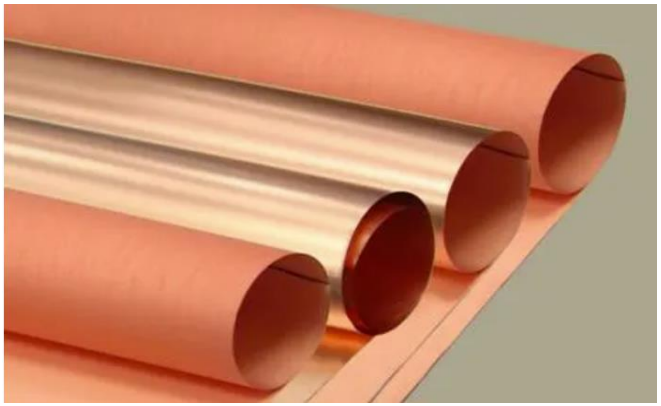


ED Cu application-Elecronic interconnection

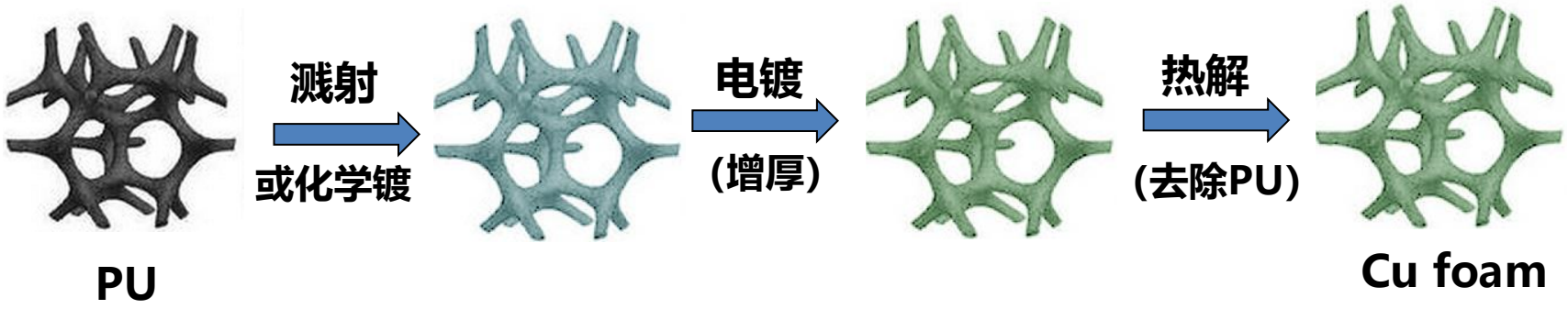
	铜箔压合或涂布	真空溅射金属	导电胶(浆)印刷/塞孔	金属液相沉积
制程				
	粗化铜箔与环氧等基材粘合或将环氧等基材涂布铜箔再进行固化制覆铜箔	在绝缘基体上通过真空溅射金属形成导电(种子)层	将导电浆料在绝缘基体上用印刷或打印方式制备导电线路；或塞孔纵向互连	通过金属液相沉积(化学镀)在附着催化剂的绝缘基体上形成金属导电层
主要优点	制备方法简单、技术成熟，金属化成本较低	可以获得精细线路	加成法制备线路，工艺与设备简单，采用高精度打印机可获得较精细线路，如用铜浆成本低	可获精细线路，工艺设备简单，任意形状可均匀沉积，除催化剂外成本低,可加成法制备线路
主要缺点	难以获得精细线路；只能用减法制造线路，制造线路过程较复杂，大量金属铜被浪费和蚀刻液被消耗，环保压力大	成本高；平面布线(种子层)时只能用于减法制造线路；用于孔金属化种子层时死角位置无法溅射上	在有机基体上难以获得高电导率线路；印刷方法线路精度有限；打印方式批量生产效率较低；如用银浆，成本高	钯活化剂成本高
目前应用	PCB和封装基板金属导电层	芯片内布线(种子层)、TSV种子层、精细封装基板种子层	积层板导电塞孔互连、RFID、陶瓷板平面布线、互连孔直通电镀	PCB及封装基板纵向孔互连金属化

ED Cu application-Current collector

Cu foil current collector-2D



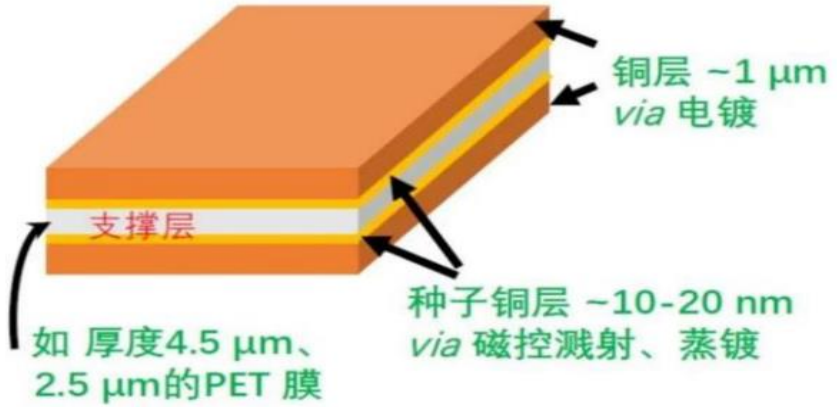
Porous Cu current collector-3D

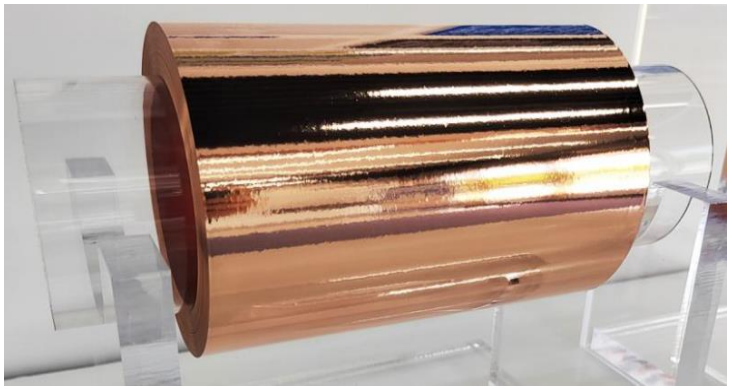


Precious metal Pd activator is often used in the preparation of foam copper collector

ED Cu application-Current collector

The composite current collector with a 3-layer structure of "metal polymer material metal", is one of the important technological paths in reducing the cost, improving energy density and safety of lithium-ion batteries.



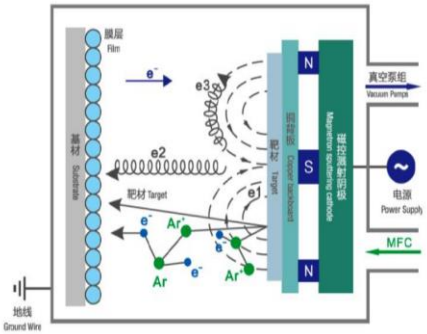


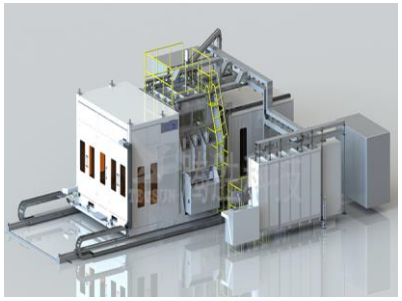
Comparing with traditional Cu foil:

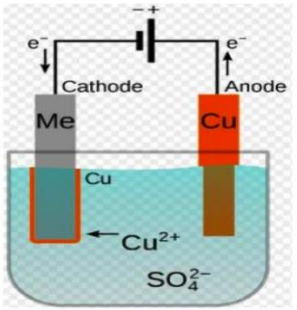
- Improve the safety of lithium-ion batteries;
- Save material costs by nearly 40%;
- 60% lighter in quality than traditional Cu foil;
- Energy density increased by 5-10%

ED Cu application-Current collector

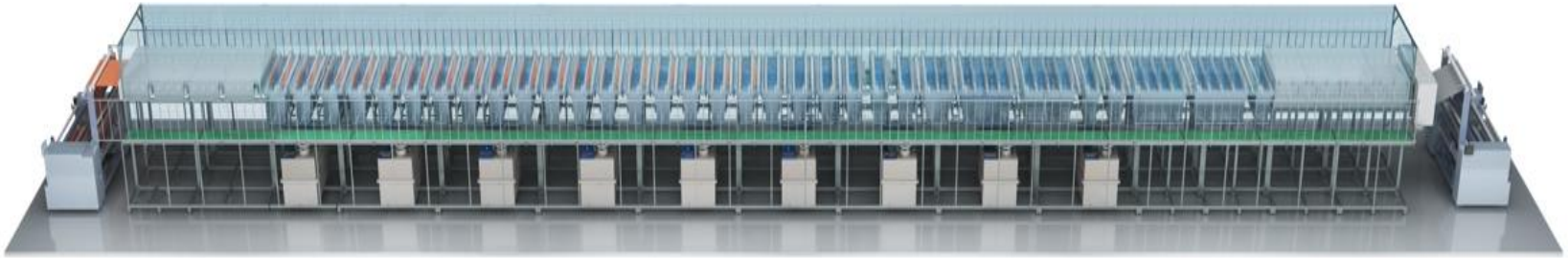
Composite copper foil current collector is currently mainly prepared by a two-step method(PVD+Plating)







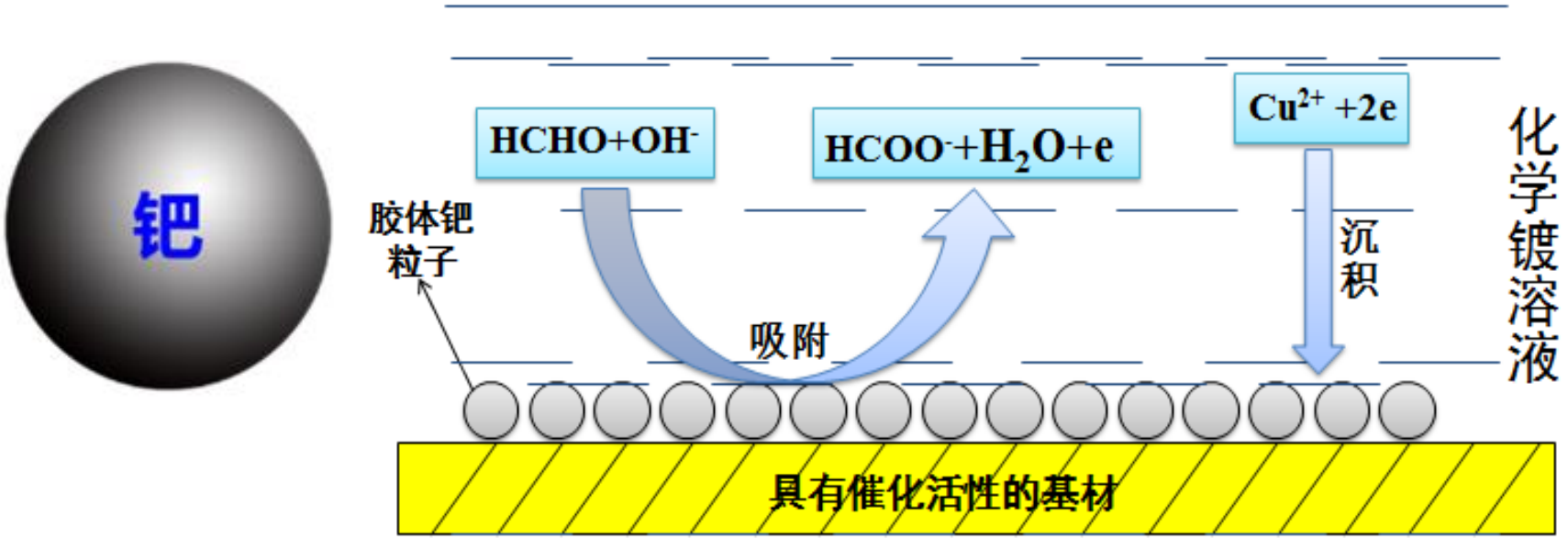
PVD+Plating: Equipment investment? Yield? Cost?



