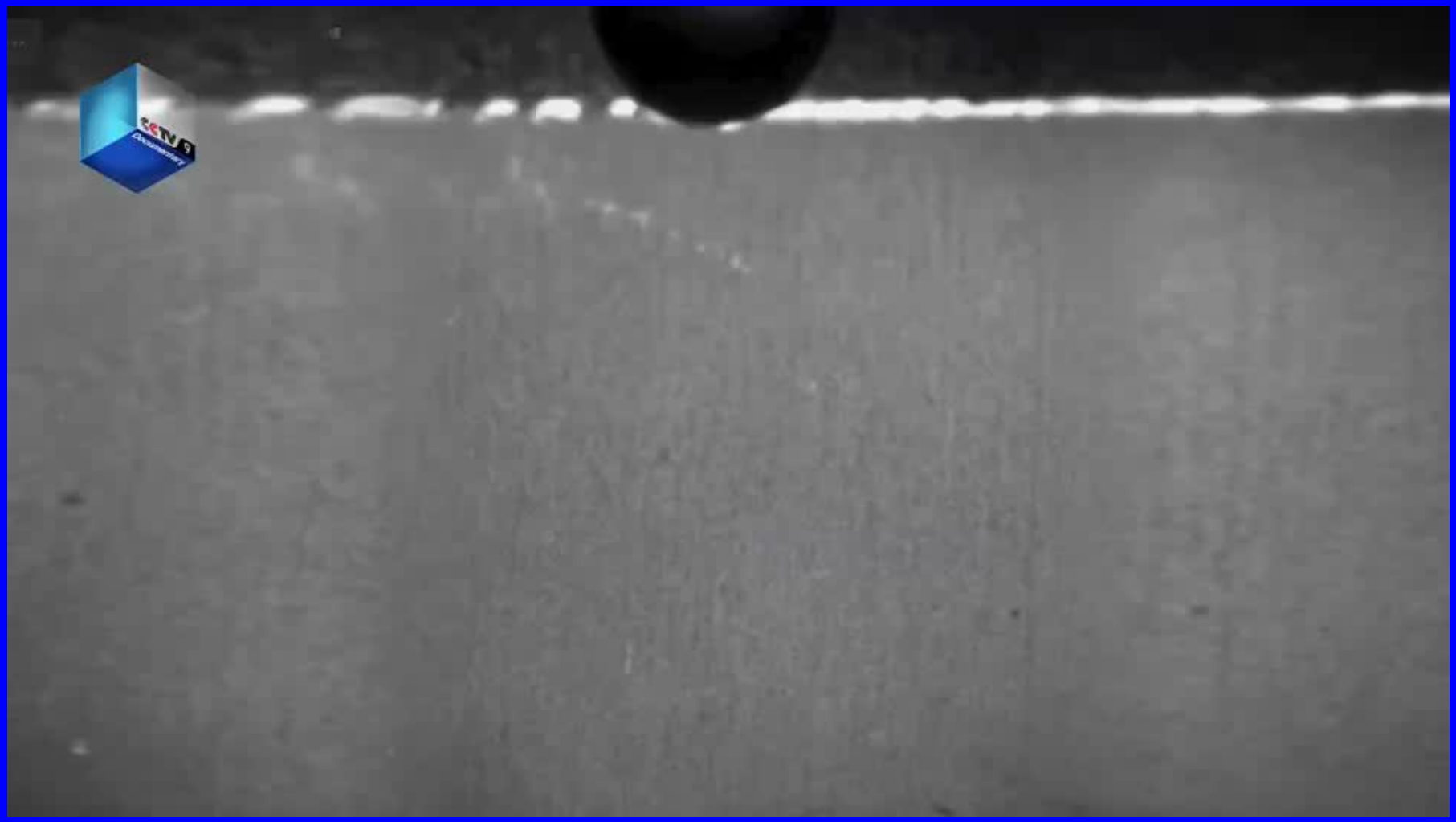
纳米绿色印刷技术与产业绿色变革

中国科学院化学研究所

绿色印刷重点实验室

宋延林



纳米绿色印刷制造技术

设计、制备、
组装与应用

纳米粒子

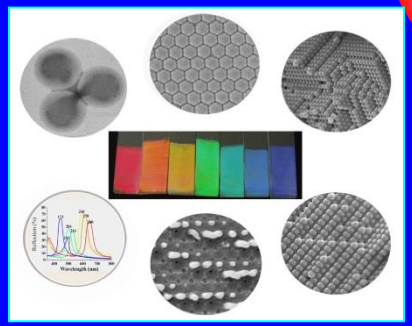
- 500 papers, H-index100
- 16 books
- 130+26发明专利

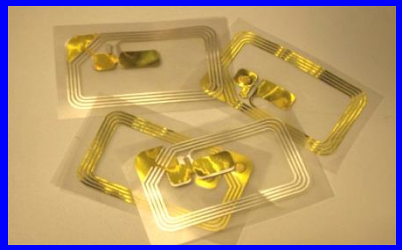
绿色化、功能化
立体化、器件化

聚合物

金属颗粒

无机颗粒





P&G

SAMSUNG

SPOTLIGHT · 20 MARCH 2019

The Chinese researcher painting the printing industry green

Chemist Yanlin Song uses nanomaterials to reduce the pollution caused by conventional lithography.

Sarah O'Meara

Credit: Stefen Chow for *Nature*

Chemist Yanlin Song uses nanomaterials to reduce the pollution caused by conventional printing processes. Nature speaks to him about his work at the Chinese Academy of Sciences Institute of Chemistry in Beijing and why it matters to China.

PDF ver

RELATED A

Materials science is helping to transform tech econo

High-press research a return to C meet Haiy

How biomateria support Ch ageing pop

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These falling drops don't splash—they spin

By Lakshmi Supriya | Mar. 5, 2019 , 11:00 AM

Falling drops usually make a splash, but these drops do the twist. Researchers have cre surfaces that can make droplets spin and whirl at more than 7300 revolutions per minu they rebound.

To make the water droplets spin, researchers first had to make sure they didn't wet the they fell on—otherwise, they'd just splash. The researchers did this by coating alumina a fluorinated nonstick coating, similar to those found in nonstick cooking pans. Next, th some regions of the surface and shone ultraviolet (UV) light on the entire plate. The reg exposed to the UV became highly "wettable," meaning water touching those regions spr immediately rather than bouncing back up. The team created several designs of the we regions, including one with spiral arms radiating out from a center, much like a pinwhee

印刷制版技术的发展

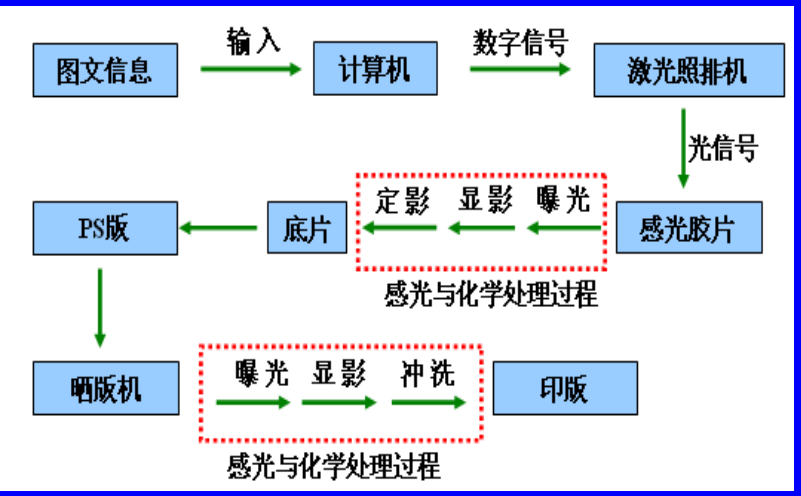
雕版印刷

毕昇

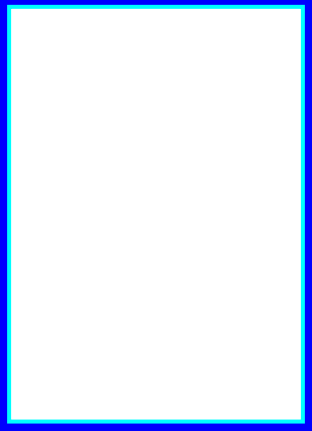
木活字

激光照排技术

汉字激光照排技术



激光照排制版工艺



亲水版材

打印

亲油图案

印刷

印刷样品

纳米材料绿色制版技术原理

问题：

- 感光成像，避光操作
- 化学显影，废液排放
- 预先涂层，资源浪费

优势：

- 不避光
- 无污染
- 成本低
- 可回收

创新点：

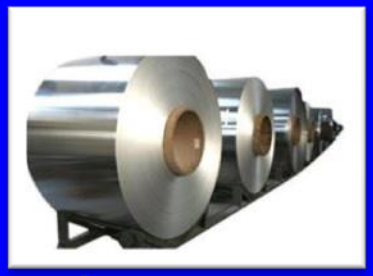
控制材料浸润性形成

“0”“1”，

“弃暗投明”

绿色印刷产业链关键技术

- 纳米绿色制版取代感光冲洗制版；
- 纳米涂层版材取代电解氧化版基；
- 水性印刷油墨取代毒害溶剂油墨。
- 形成包括绿色制版、绿色版基和绿色油墨的完整绿色印刷技术体系，从源头彻底解决印刷产业链的污染问题。



√ 绿色版基技术

√ 绿色油墨技术

√

绿色制版技术

绿色印刷产业链

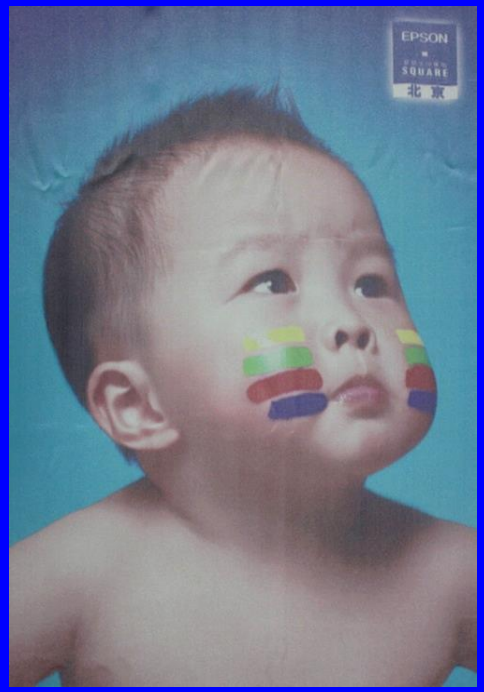
绿色印刷制版平台

绿色食品包装

打印建材

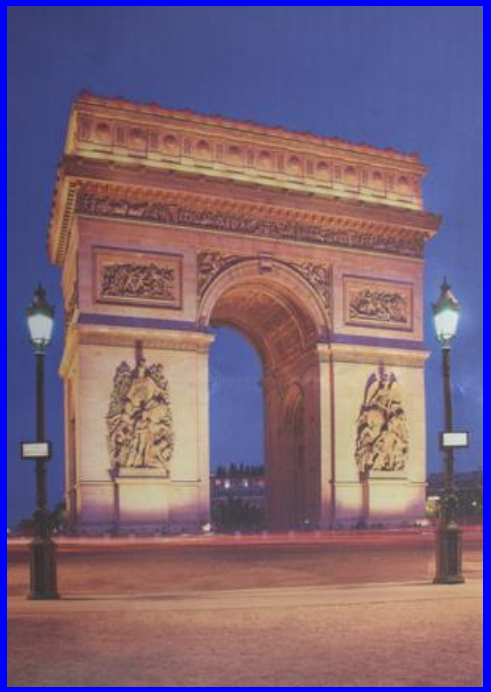
打印在瓷砖（左上）
和玻璃上（右下）的图案

绿色印染



打印在丝绸上

打印在棉布上

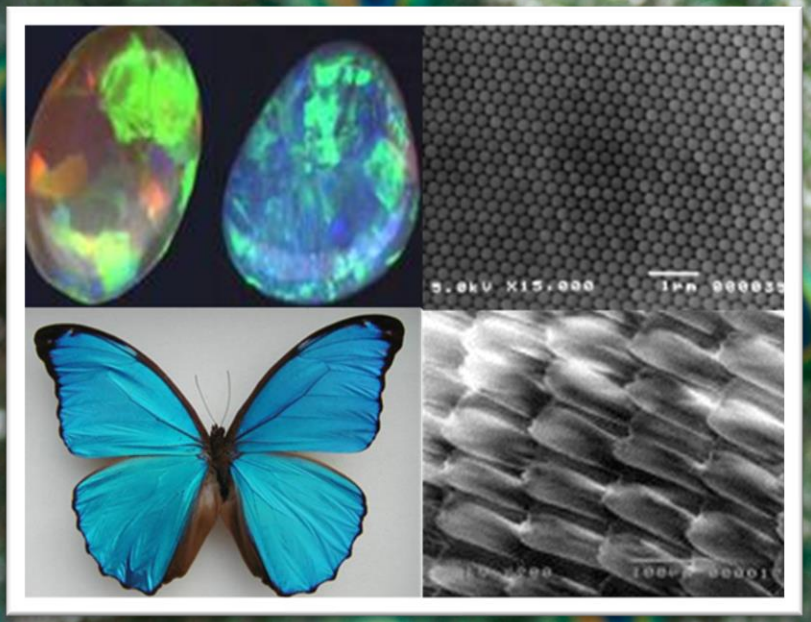


打印在化纤织物上

色彩与染料产业

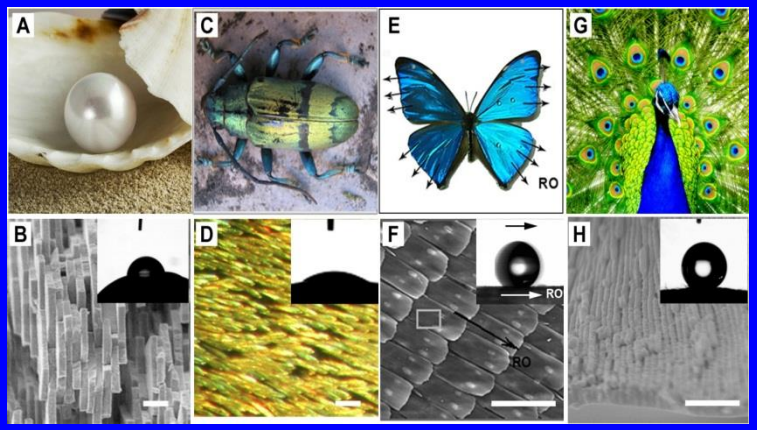
- 生活中大部分色彩来源于染料和颜料

- 染料的生产过程对环境带来严重破坏



色彩明亮、饱和度高、
特殊光泽、永不褪色
无需色素、环境友好

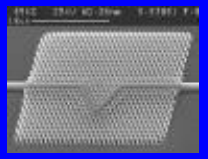
光子晶体制备及应用



- 特殊的周期结构
- 调控光的传播
- “光半导体”