The one-step chemical deposition method for preparing composite current collectors has advantages such as low equipment investment and simple process. But if Pd activator is used, the cost is very high.

Activator for electroless copper deposition

High cost of palladium activator

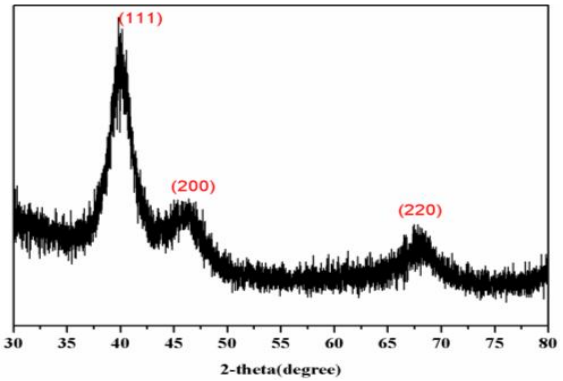


The Pd activator in ECD only acts on the surface atoms, and the newly deposited Cu itself has catalytic properties

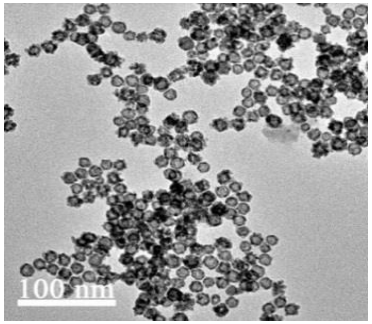
Preparation of activators

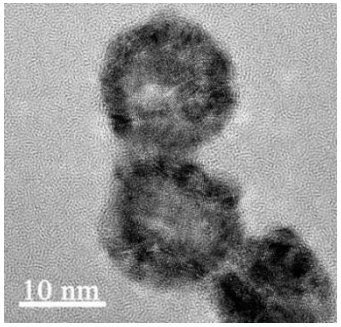
Hollow porous nano Pd sphere activator

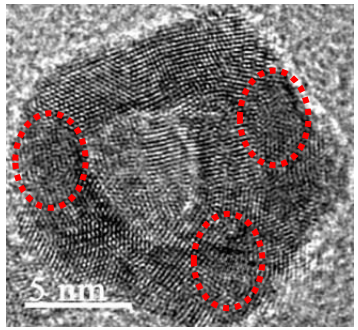
Good storage stability

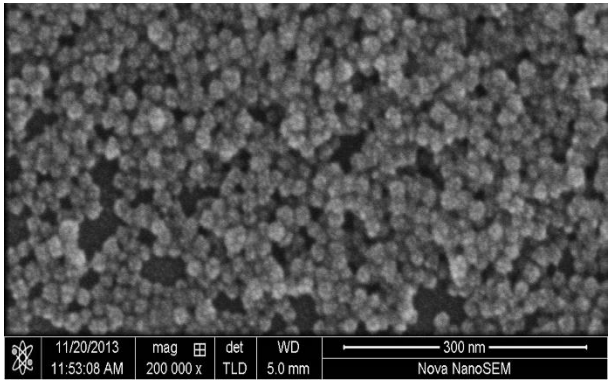


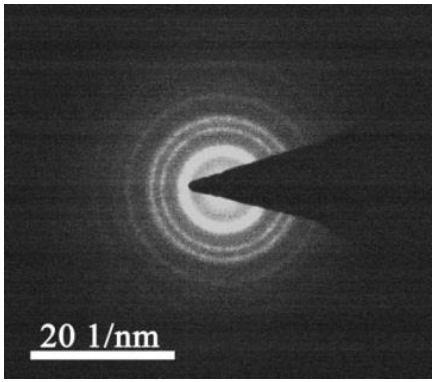
Hollow porous nanoshell can improve the utilization efficiency of precious metal activators