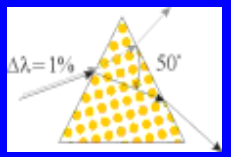
我们的研究：

- 简便制备新方法
- 信息领域新应用

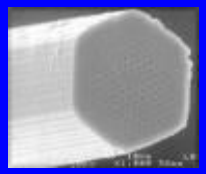


光波导

单色聚光器



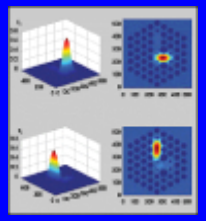
超棱镜



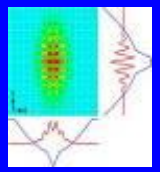
光纤

光子晶体

高性能反射镜

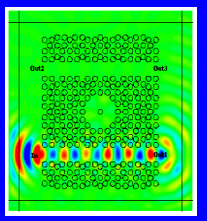


偏振片



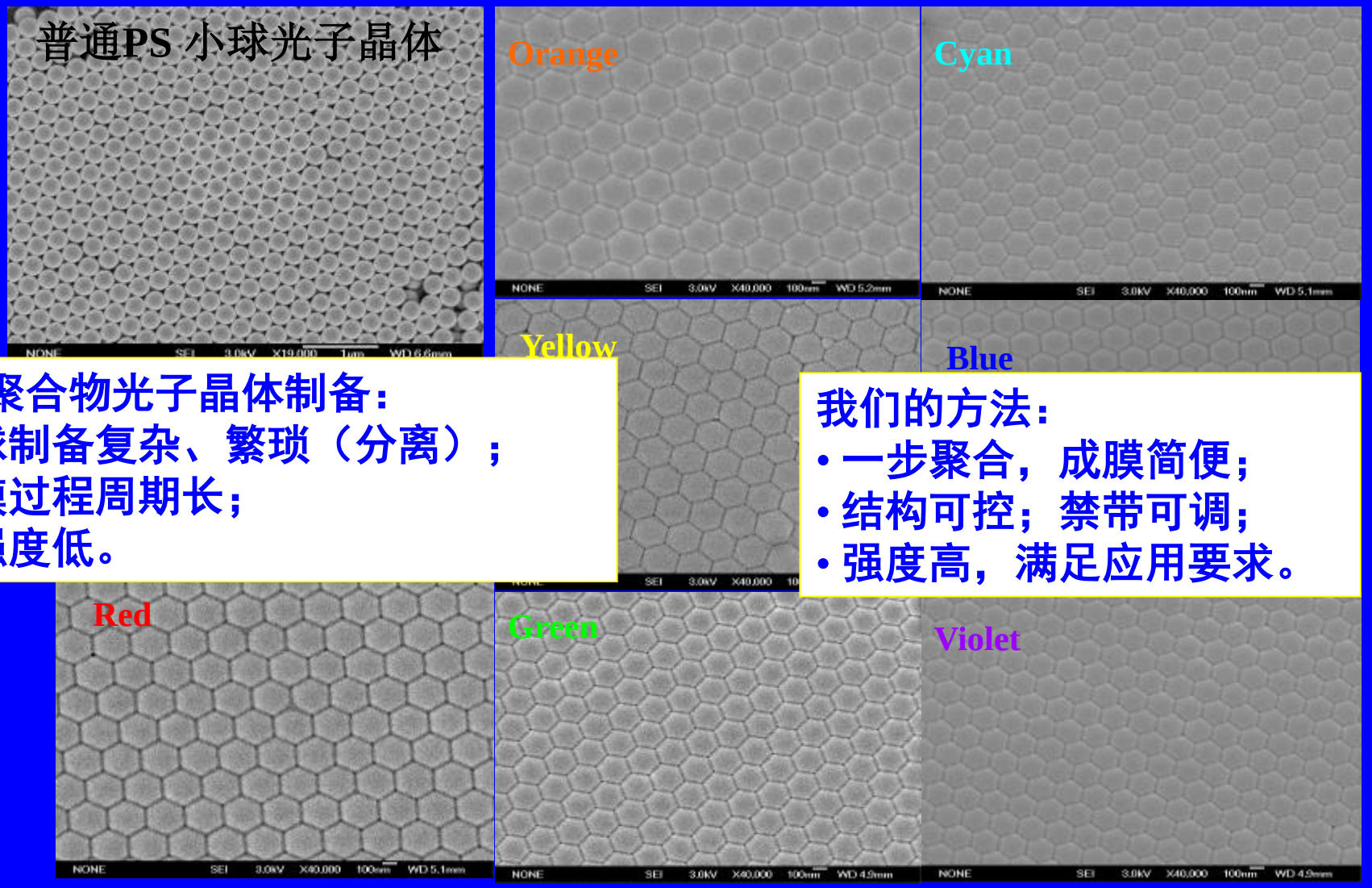
微谐振腔

高效LED



宽带滤波器

紧密堆积结构的聚合物光子晶体



现有聚合物光子晶体制备：

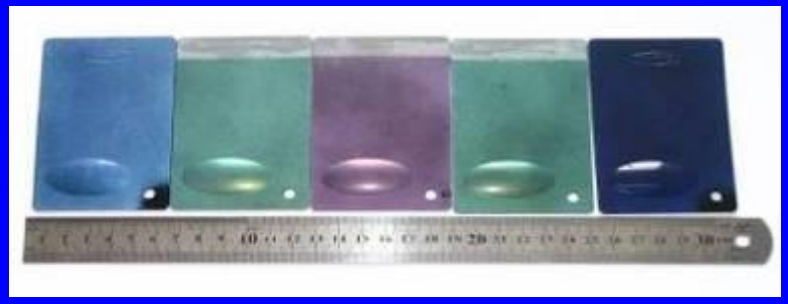
- 小球制备复杂、繁琐（分离）；
- 成膜过程周期长；
- 膜强度低。

我们的方法：

- 一步聚合，成膜简便；
- 结构可控；禁带可调；
- 强度高，满足应用要求。

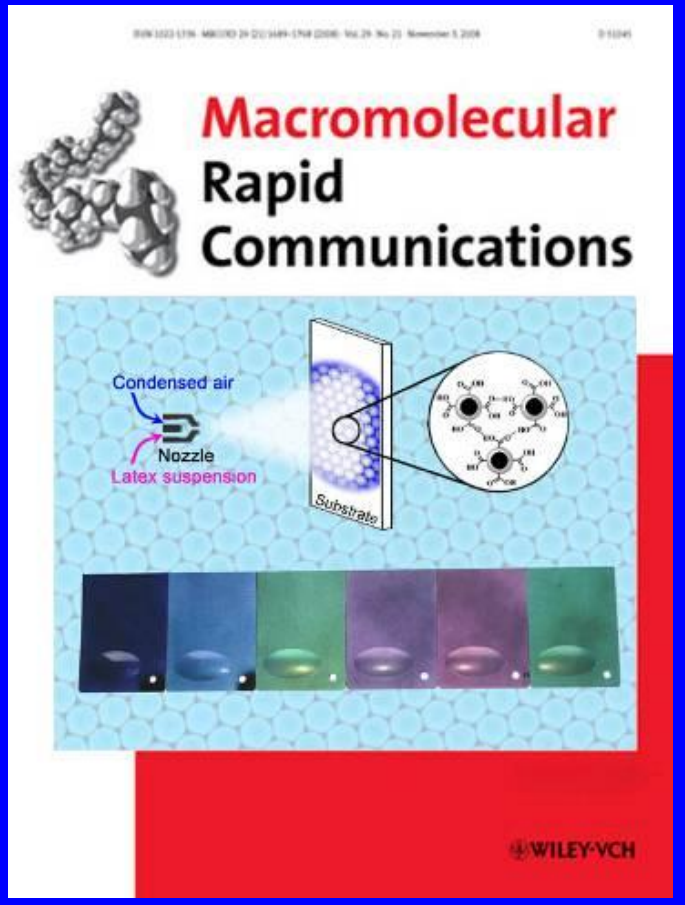
光子晶体大面积可控制备：1. 喷涂法

纸板



塑料

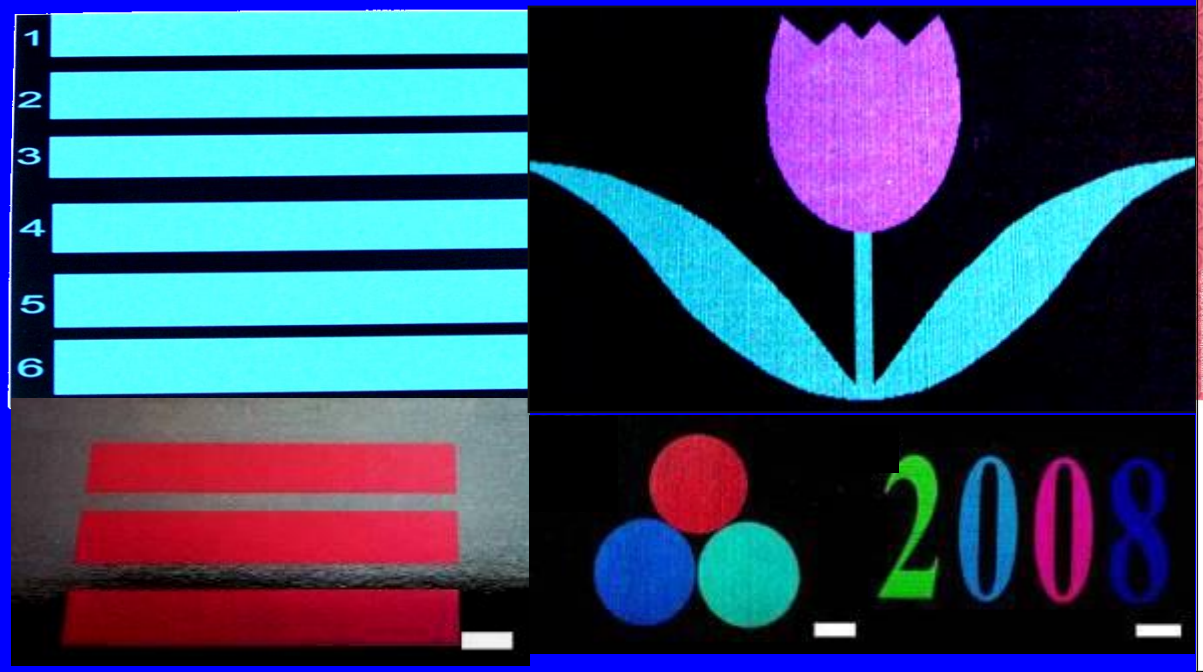
金属

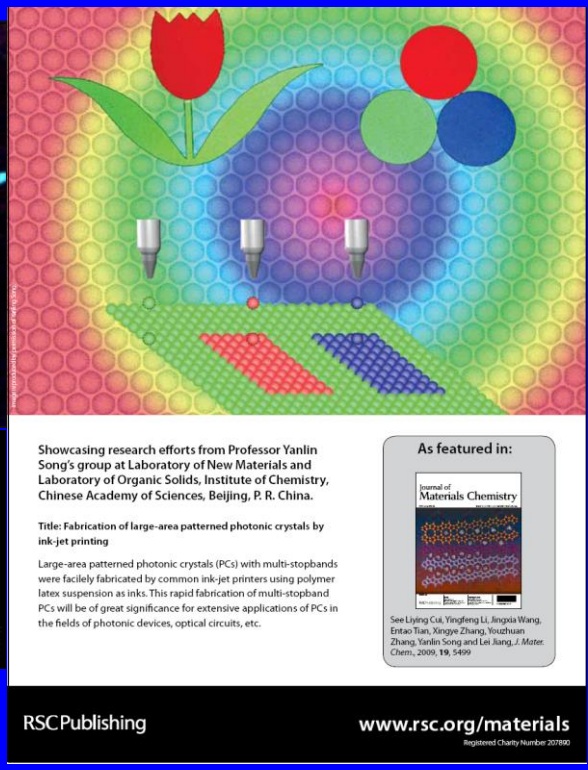


专利申请号: CN 200710064245.0

Macromol. Rapid Commun. , 2009

印刷光子晶体图案





J. Mater. Chem. 2009 *(Back cover)*

***Patents*: CN 200710179880.3**

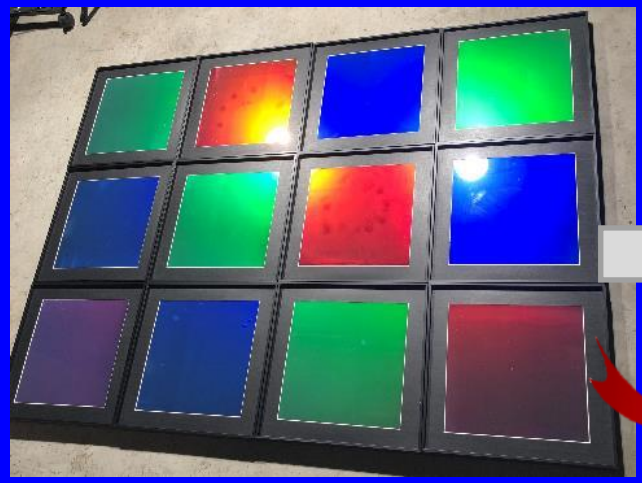
200810115540.9

科学与艺术

《百载》雕塑纪念建党100周年

印刷微透镜

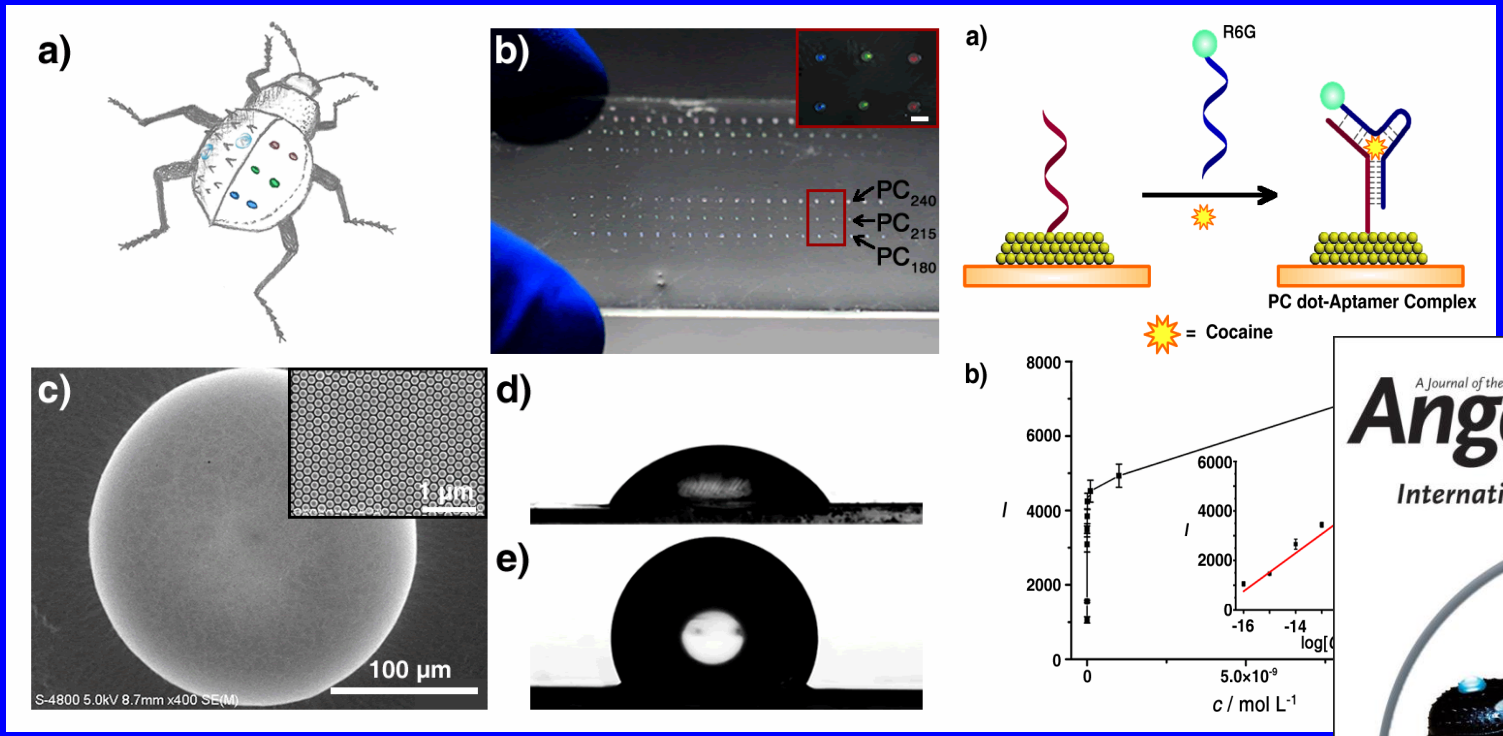
结构色：源头解决染料污染

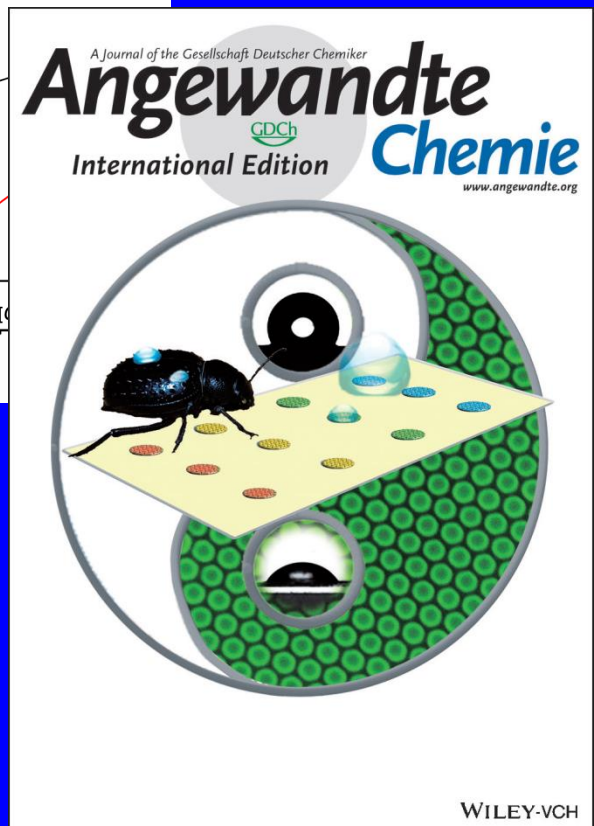


中央美院/伦敦设计博物院《万物生息》艺术展


SK-II
GENOPTICS
AURA ESSENCE

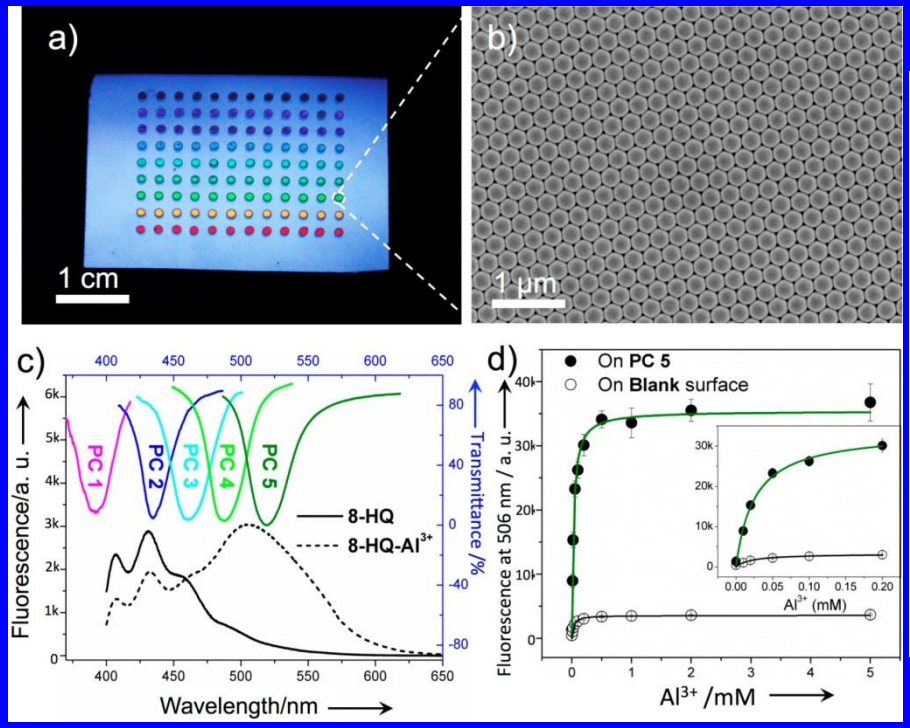
打印高灵敏检测芯片





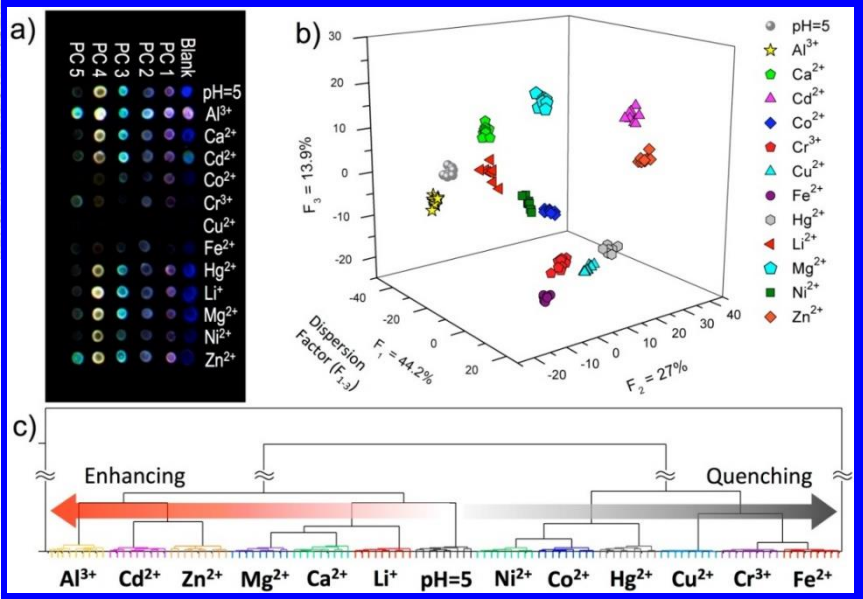
Angew. Chem. Int. Ed. 2014

多种重金属离子检测



a, b) Photograph and SEM image of a multi-stopband PCs microchip.

c, d) Selected PCs match the fluorescence spectra of 8-HQ and its fluorescent enhancement.



Fluorescent discriminant analysis of 12 metal ions on PCs microchip and rational analysis.

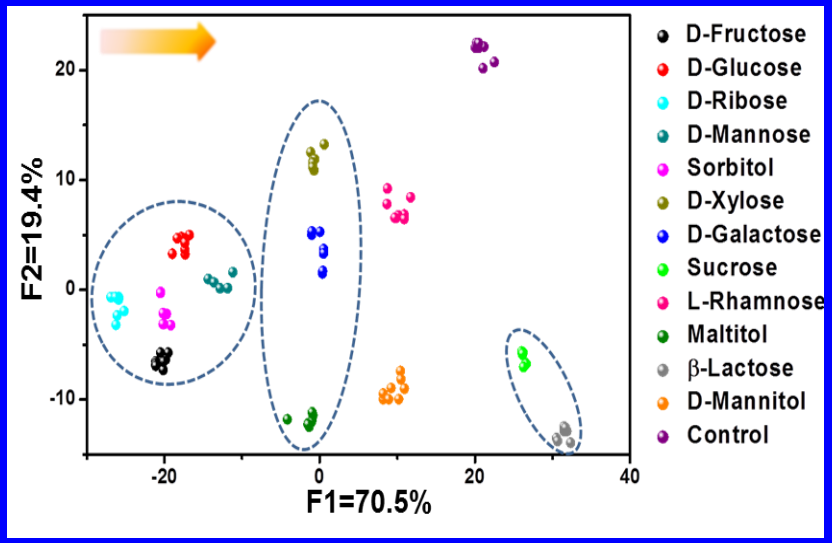
a) Fluorescent image of PCs microchip.

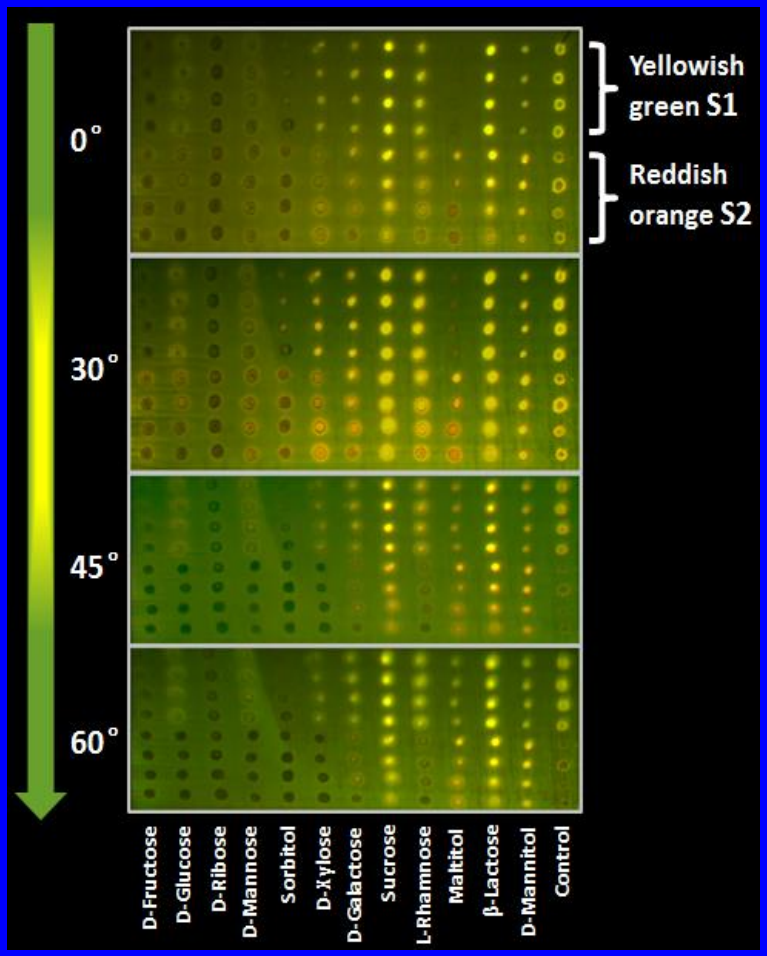
b) Graph of LDA result.

c) HCA result.