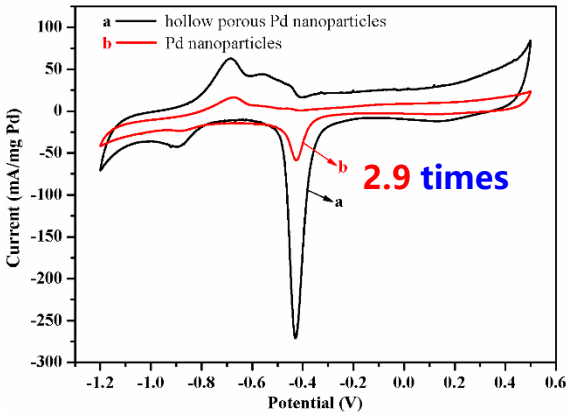


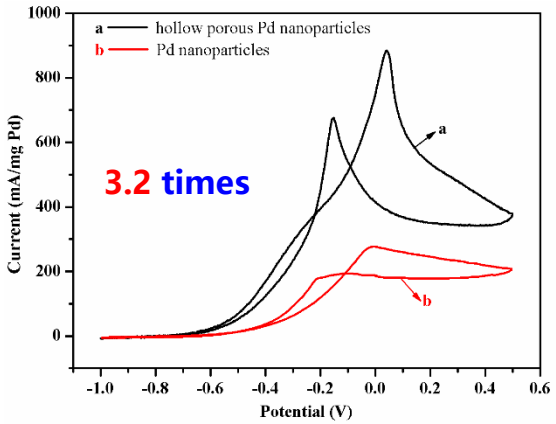




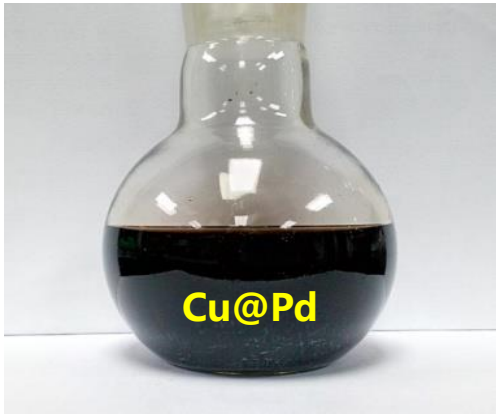




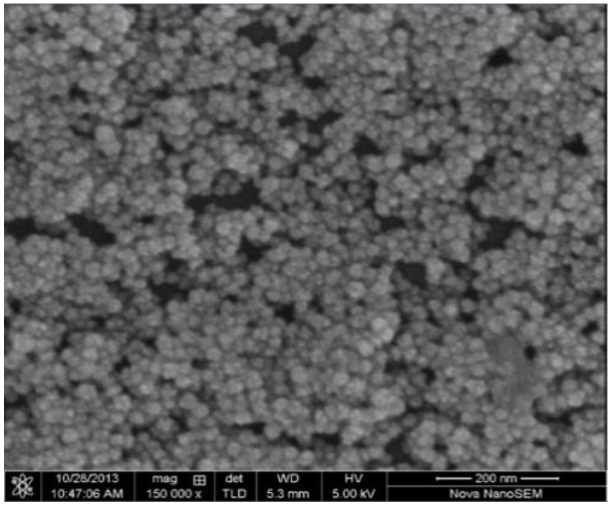


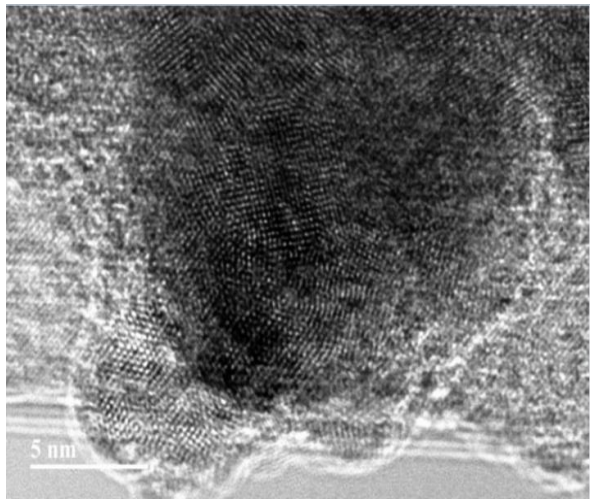


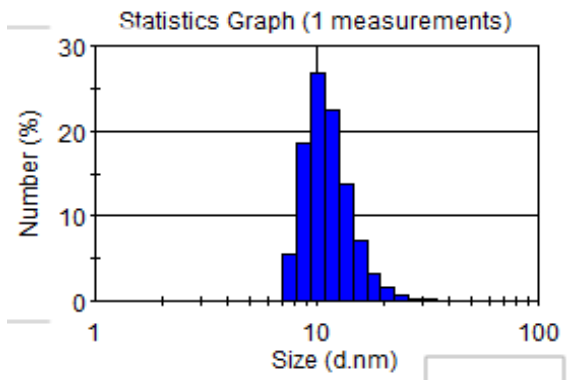
Cu@Pd core-shell nanoactivator

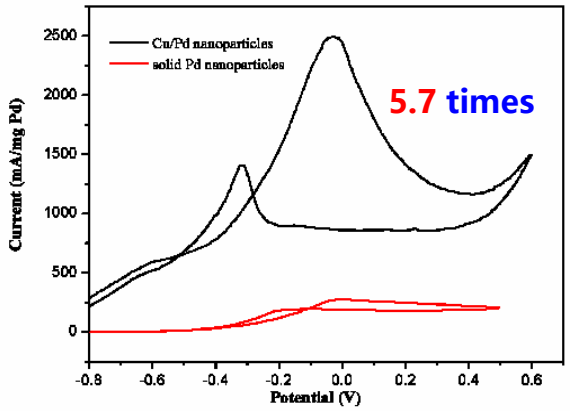


Good storage stability and antioxidant properties



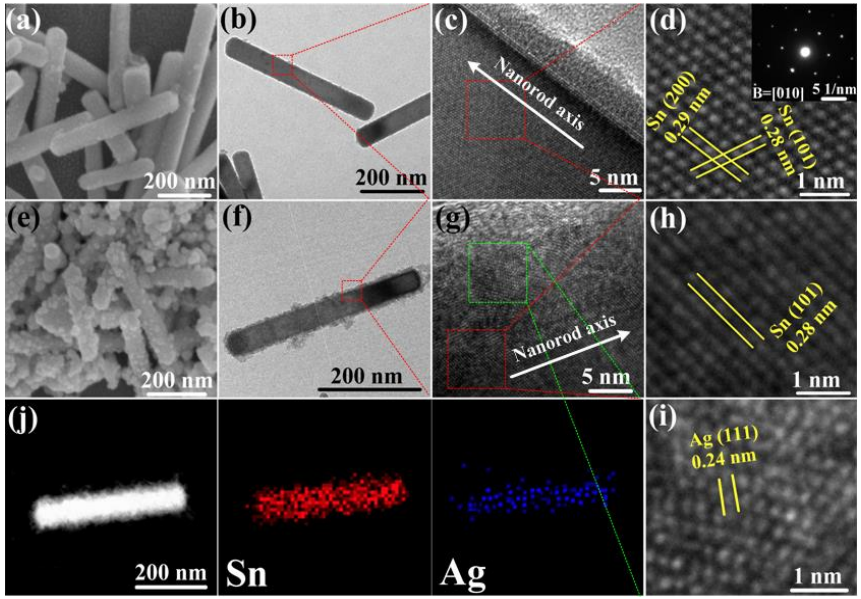


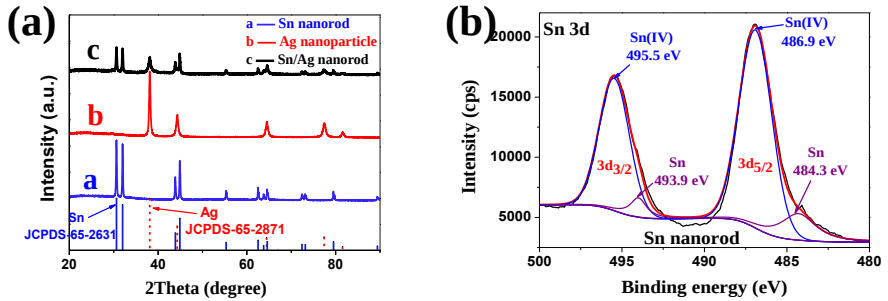


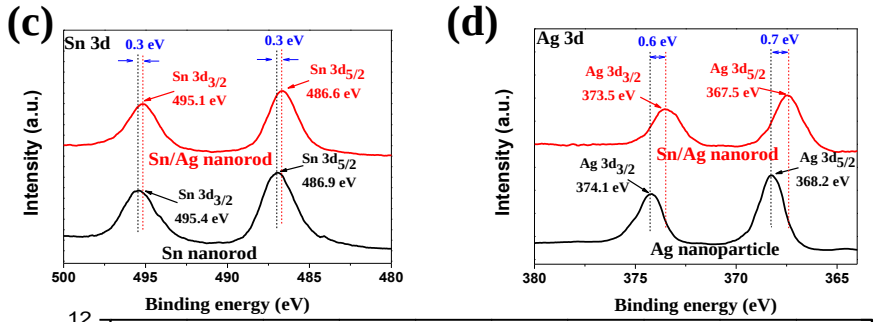


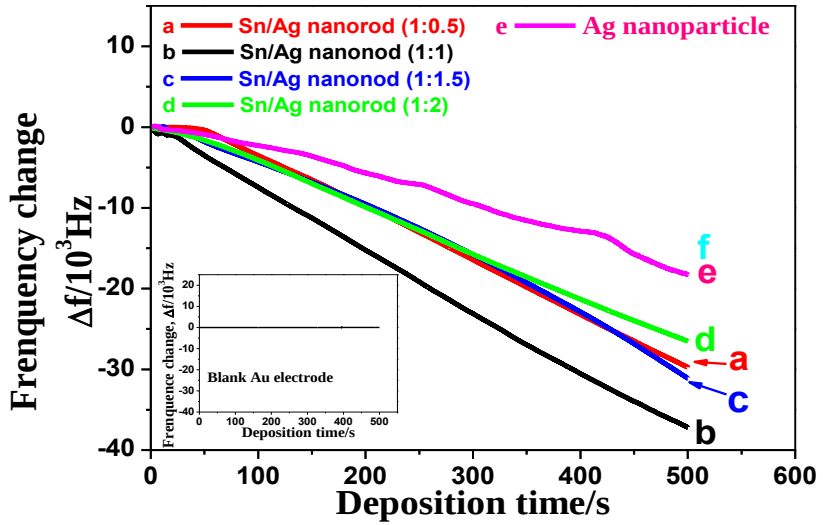
The core-shell structure exposes Pd atoms, while the inner copper layer is protected and synergistically affects Pd catalytic activity

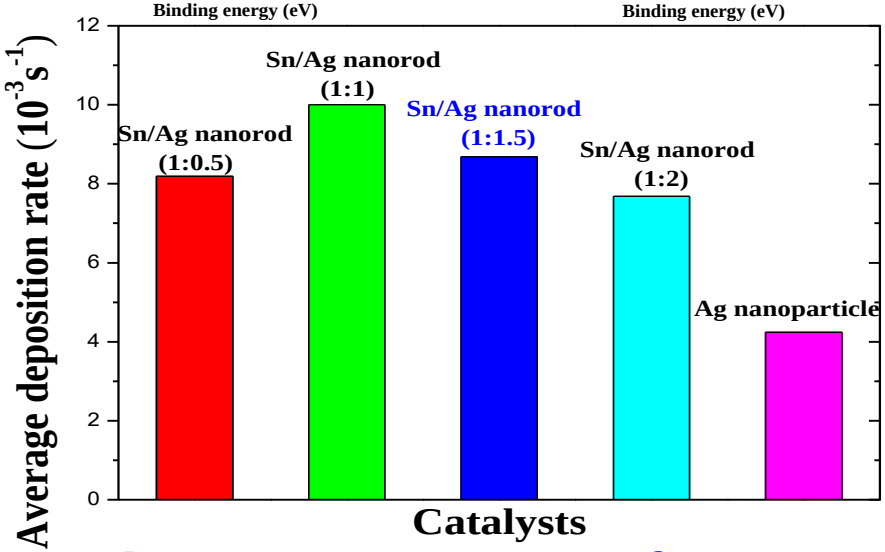
SnAg nanoactivator





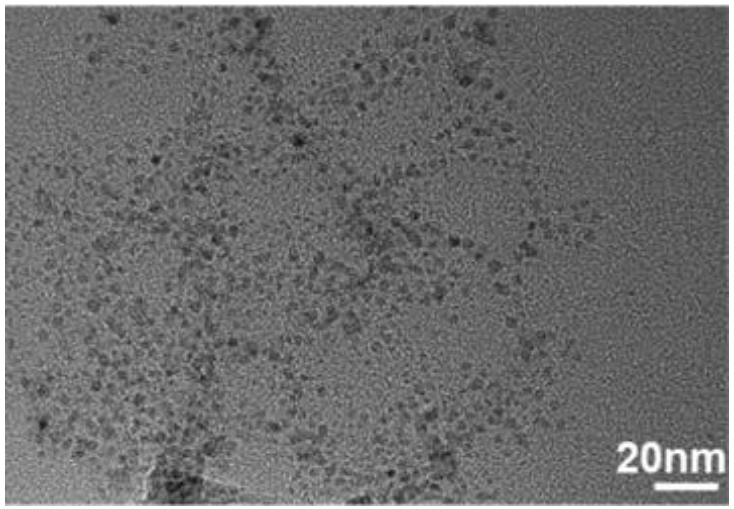


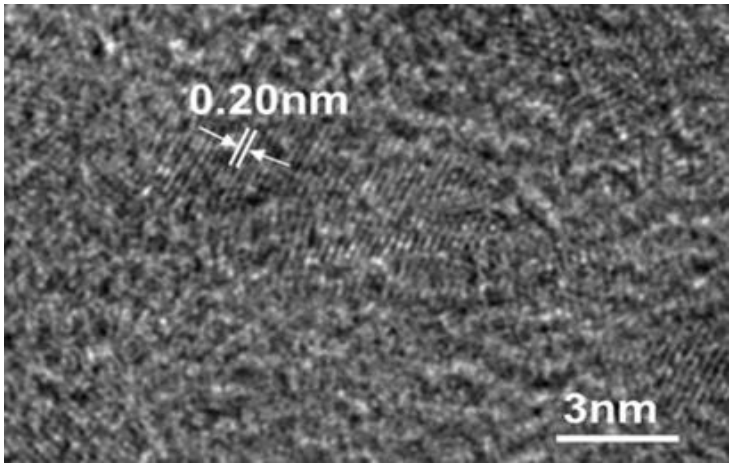


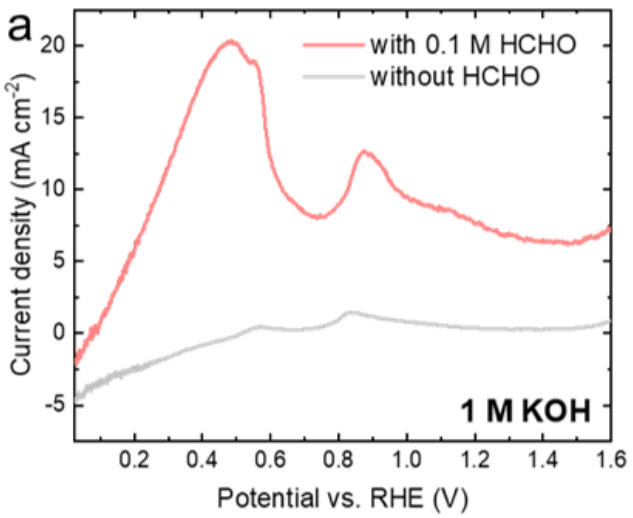


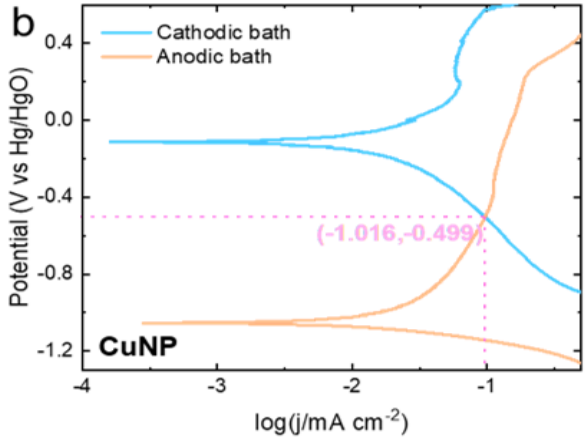
Developed Sn-Ag nano activator with excellent ECD performance and lower cost

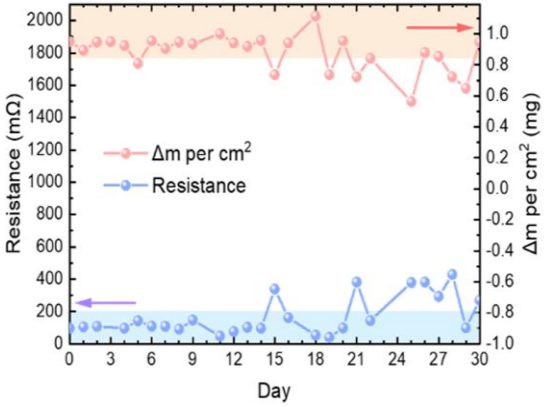
Cu nanoactivator







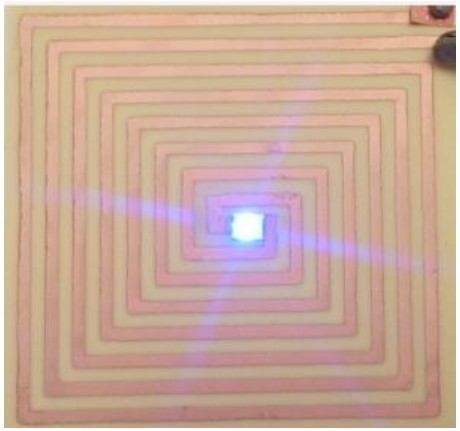


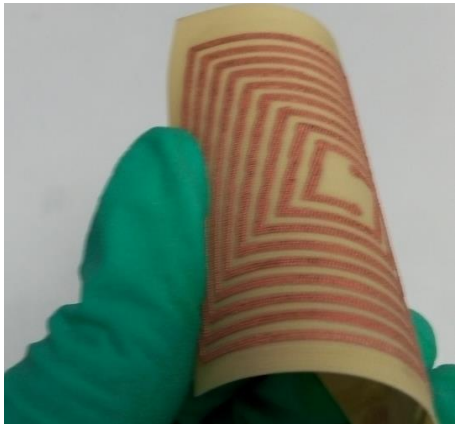


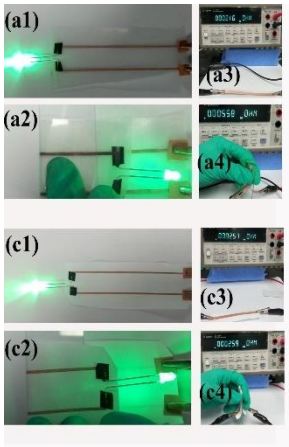
Developed low-cost Cu nanoactivators with excellent electroless copper deposition performance and stability

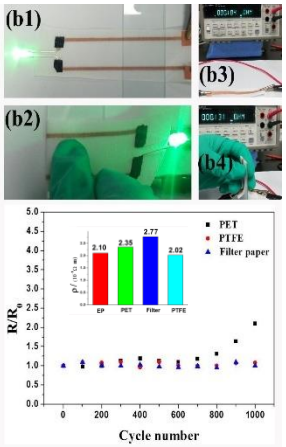
Interconnection applications

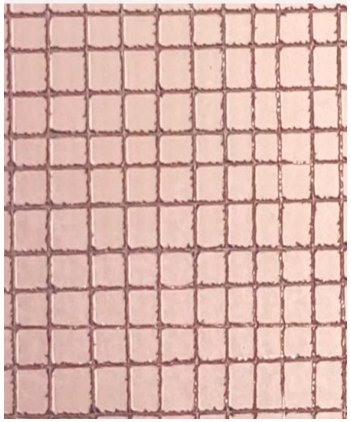
Interconnection-ECD conductive wiring

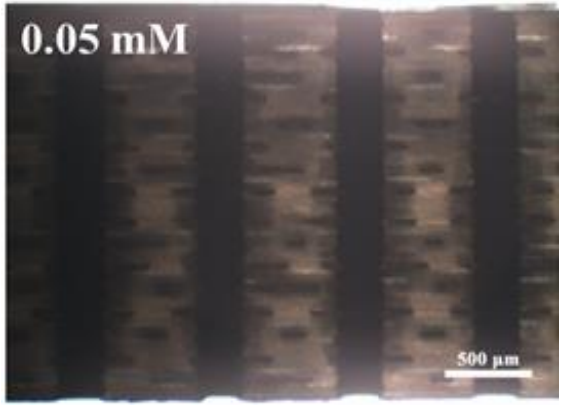


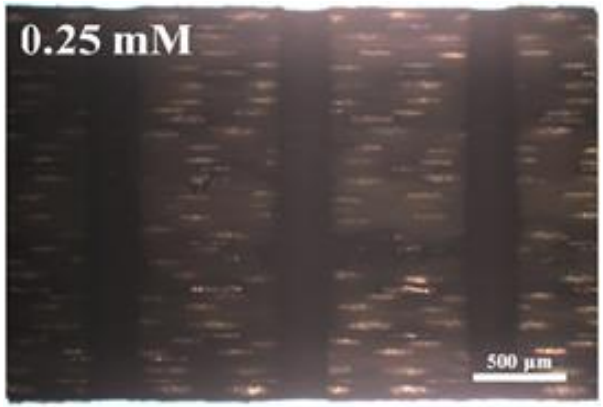


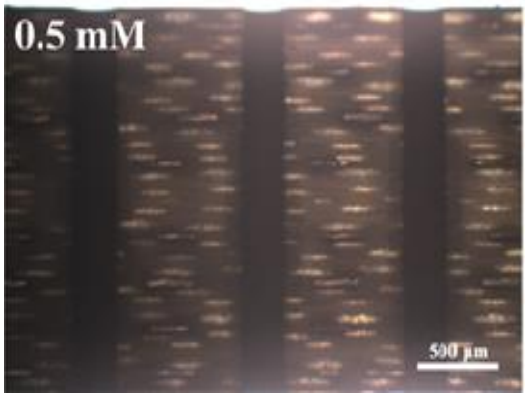




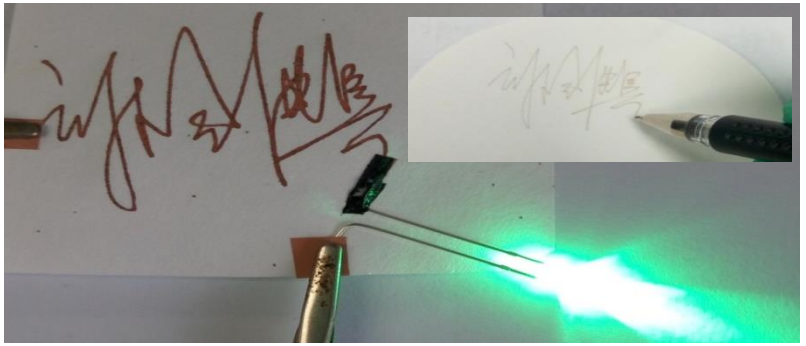




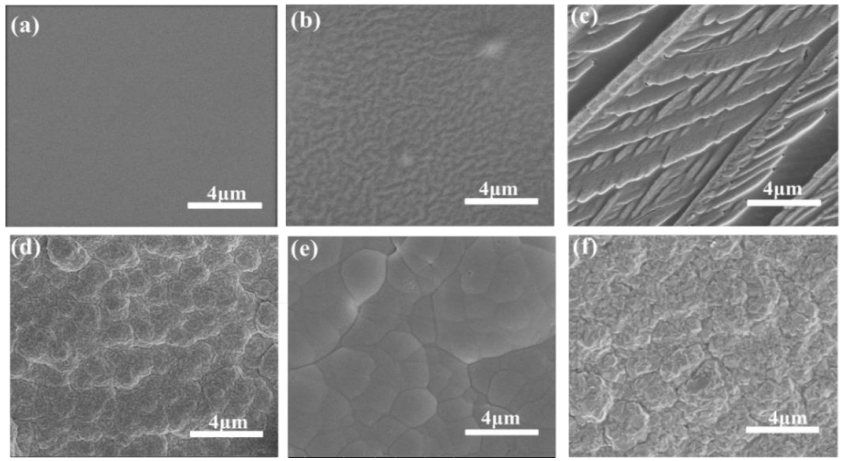


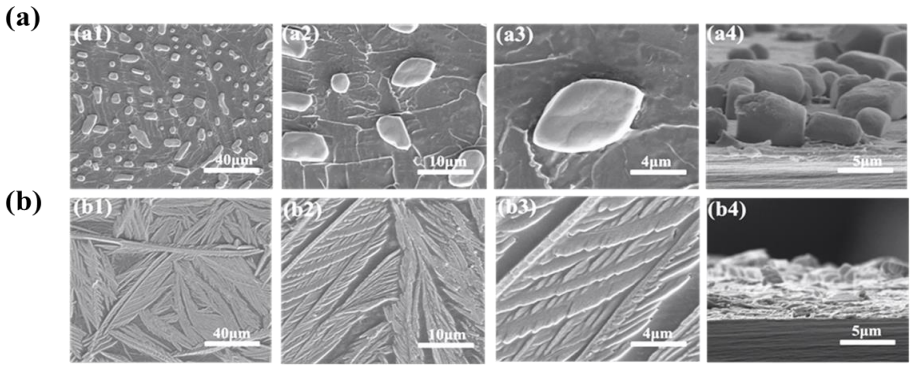


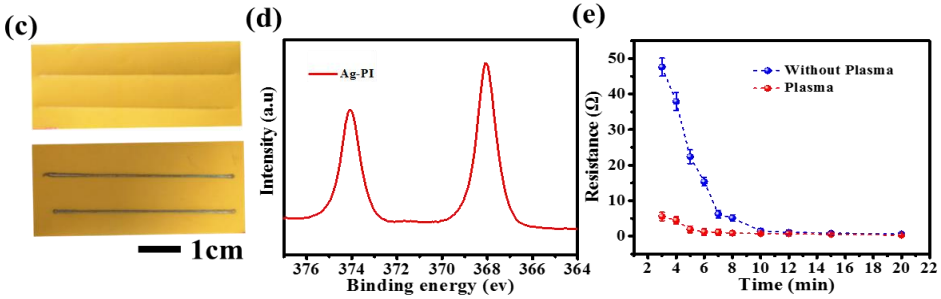
The developed high-efficiency activator and ECD technology can achieve metallurgical interconnection of copper and other metals, and be applied to fully additive wiring such as printed boards. Compared with traditional etching methods, it greatly reduces costs and environmental pressures, and can conduct conductive wiring with higher density and accuracy.