Angew. Chem. Int. Ed. 2013, 52, 7296-7299

高灵敏生物检测芯片

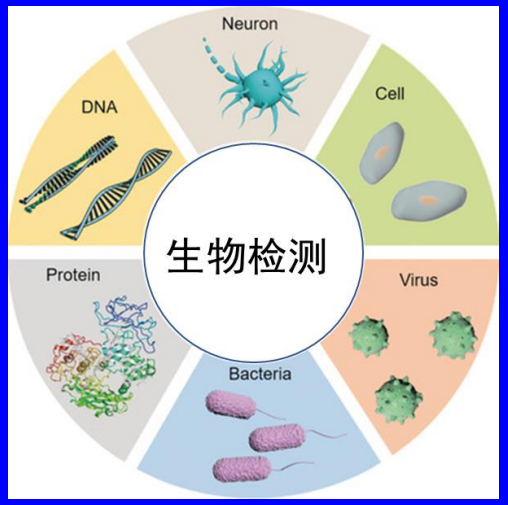




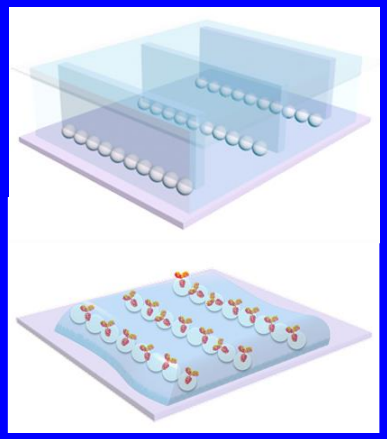
Recognition of 12 highly similar saccharides

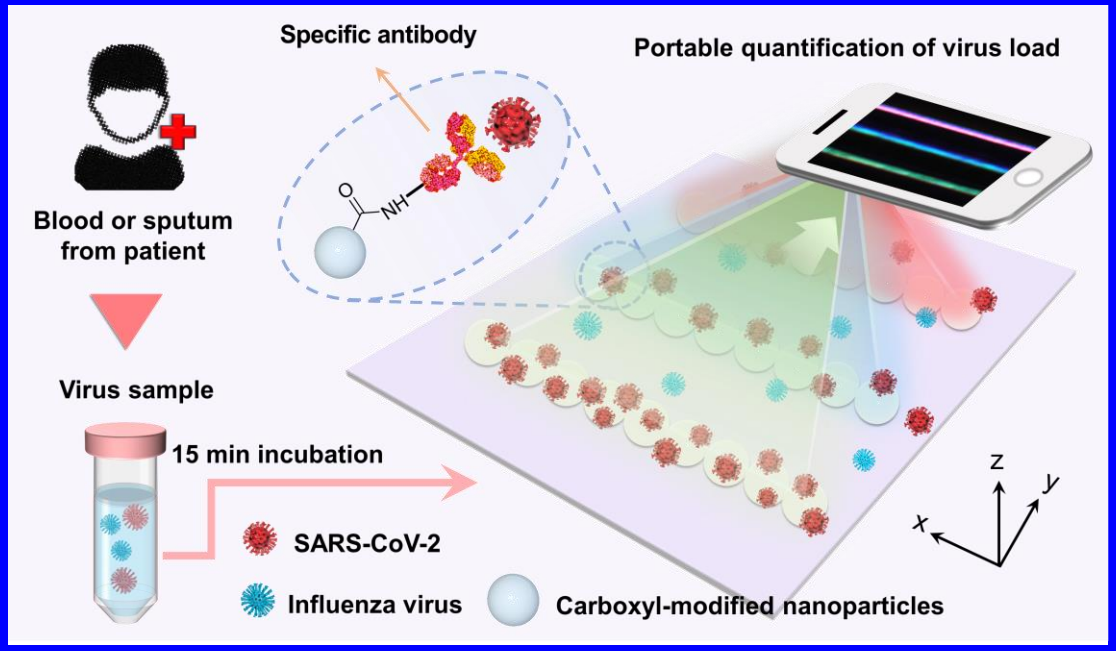
Angew. Chem. Int. Ed. 2016, *55*, 6911-6914

印刷纳米链实现手机快速检测新冠病毒

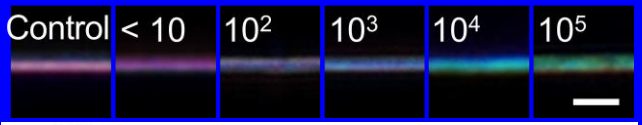


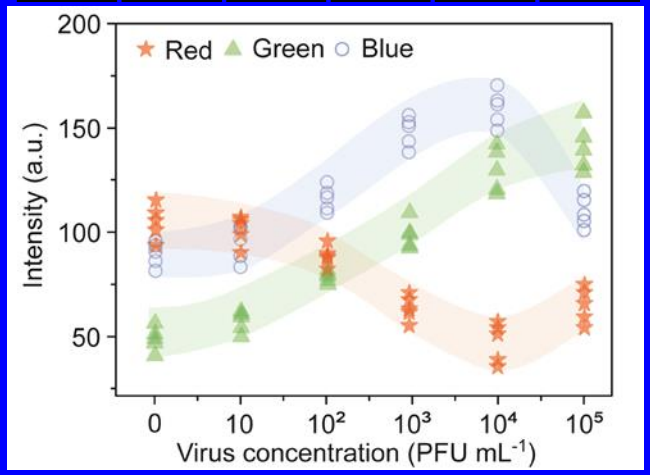
Printing nanochain





Quantitative detection

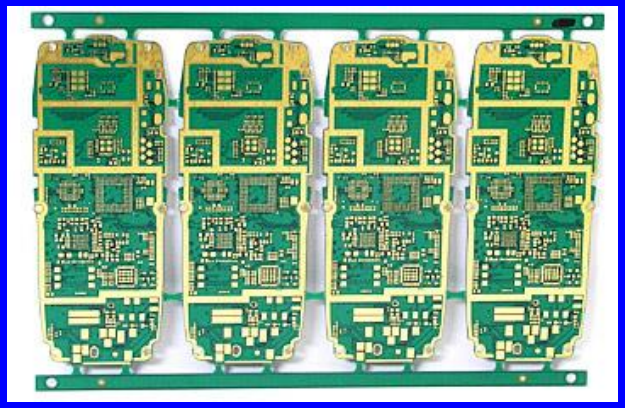




Angew. Chem. Int. Ed. **doi:10.1002/anie.202109985**

绿色印刷技术拓展-绿色印刷线路板

电脑主板



手机主板

收音机

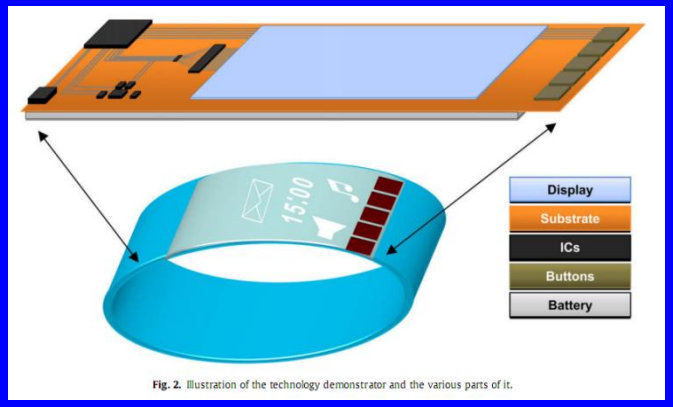
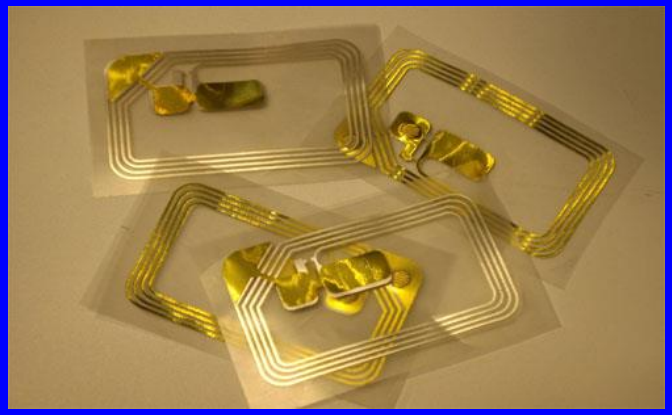
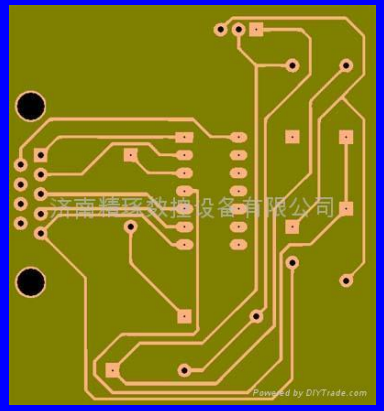


Fig. 2. Illustration of the technology demonstrator and the various parts of it.