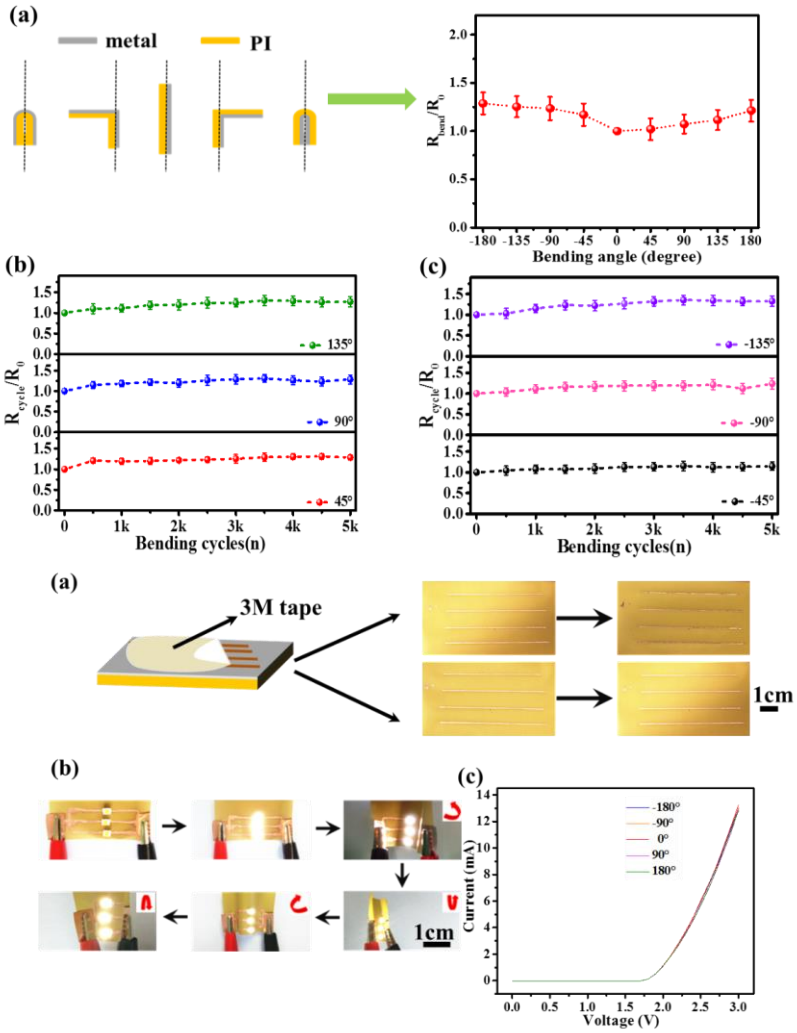


Interconnection-Metal-PI



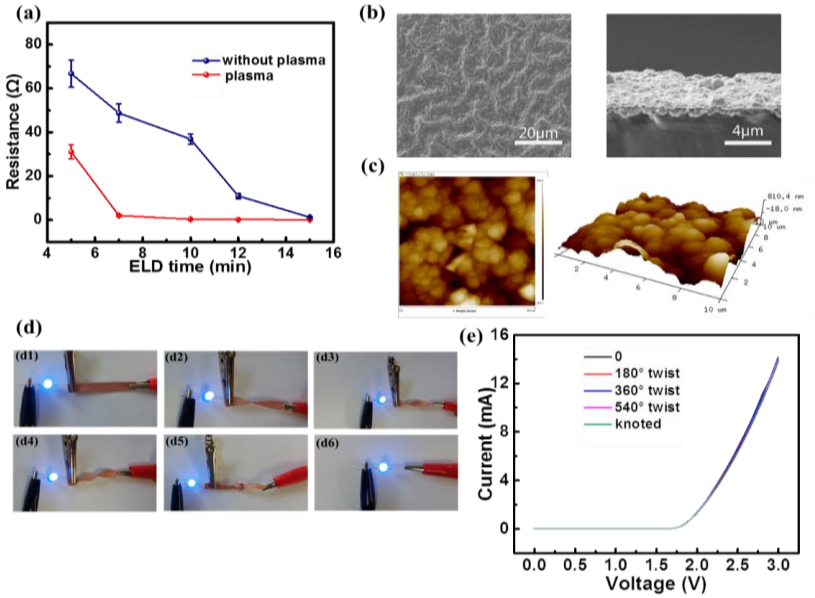


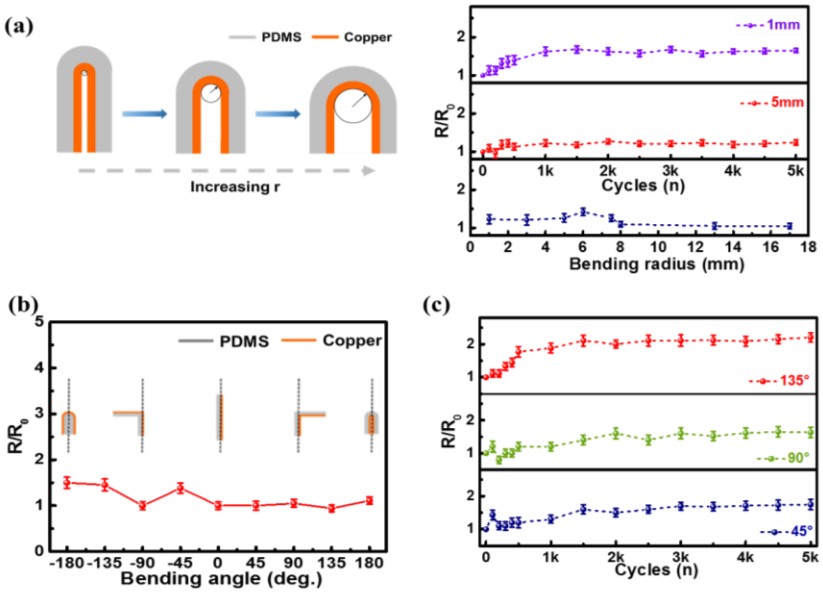


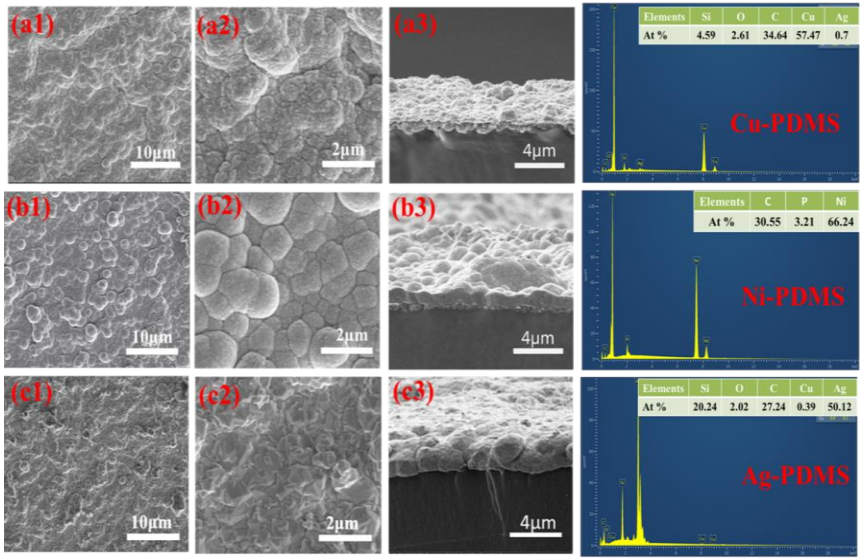


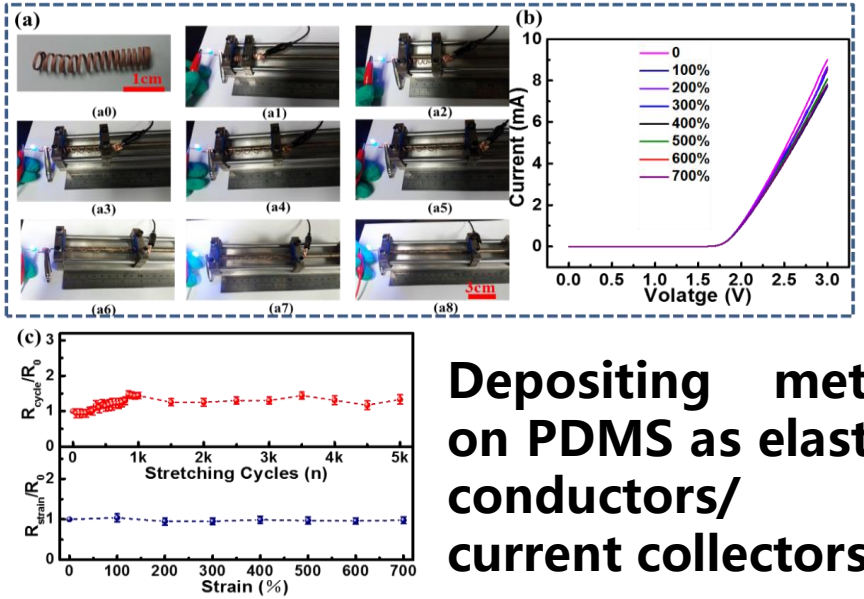
Depositing metal on PI as flexible conductive lines/current collectors

Interconnection-Metal-PDMS



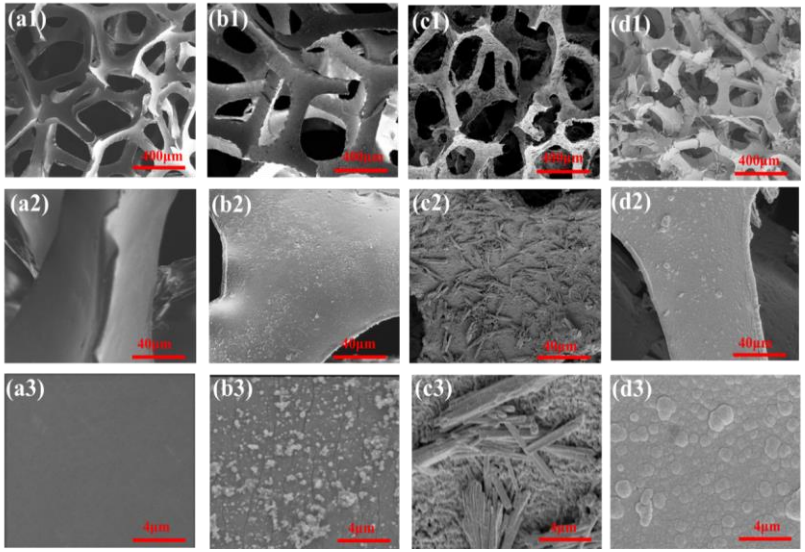


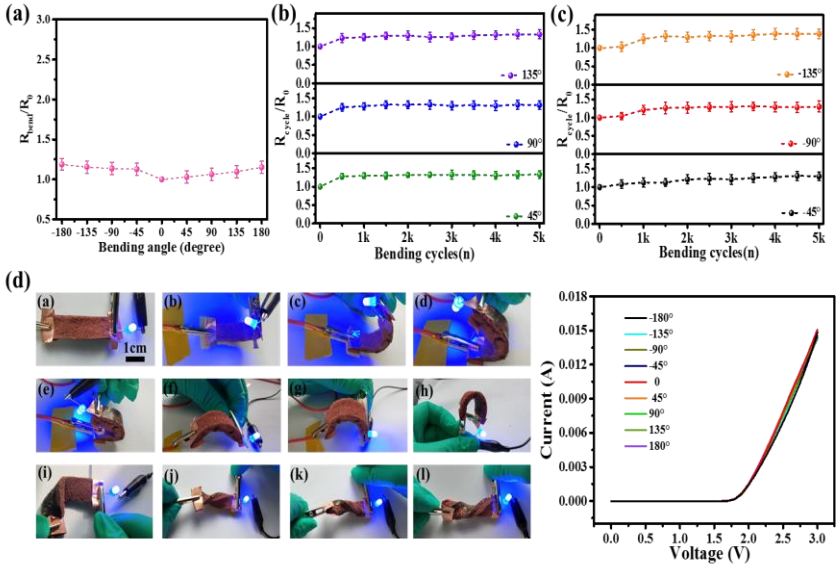


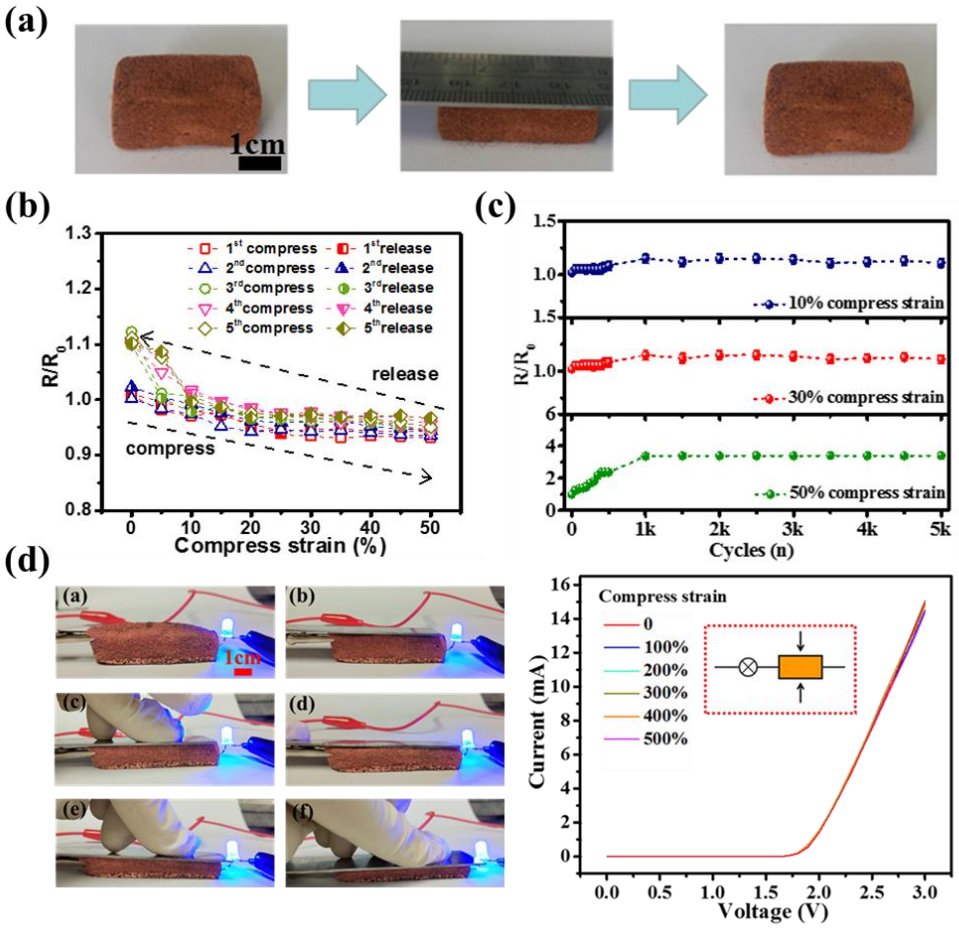


Depositing metal on PDMS as elastic conductors/ current collectors

Interconnection-Metal-PU



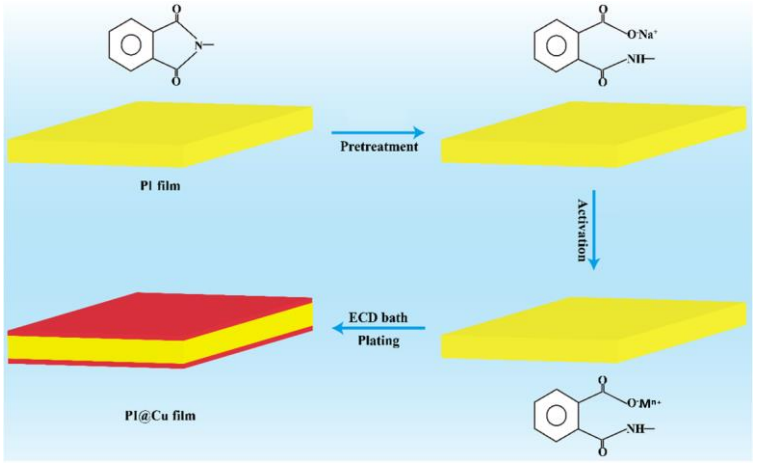


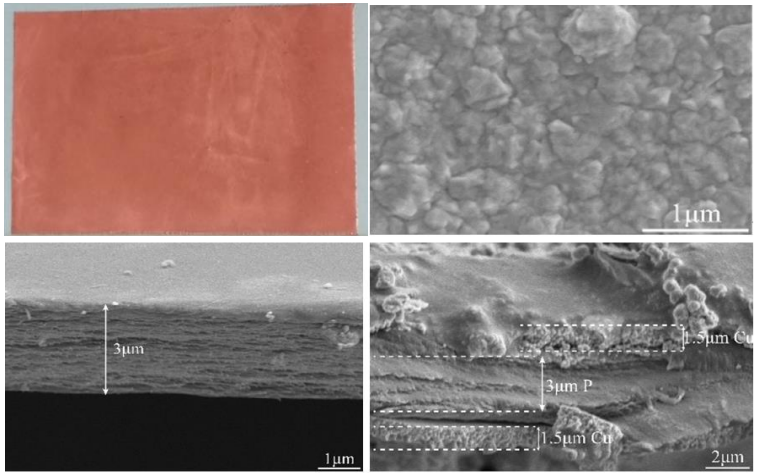


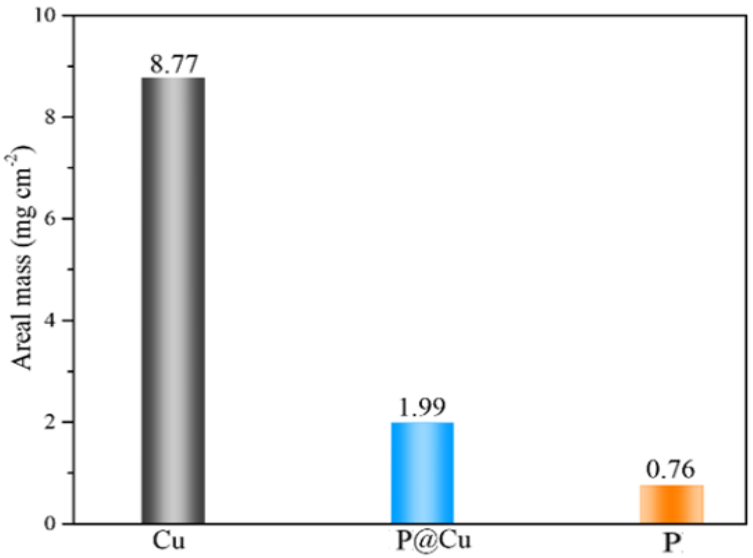
Depositing metal on PU as compressive conductor/ porous current collectors