手表

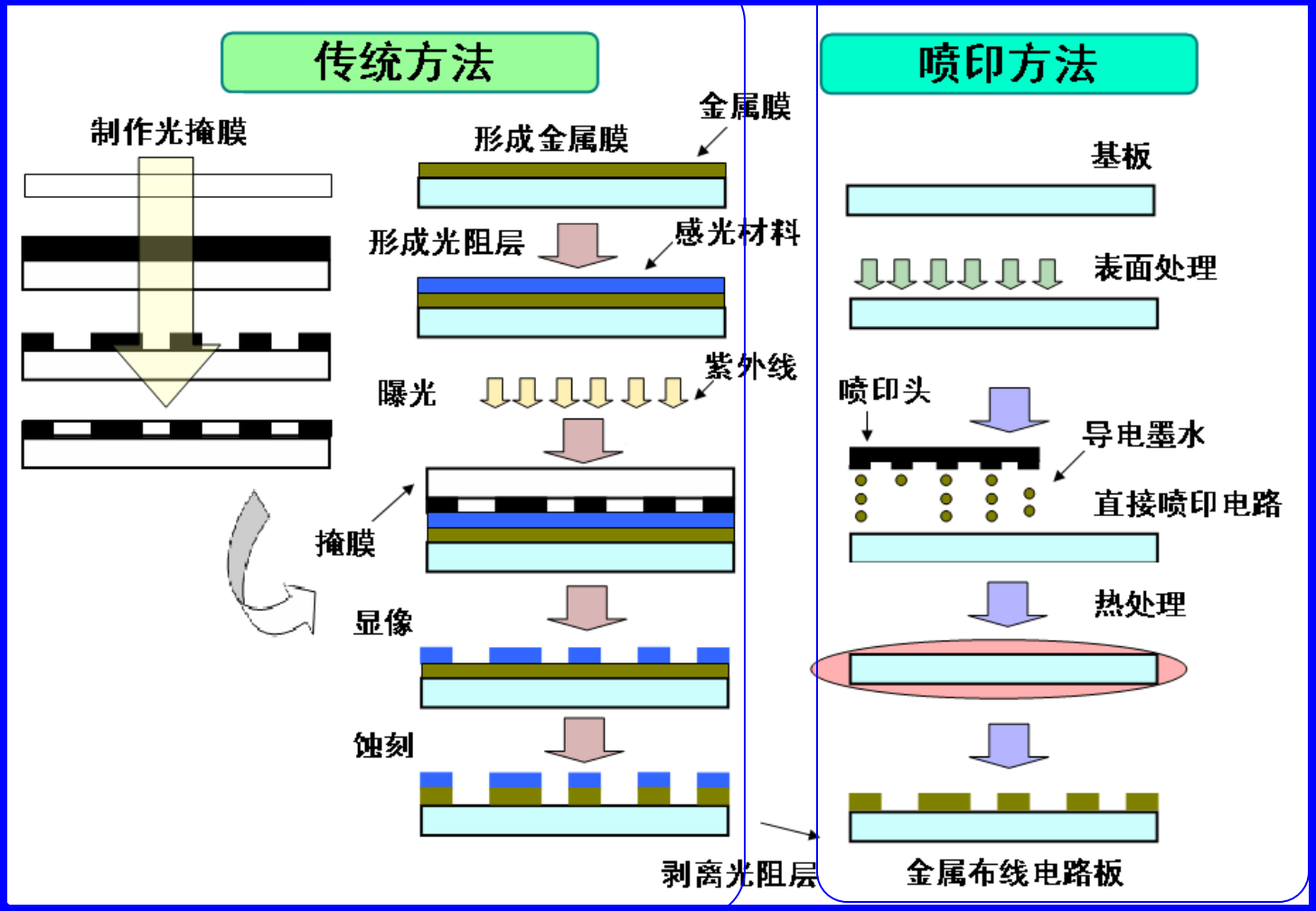


RFID天线

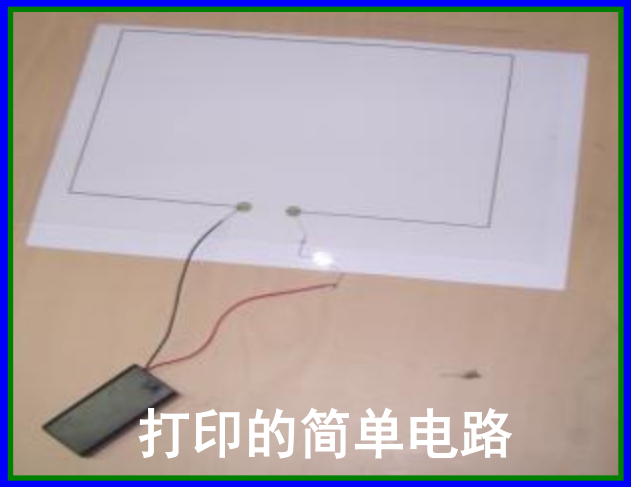


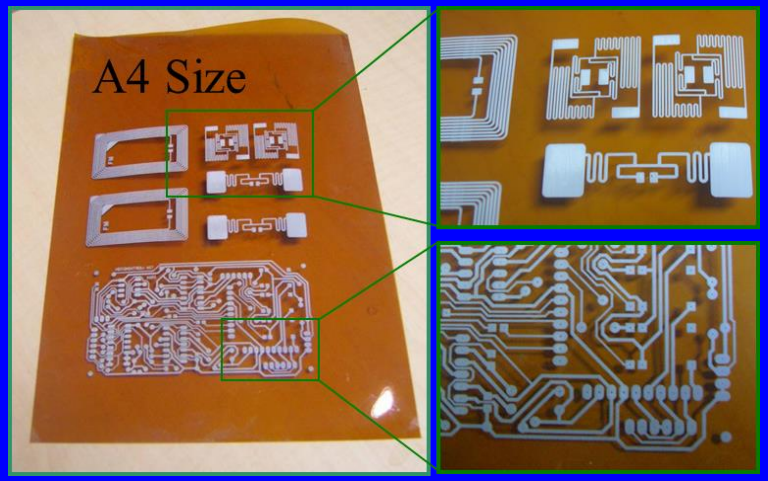
器件线路

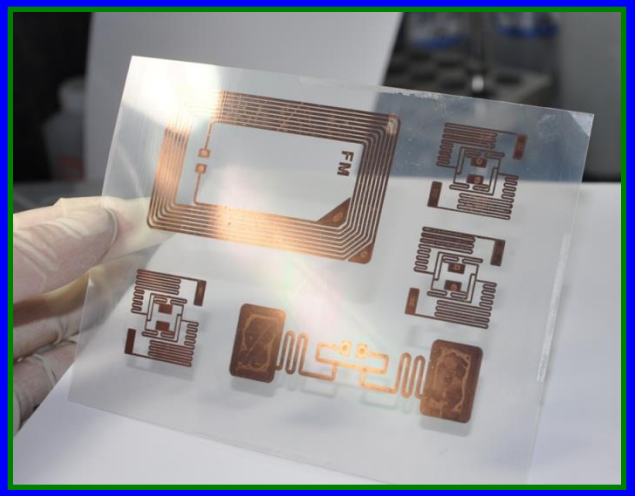
印刷线路板制备技术

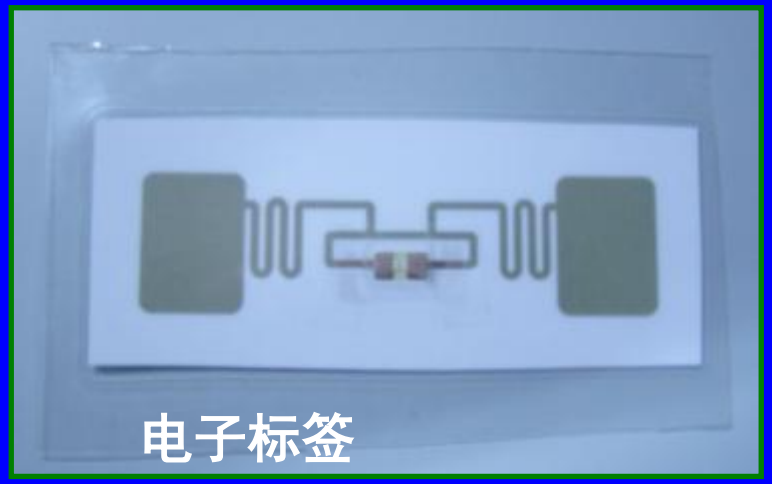

传统方法
喷印方法
制作光掩膜
形成金属膜
金属膜
形成光阻层
感光材料
曝光
紫外线
掩膜
显像
蚀刻
剥离光阻层
基板
表面处理
喷印头
导电墨水
直接喷印电路
热处理
金属布线电路板

绿色印刷电子


打印的简单电路






电子标签

印刷电子材料与技术

印刷中的关键科学问题

——浸润、融合、组装行为

咖啡环效应
Coffee ring effect

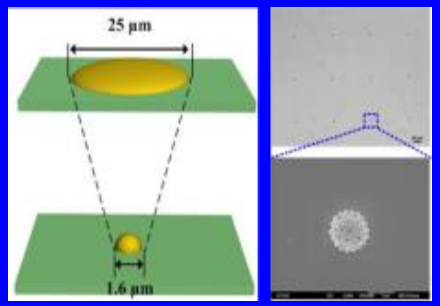
马拉格尼效应
Marangoni effect

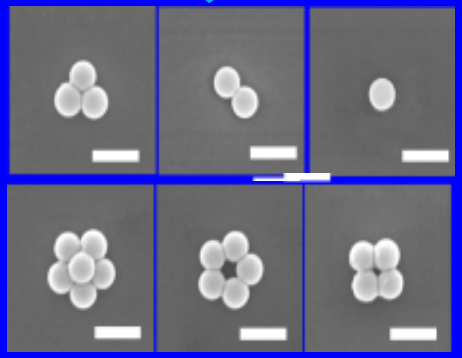
瑞利失稳效
Rayleigh instability

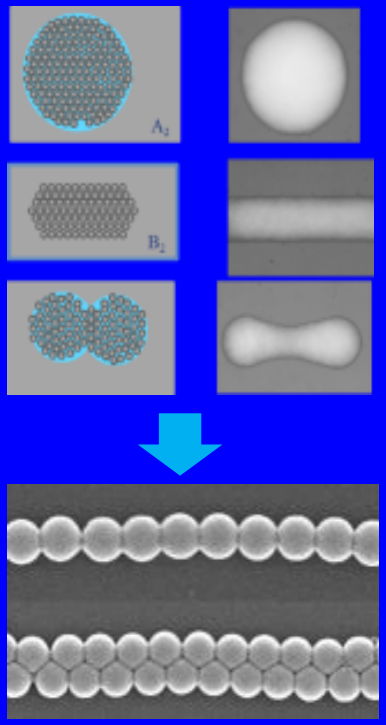
印刷中的关键科学问题突破

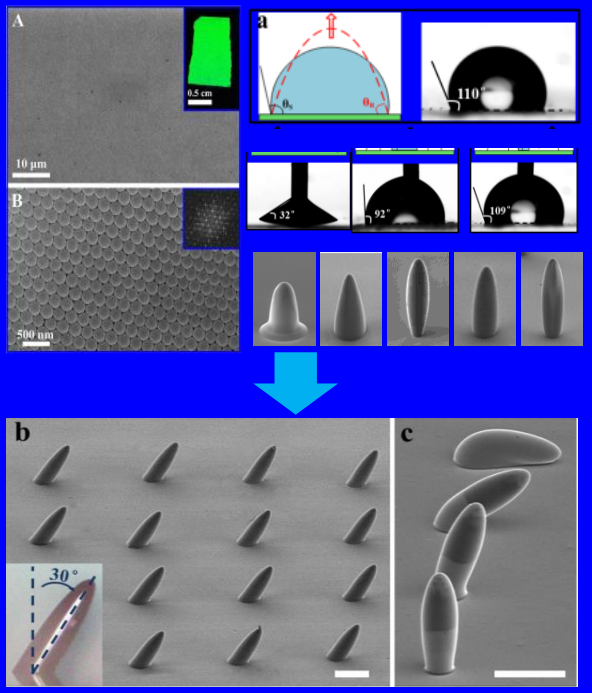
点、线、面、体控制

液滴扩散控制（点） ➡ 液滴融合与控制（线） ➡ 三维结构控制（面-体）



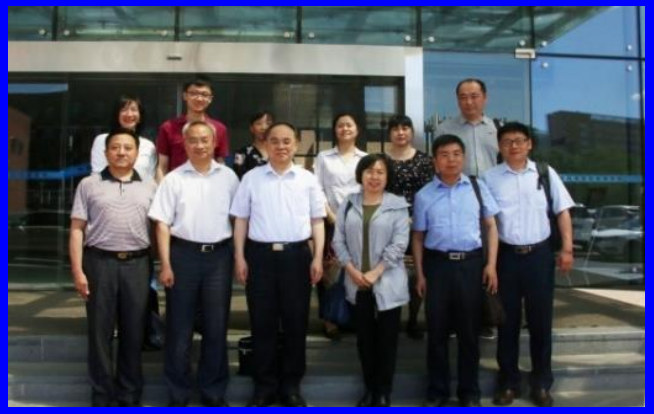




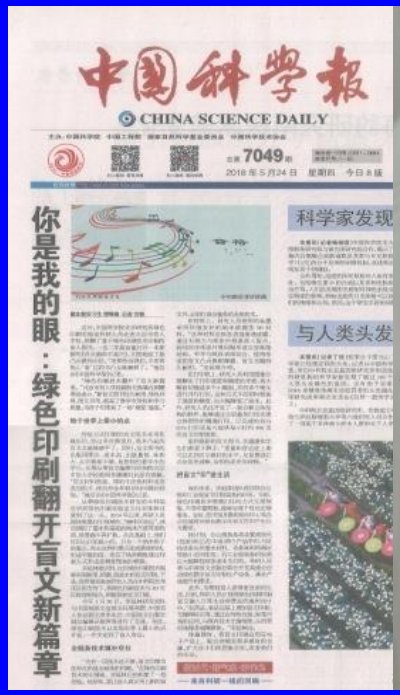


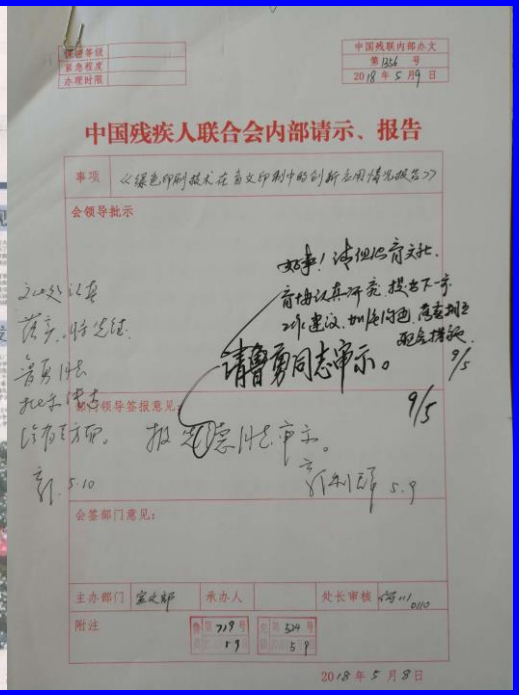
- 研究咖啡环效应(Coffee ring effect)、瑞利失稳(Rayleigh instability)和马拉戈尼效应(Marangoni effect) 等系列科学难题，实现对墨滴从零维到三维结构的精确控制

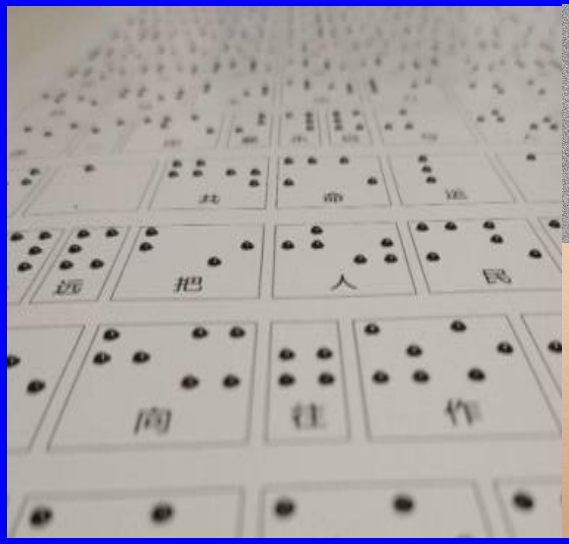
变革盲文出版技术



将在中国盲文出版社应用
并向全世界推广

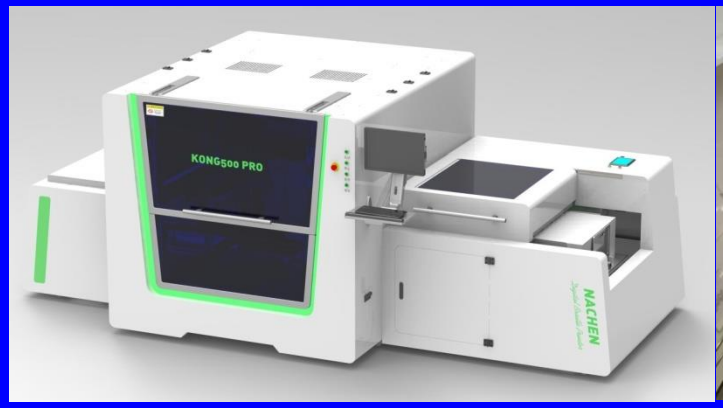

中国科学报
CHINA SCIENCE DAILY
你是我的眼·绿色印刷翻开盲文新篇章
科学家发现
与人类头发


中国残疾人联合会内部请示、报告



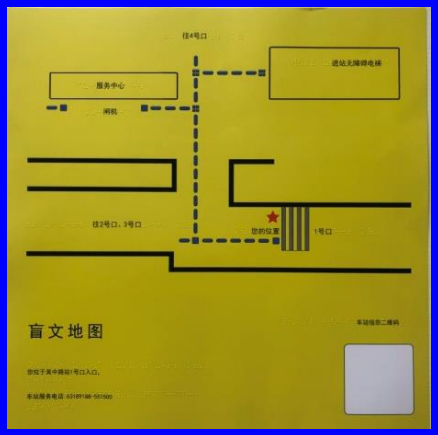
北京盲校捐赠盲文书籍、教具

绿色印刷盲文出版技术



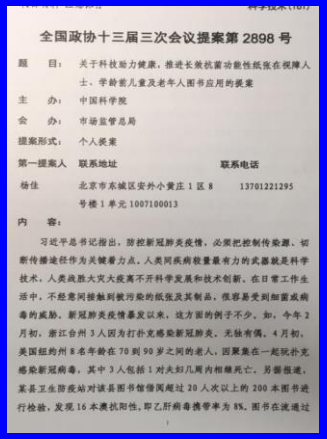
高速盲文出版物印刷机

南京博物院博爱馆首个明盲对照的全融合展览



上海地铁站内无障碍导引图

福建省推出首份盲用触感地图



全国政协十三届三次会议提案第 2898 号

题　　目：关于科技助力健康，推进长效抗菌功能性纸张在视障人士、学龄前儿童及老年人图书应用的提案

主　　办：中国科学院

会　　办：市场监管总局

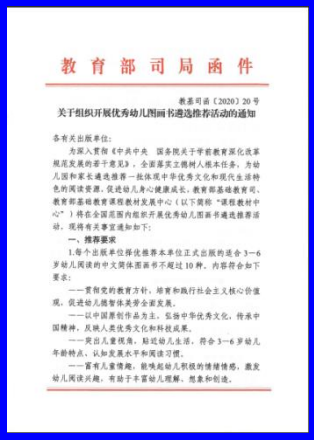
提案形式：个人提案

第一提案人　联系地址　　联系电话

杨佳　　北京市东城区安外小黄庄 1 区 8 号楼 1 单元 1007100013　　13701221295

内　　容：

习近平总书记指出，防控新冠肺炎疫情，必须把控制传染源、切断传播途径作为关键着力点，人类同疾病较量最有力的武器就是科学技术，人类战胜大灾大疫离不开科学发展和技术创新。在日常工作生活中，不经意间接触到被污染的纸张及其制品，很容易受到细菌或病毒的威胁。新冠肺炎疫情暴发以来，这方面的例子不少。如，今年 2 月初，浙江台州 3 人因为打扑克感染新冠肺炎。无独有偶，4 月初，美国纽约州 8 名年龄在 70 到 90 岁之间的老人，因聚集在一起玩扑克感染新冠病毒，其中 3 人包括 1 对夫妇几周内相继死亡。另据报道，某县卫生防疫站对该县图书馆借阅超过 20 人次以上的 200 本图书进行检验，发现 16 本澳抗阳性，即乙肝病毒携带率为 8%。图书在流通过