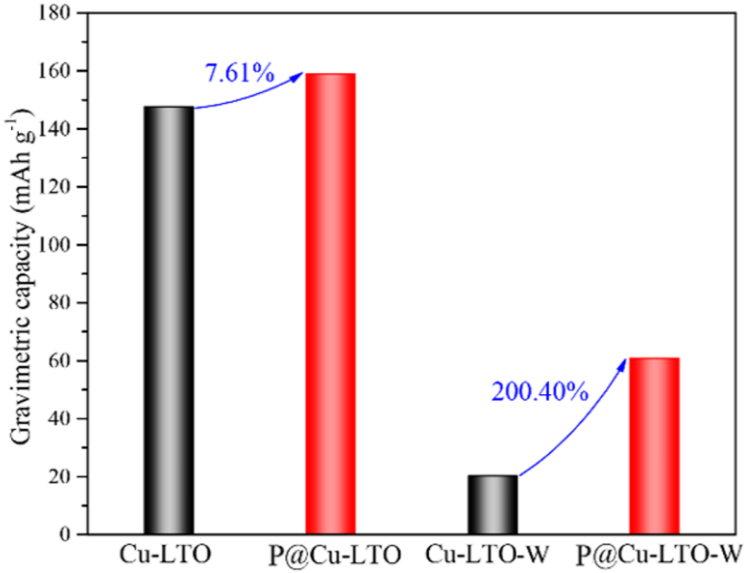
Current collector Applications

Current collector- composite Cu foil



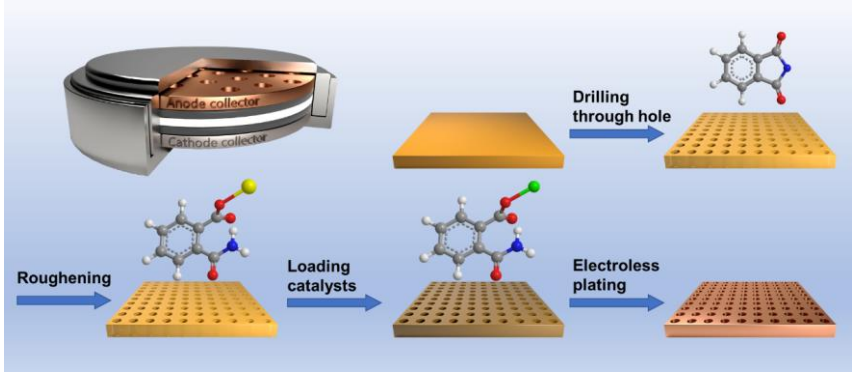


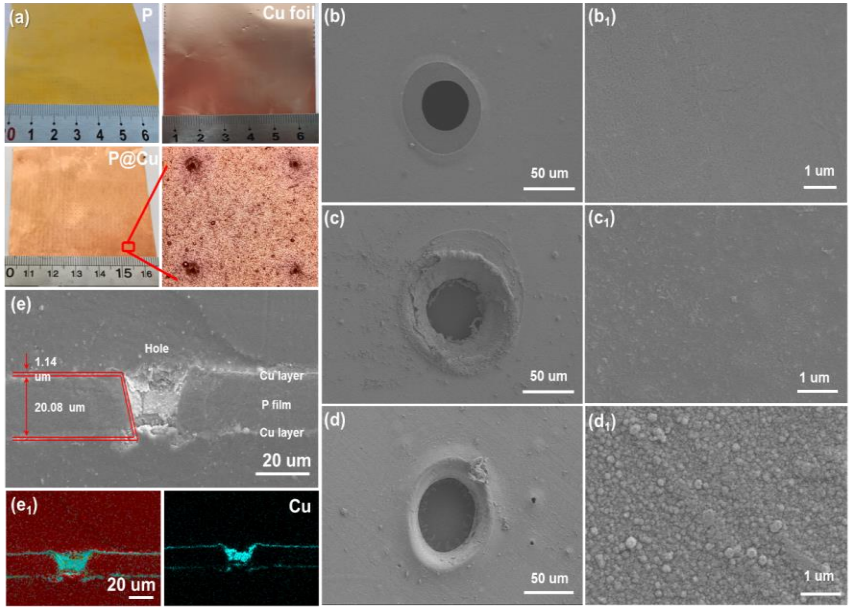


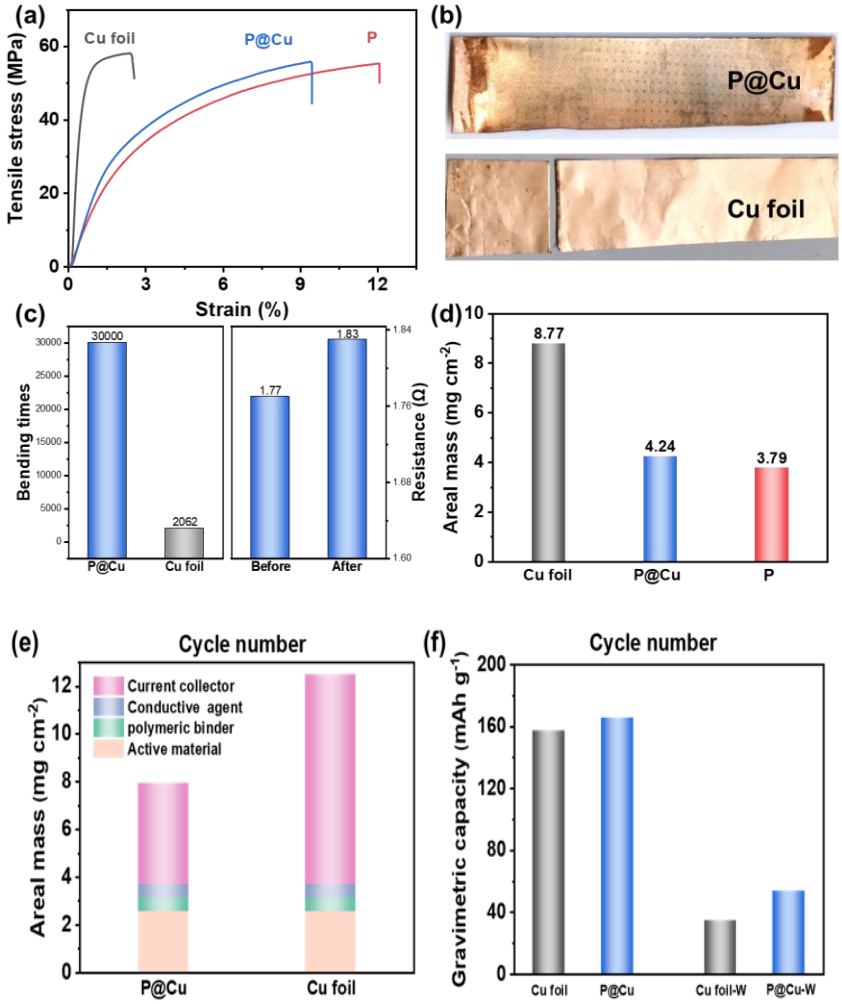


Developed non palladium activators to achieve low-cost one-step ECD of composite copper foil current collectors

Current collector-composite Cu foil with hole array

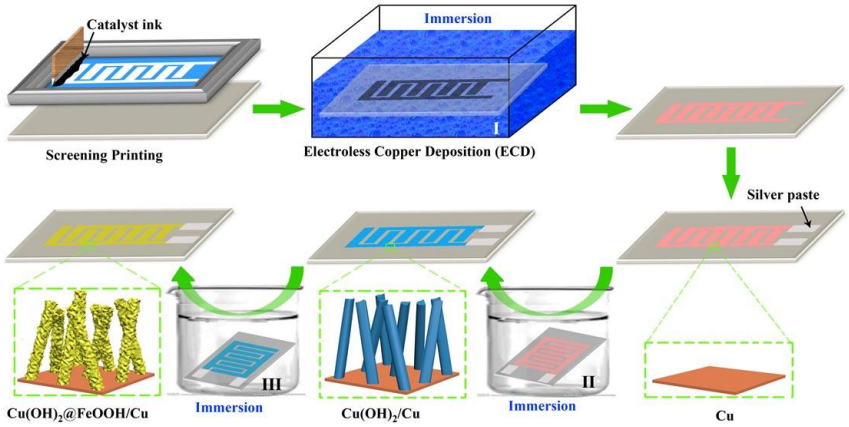


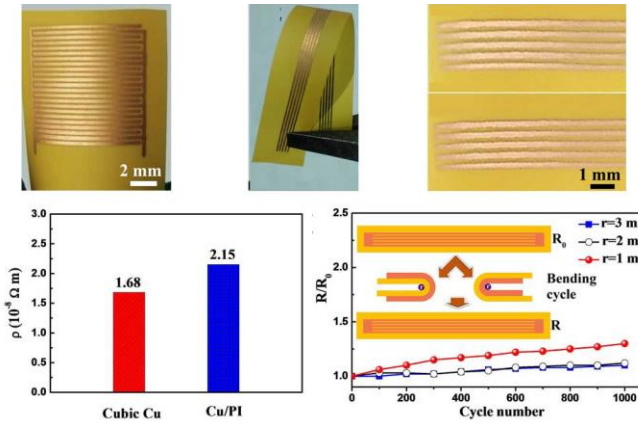


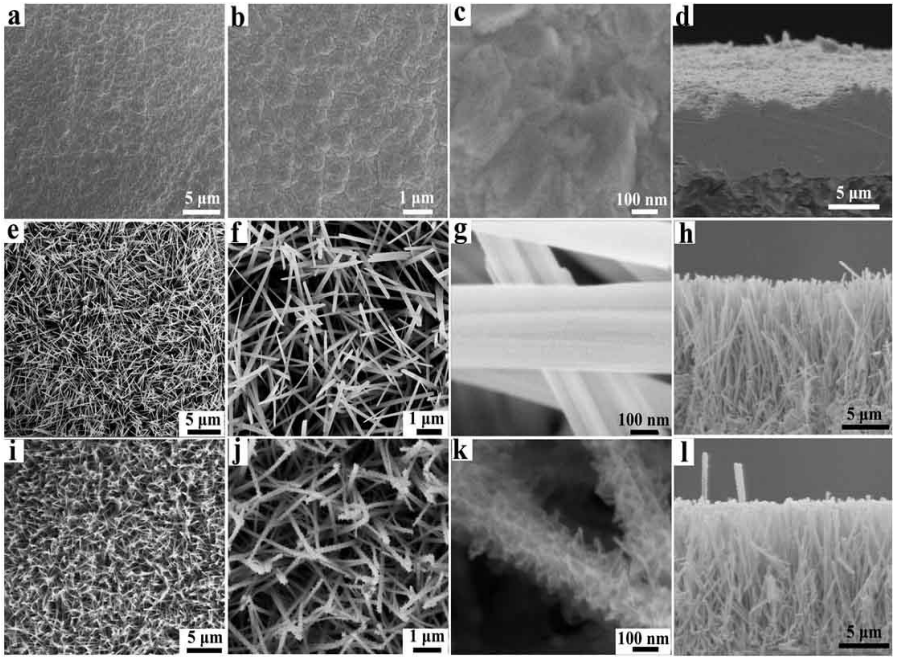


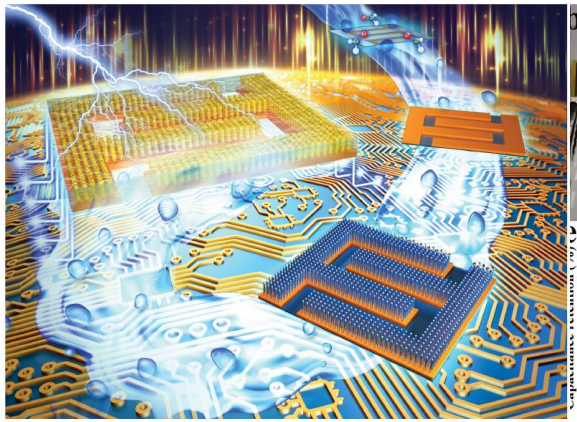
Array through-hole composite copper foil current collector can enhance the performance of lithium-ion batteries

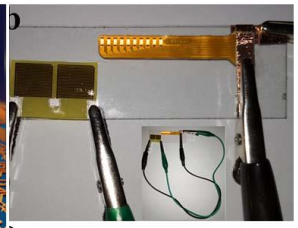
Current collector-Integrated energy storage device

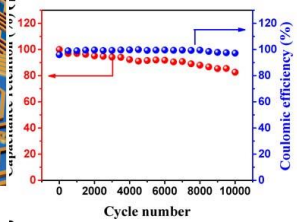








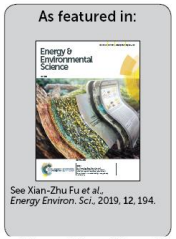


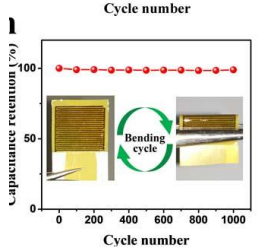


Showcasing research from Prof. Xian-Zhu Fu's group at the Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences.

In situ growth of $Cu(OH)_2$@FeOOH nanotube arrays on catalytically deposited Cu current collector patterns for high-performance flexible in-plane micro-sized energy storage devices

Rationally designed interdigitated $Cu(OH)_2$@FeOOH nanotube array electrodes are facilely *in situ* converted from catalytically deposited Cu current collector patterns for high-performance flexible micro-sized integrated energy storage devices for microelectronics.