教 育 部 司 局 函 件

教基司函〔2020〕20 号

关于组织开展优秀幼儿图画书遴选推荐活动的通知

各有关出版单位：

为深入贯彻《中共中央　国务院关于学前教育深化改革规范发展的若干意见》，全面落实立德树人根本任务，为幼儿园和家长遴选推荐一批体现中华优秀文化和现代生活特色的阅读资源，促进幼儿身心健康成长，教育部基础教育司、教育部基础教育课程教材发展中心（以下简称“课程教材中心”）将在全国范围内组织开展优秀幼儿图画书遴选推荐活动，现将有关事宜通知如下：

一、推荐要求

1.每个出版单位择优推荐本单位正式出版的适合 3—6 岁幼儿阅读的中文简体图画书不超过 10 种，内容符合如下要求：

——贯彻党的教育方针，培育和践行社会主义核心价值观，促进幼儿德智体美劳全面发展。

——以中国原创作品为主，弘扬中华优秀文化，传承中国精神，反映人类优秀文化和科技成果。

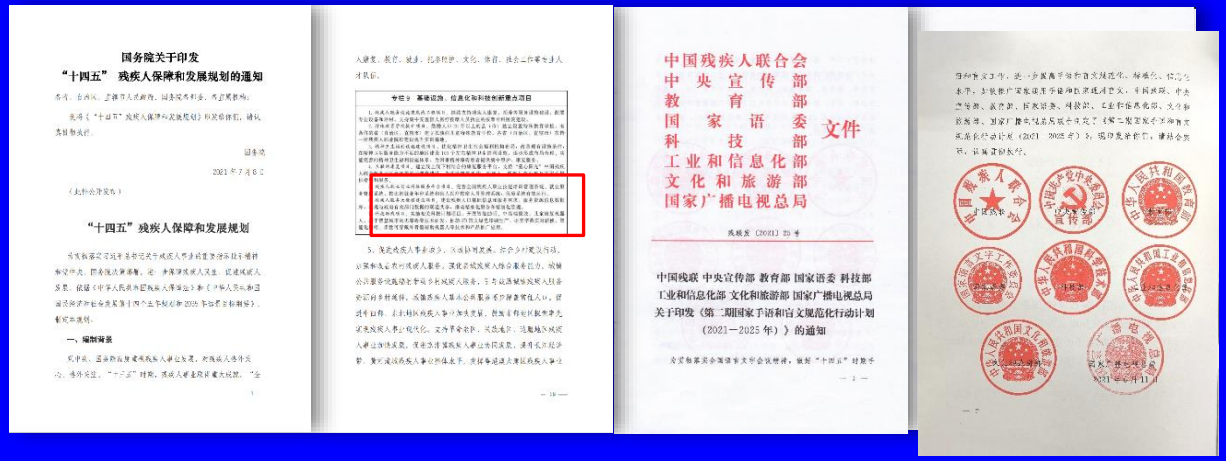
——贴出儿童视角，贴近幼儿生活，符合 3—6 岁幼儿年龄特点，认知发展水平和阅读习惯。

——富有儿童情趣，能唤起幼儿积极的情绪情感，激发幼儿阅读兴趣，有助于丰富幼儿理解、想象和创造。

全国政协提案
推进盲文印刷和抗菌图书的应用

绿色印刷盲文技术应用

中残联“十四五”规划将绿色印刷盲文列入重点推广的科技创新项目



国务院关于印发
“十四五” 残疾人保障和发展规划的通知

“十四五”残疾人保障和发展规划

中国残疾人联合会
中央宣传部
教育部
国家语委
科技部
工业和信息化部
文化和旅游部
国家广播电视总路
文件

中国残联 中央宣传部 教育部 国家语委 科技部
工业和信息化部 文化和旅游部 国家广播电视总局
关于印发《第二期国家手语和盲文规范化行动计划
（2021—2025 年）》的通知

首套明盲对照明信片

浮雕触感邮资明信片《福州古厝》发行

17月6日，福州市首校学生张雨涵触摸《福州古厝》明信片，感受福外古厝之美。

当日，在第44届世界遗产大会即将开幕之际，浮雕触感邮资明信片《福州古厝》在福州发行。该套明信片共4枚，使用增效打印技术制作，视障

新华社记者 林善传 摄

17月6日，福州市首校学生张雨涵触摸《福州古厝》明信片，感受福外古厝之美。

2022北京冬残奥观众指南、运动员和官员手册

北京2022年冬奥会和冬残奥会
观众指南
（盲文 · 大字）

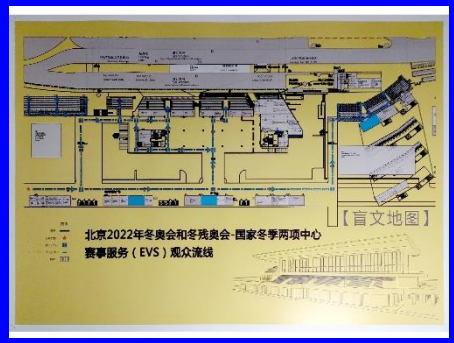
The Olympic and Paralympic
Winter Games Beijing 2022
Spectators Guide
(Braille & Large Print)

北京2022年冬奥会和冬残奥会
运动员和随队官员服务手册
（盲文 · 大字）

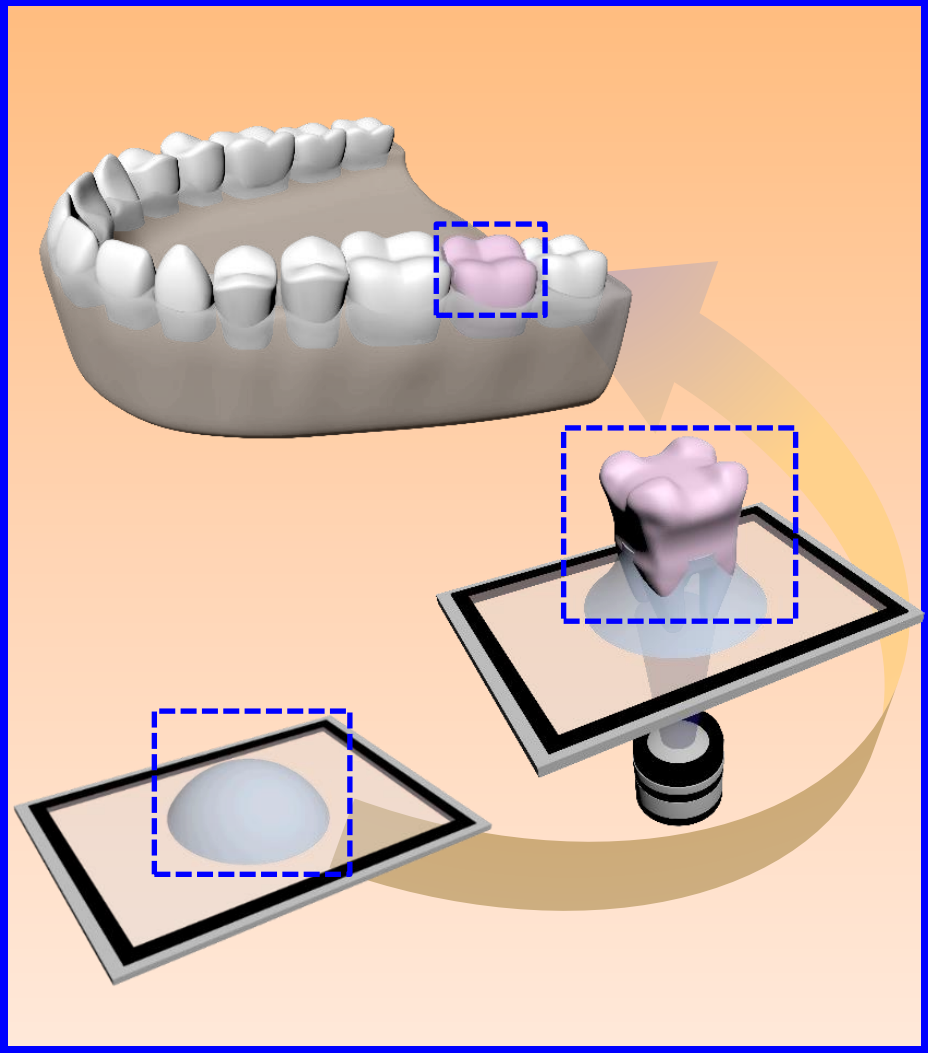
The Olympic and Paralympic
Winter Games Beijing 2022
Service Manual for Athletes and
Team Officials
(Braille & Large Print)

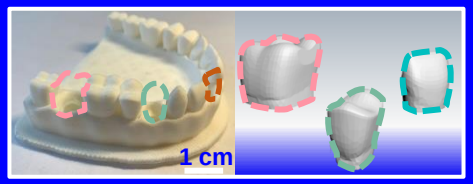
大兴机场

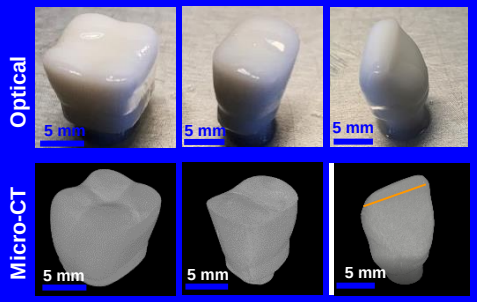
冬奥比赛场馆地图



单墨滴3D打印成型控制

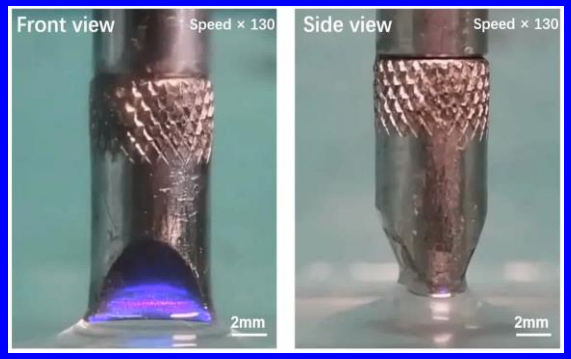


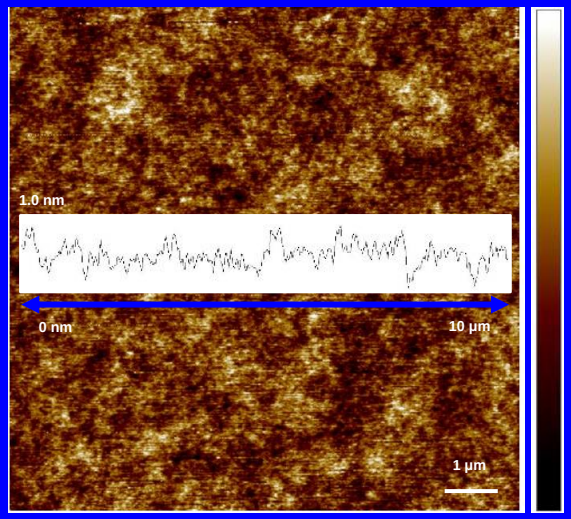




Nature Commun. 2020

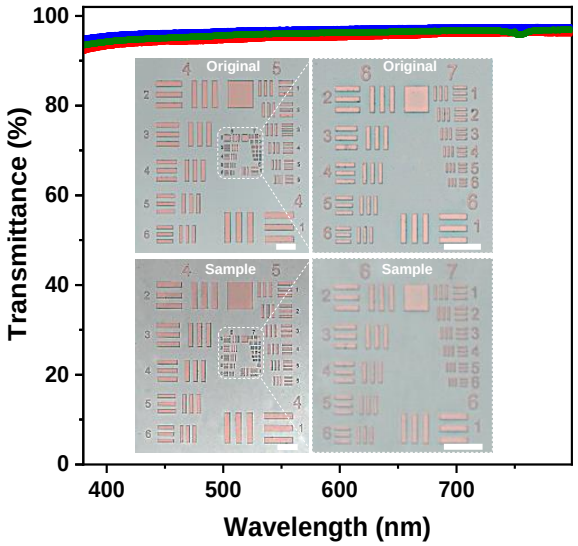
3D打印高精度隐形眼镜结构





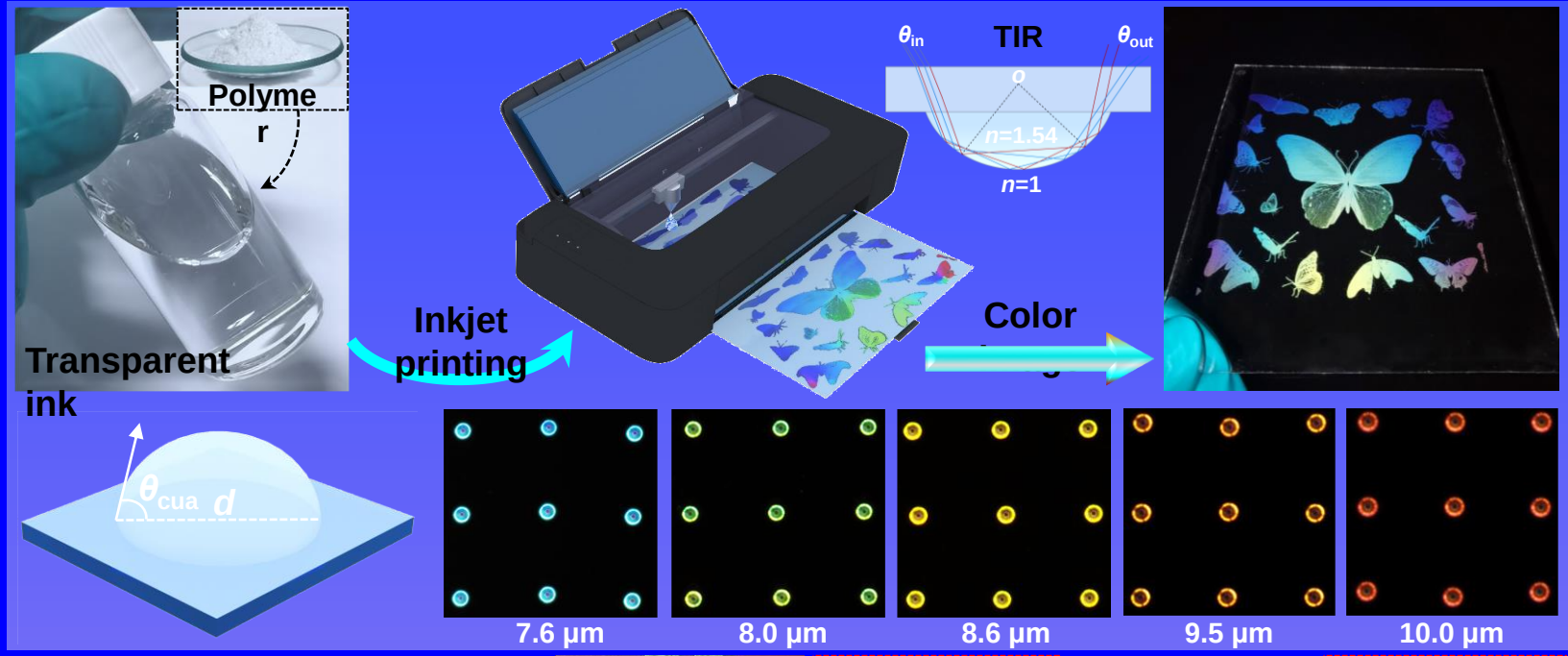
高精度（1.3 nm）；光滑形貌

Adv. Mater. 2022, 34, 2270030.



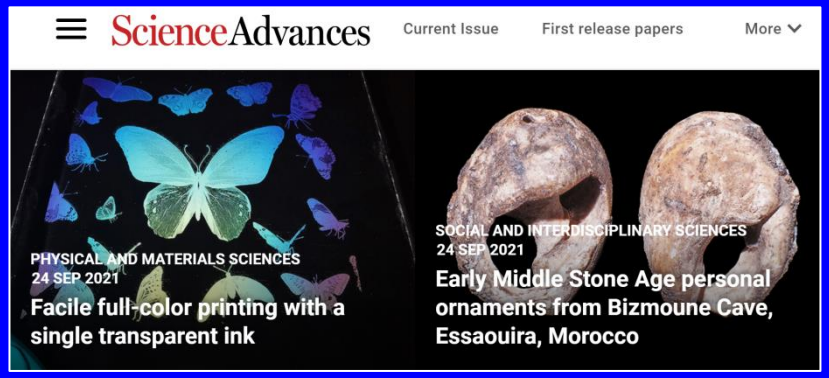
高透光性（≥96%）；
高光学分辨率（2.19 μm）

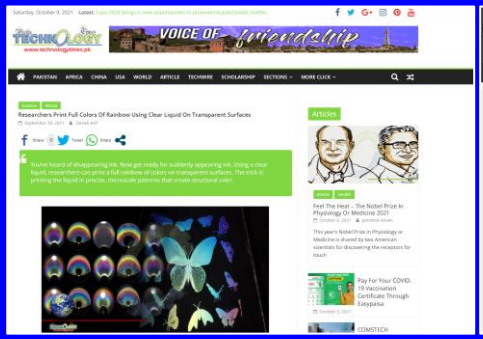
单一透明墨水的全色结构色打印



Sci. Adv. 2021, 7 , eabh1992

空既是色



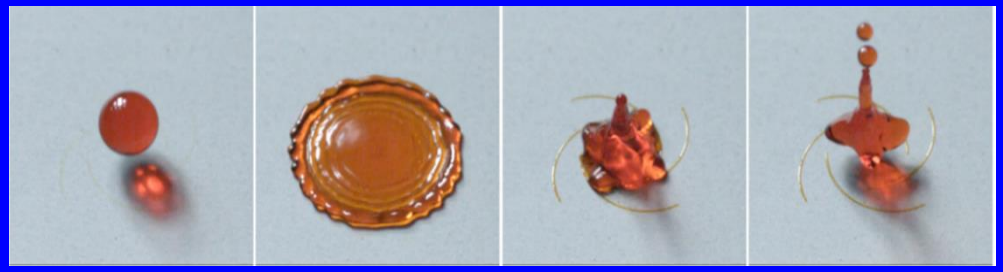


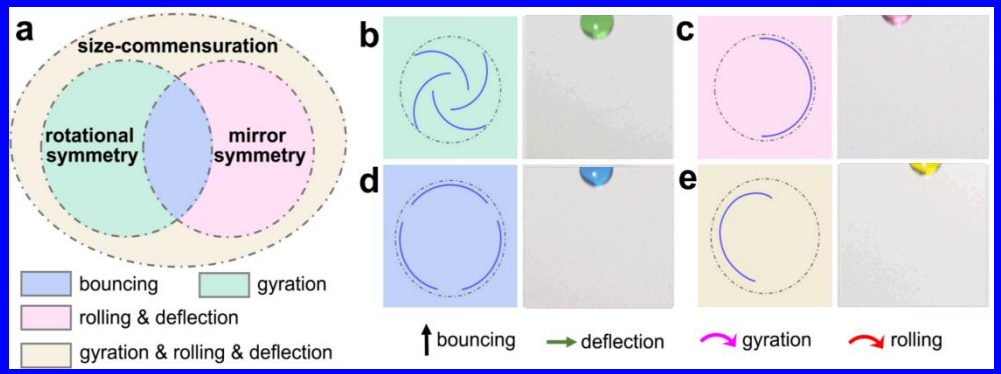
"I was excited to see that somebody had used [structural color] for this purpose," says Lauren Zarzar, a materials chemist at Penn State who has studied similar structural colors cast by water and oil droplets. "They had some nice examples that I

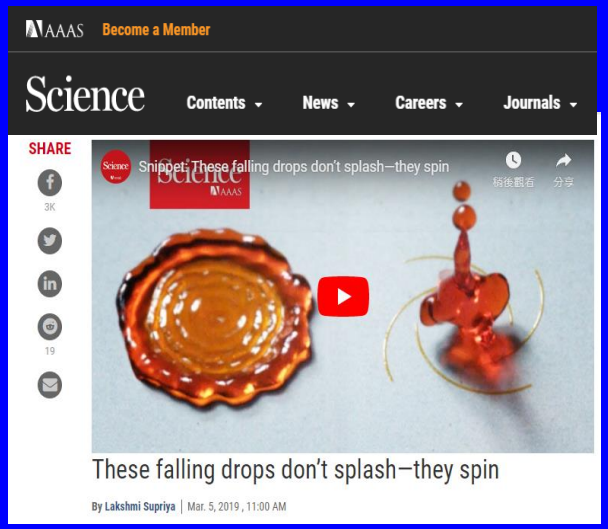
Printing similar light-scattering structures using transparent polymers could offer advantages over standard colour printing techniques, particularly as the chemicals used to produce some dyes and pigments have caused serious health and pollution problems, says Yanlin Song, a chemist at the Chinese Academy of Sciences in Beijing.

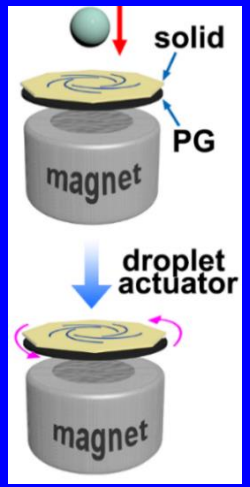
中国科学院 CHINESE ACADEMY OF SCIENCES
ScienceNews
physicsworld
TECHNOLOGY www.technologytimes.pk
NEWS
PHYS.ORG
tiempo la noticia digital
GIZMODO Australia

图案化基底对液滴动态行为的调控

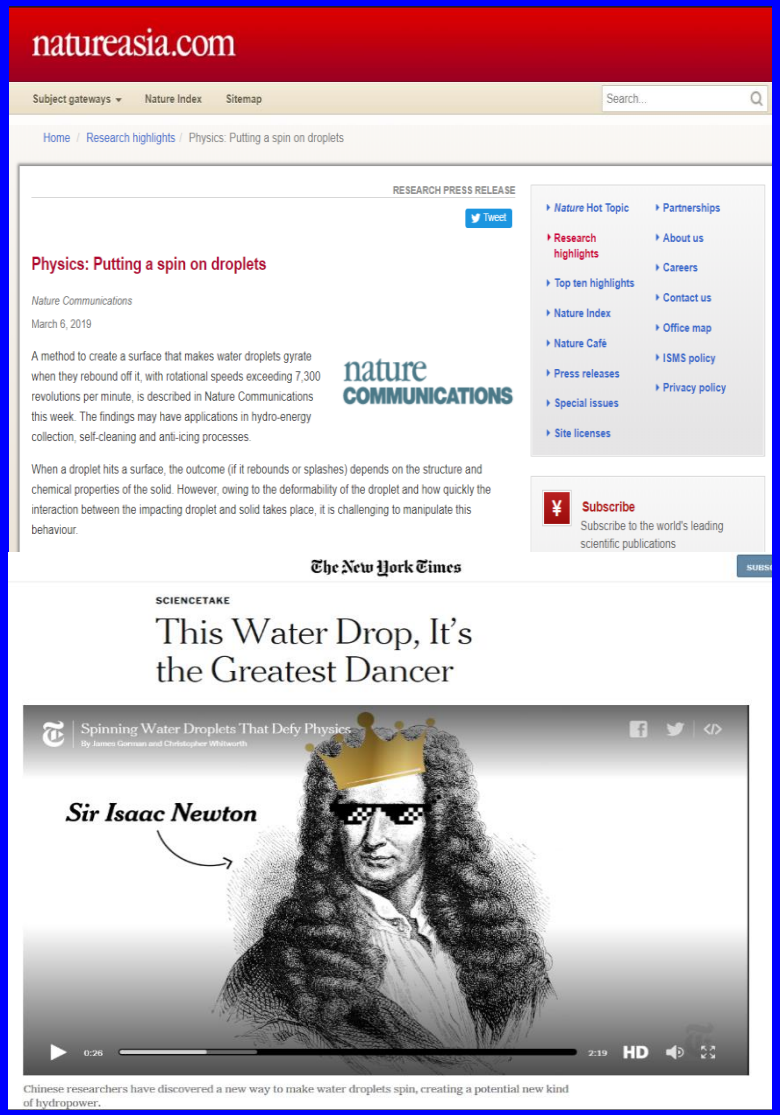








液滴驱动器水能发电



Science nature International journal of science C&EN

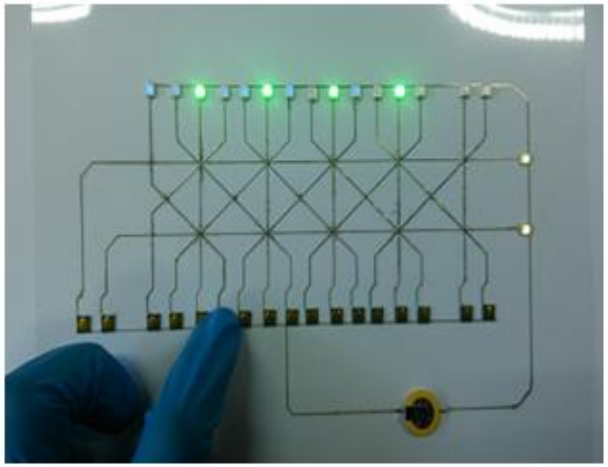
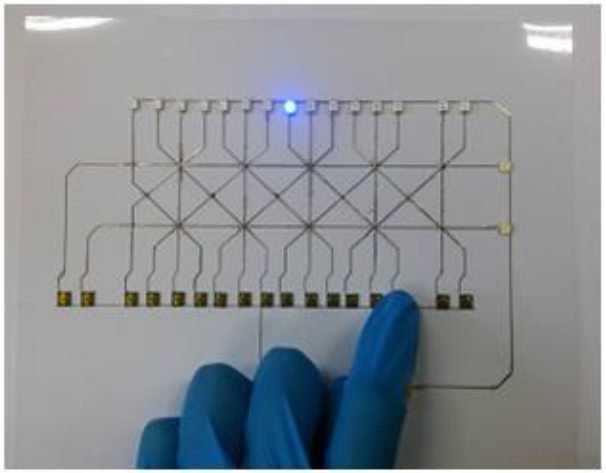
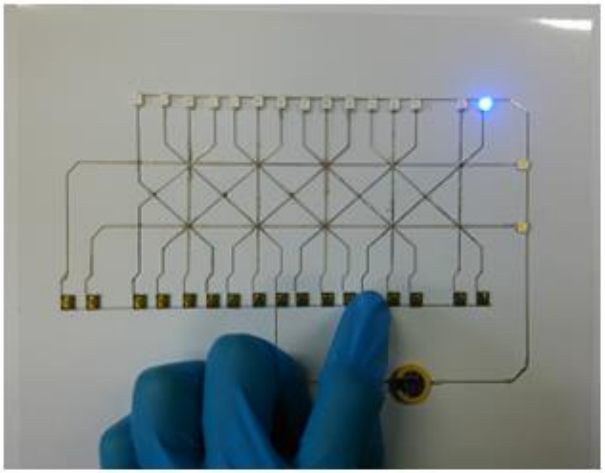
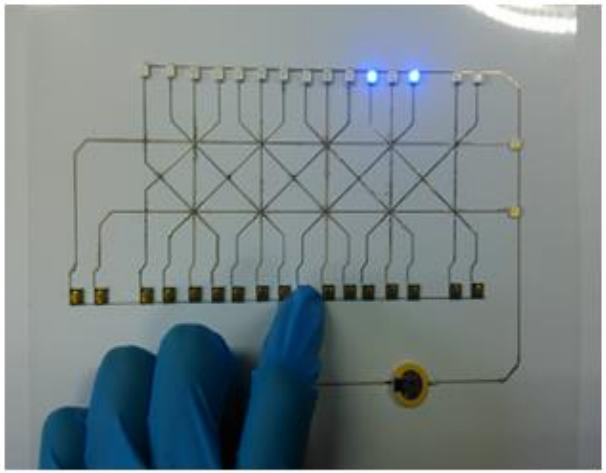
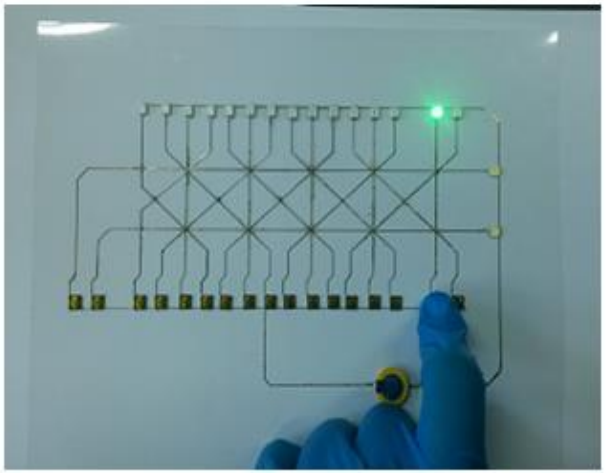
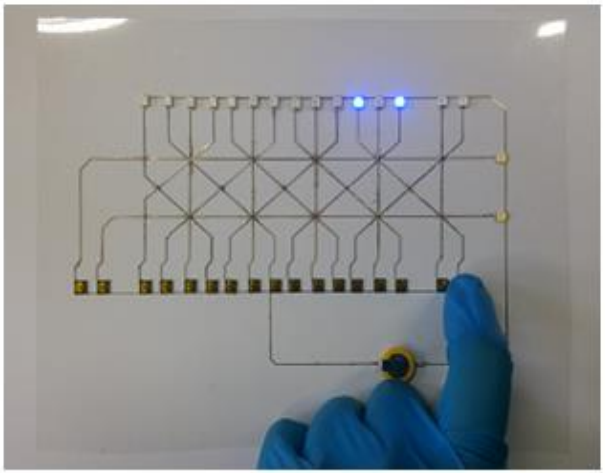
Mail Online PHYS.ORG