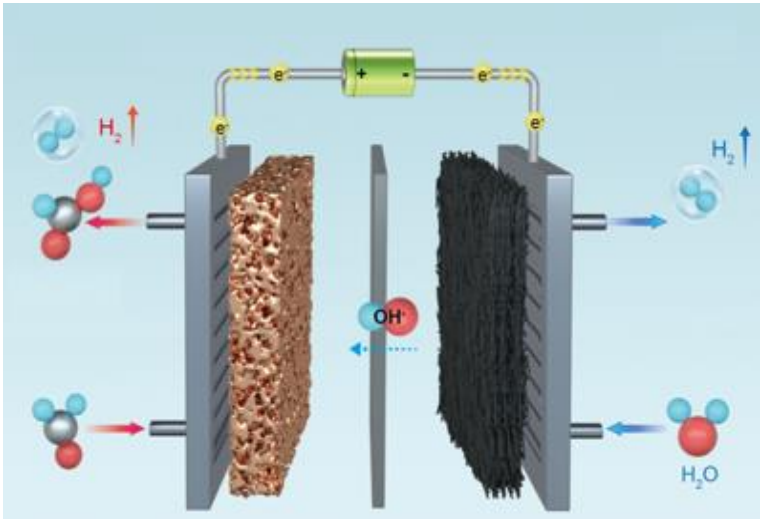


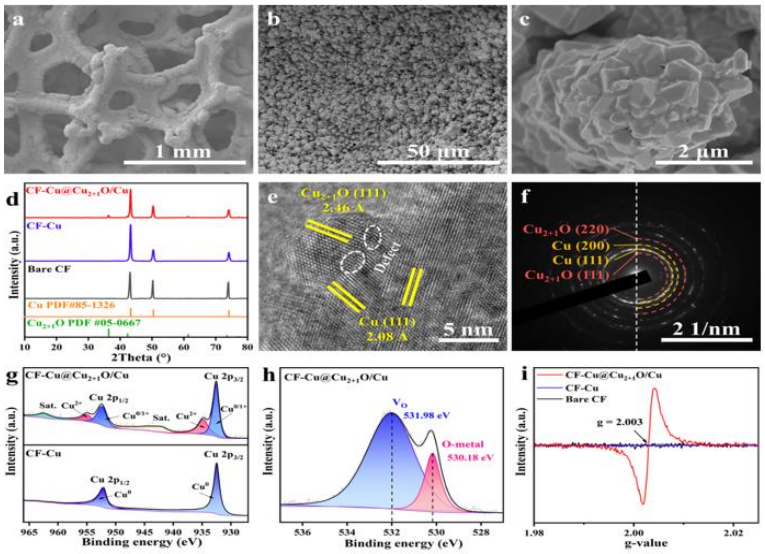
Time (s)

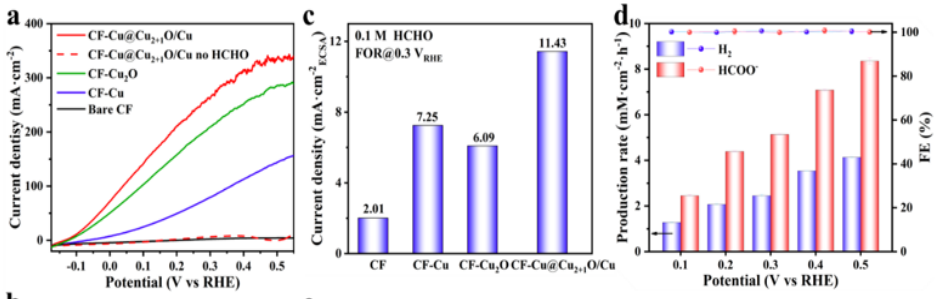
Potential (V)

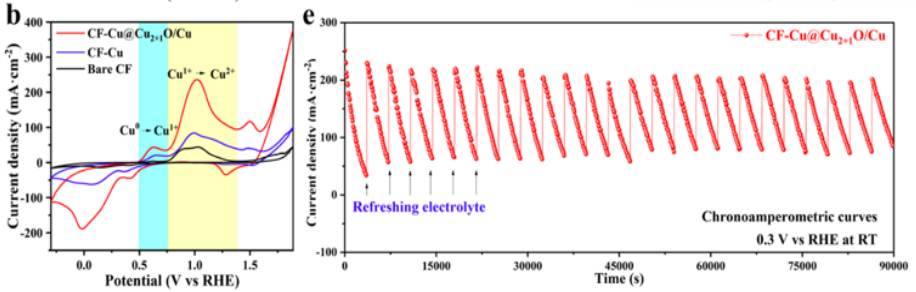
High conductivity planar energy storage device electrodes can be obtained by in-situ transformation of ECD current collectors

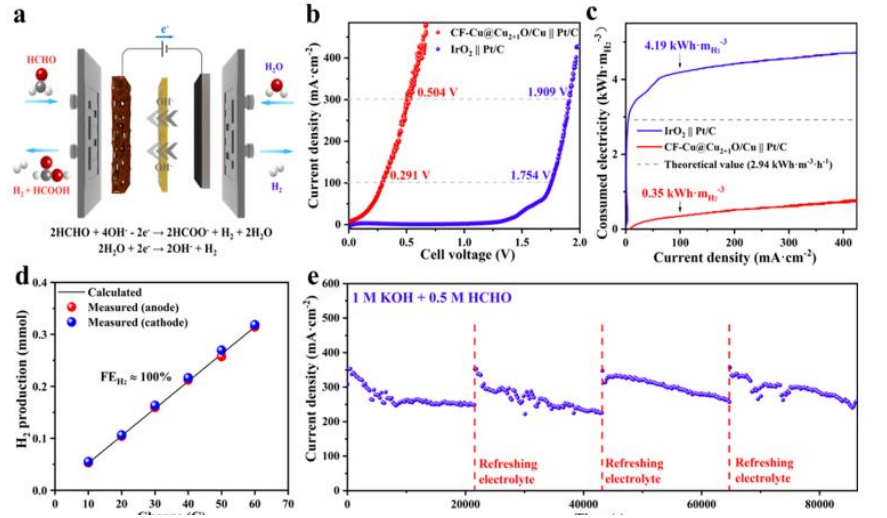
Current collector-Electrolysis





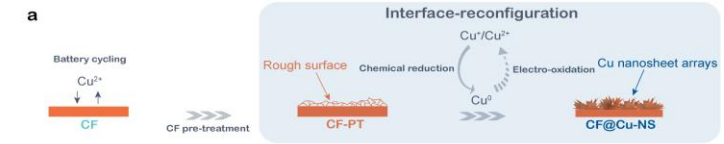


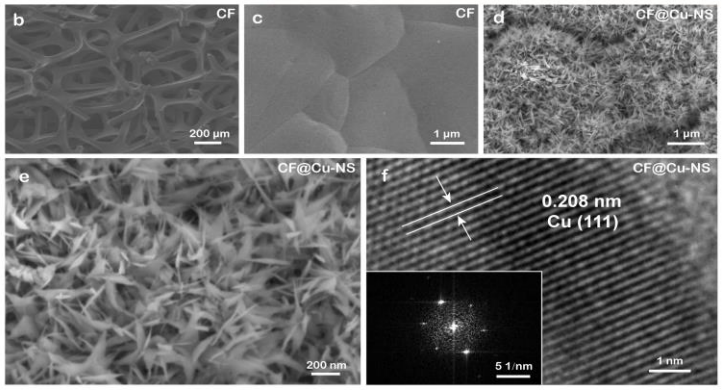


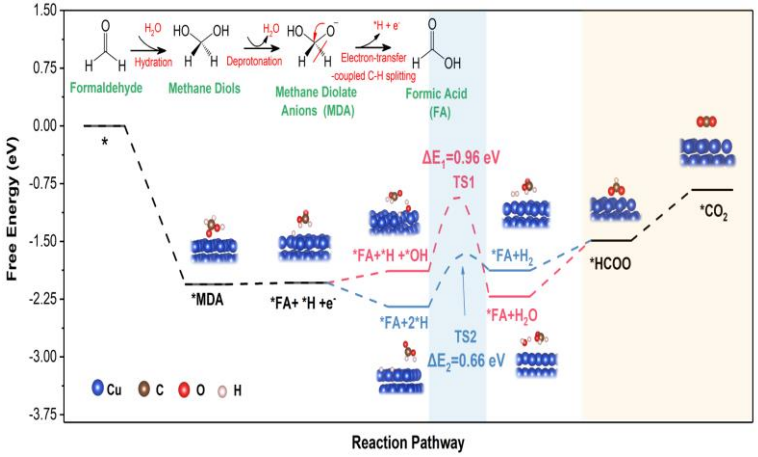


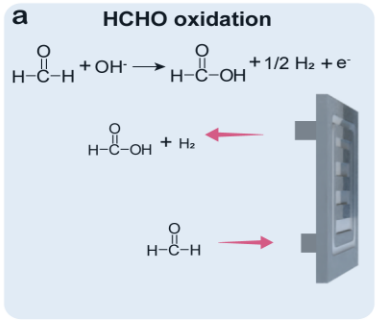
Co-electrolysis of water aldehydes on Cu electrode can produce hydrogen at extremely low voltages, with energy consumption less than 10% of traditional electrolysis of water for hydrogen production.

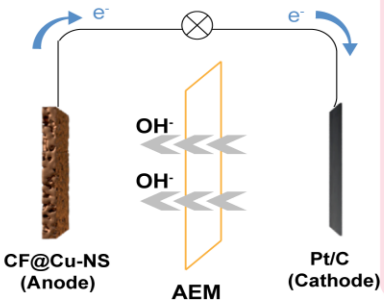
Current collector-Fuel cells

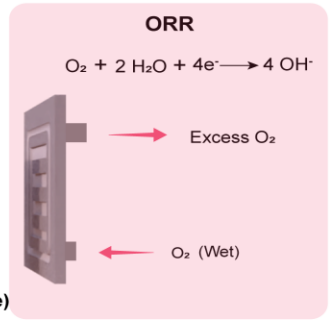


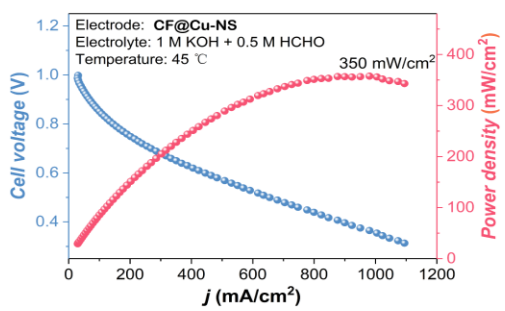


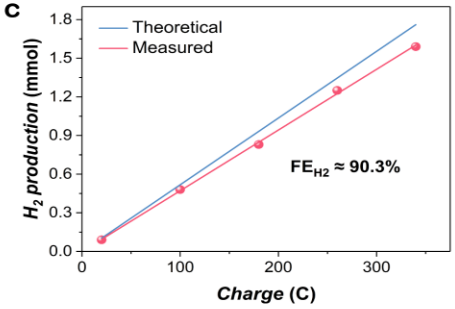


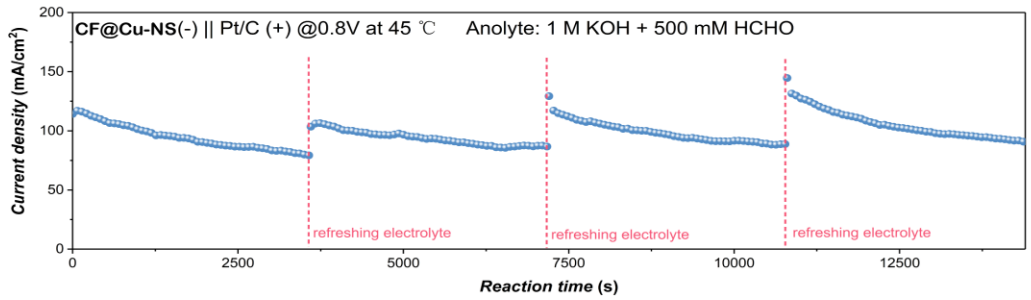












Fuel cell with Cu electrode can achieve CO_2 free power generation from liquid fuels such as formaldehyde and co produce pure H_2 gas

总 结

- 合成了空心Pd和PdCu、Sn-Ag及纯铜低成本活化剂
- 合成的活化剂可以实现化学镀铜加成法布线及金属化
- 化镀铜制备了高性能聚合物-铜及Cu@Ni复合集流体
- 化镀铜高选择性电催化阳极可极低能耗共电解制纯氢
- 化镀铜构建新型阳极可实现碳基燃料无CO_2排放发电

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