The New York Times

Nat. Commun. 2019, 10, 950

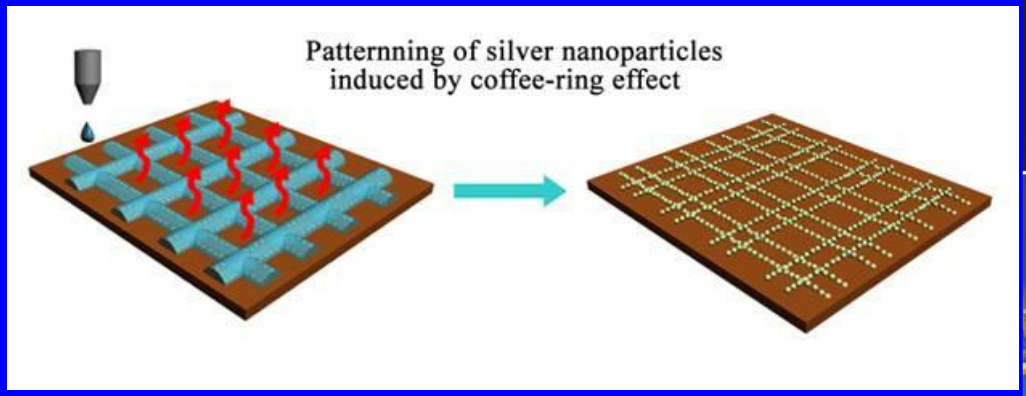

世界のオモシロ学者のスゴ動画祭
世界最大規模の科学研究機関
中国科学院
NHK G
まるで魔法!?踊る水滴
中国科学院 化学研究所
宋 延林先生

全打印制备多层柔性电路

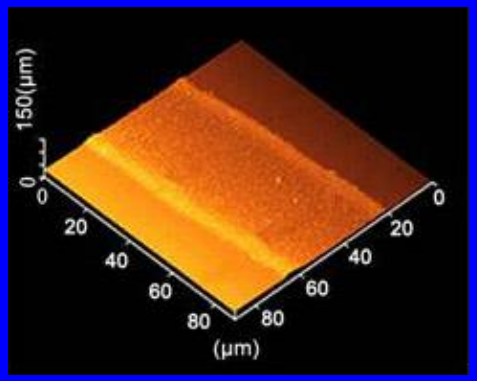







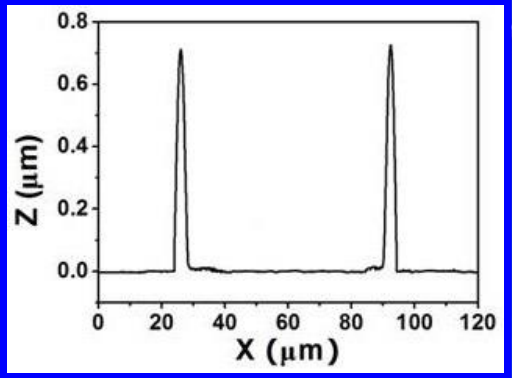
Adv. Mater. 2016, *28*, 1420-1426.

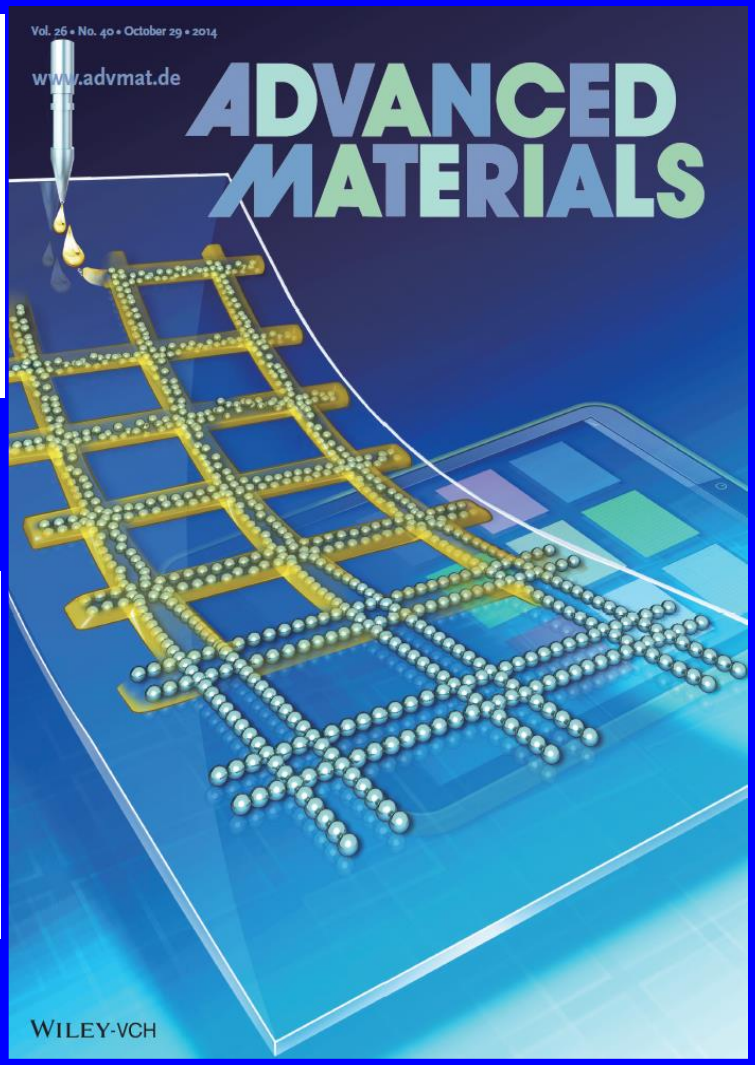
印刷高透明导电图案



利用“咖啡环”效应打印连续导电线



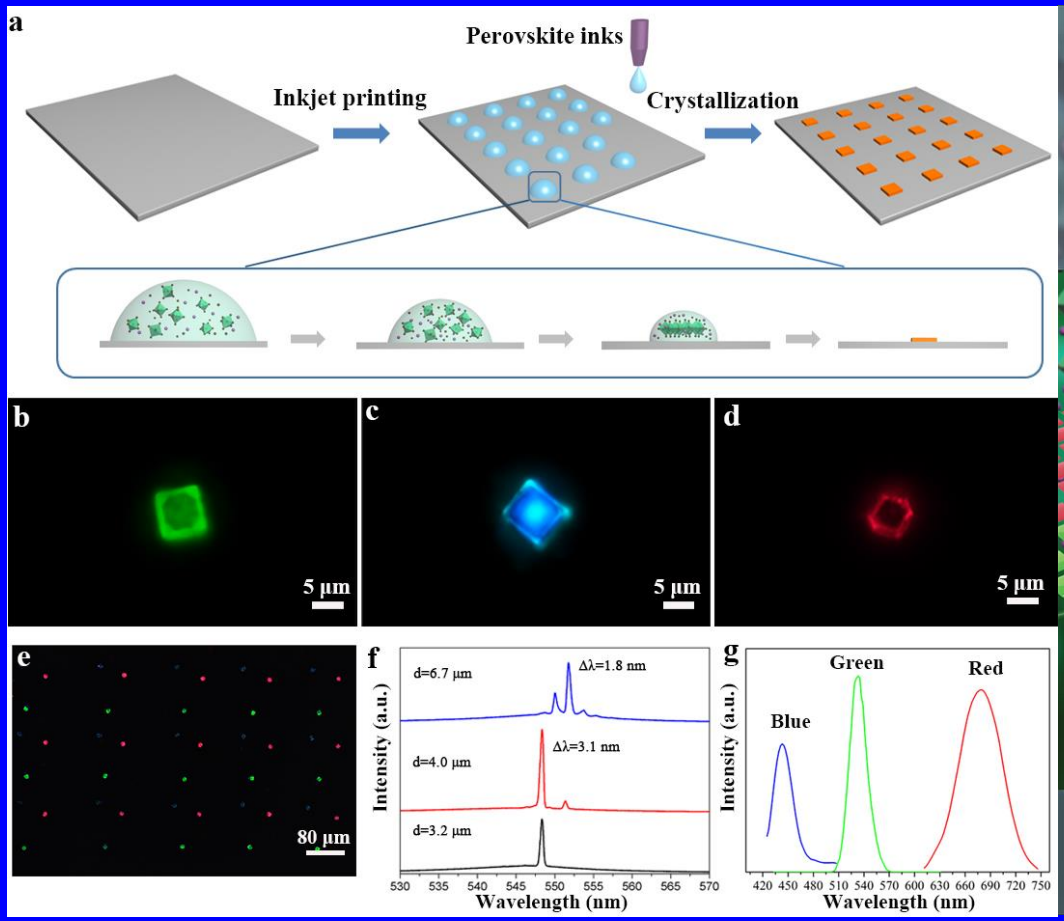




Adv. Mater. 2013, *25*, 6714-6718

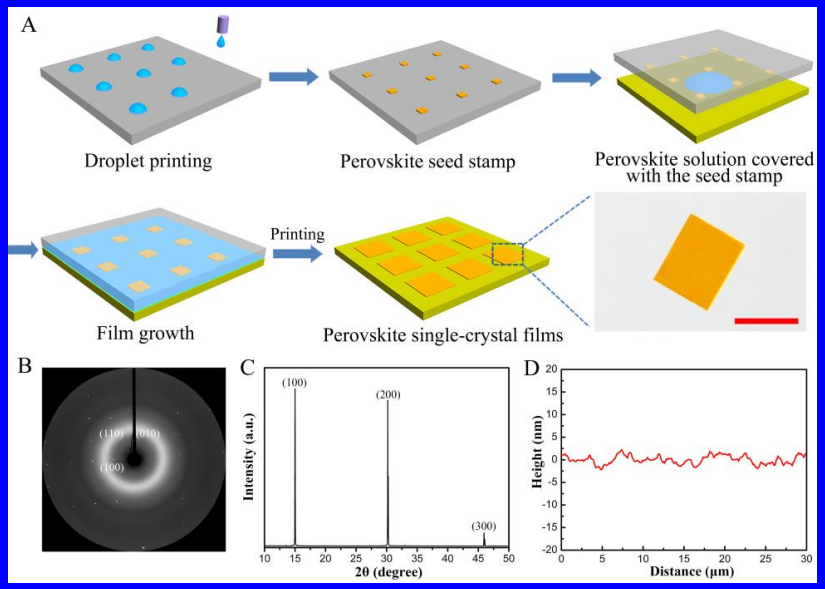
Adv. Mater. 2014, *26*, DOI: 10.1002/adma.201305416

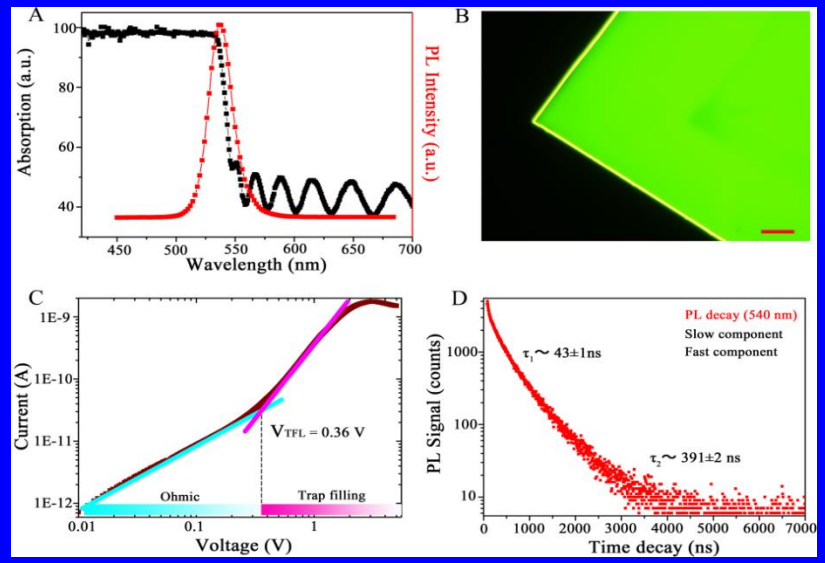
从活字印刷到“活性印刷”

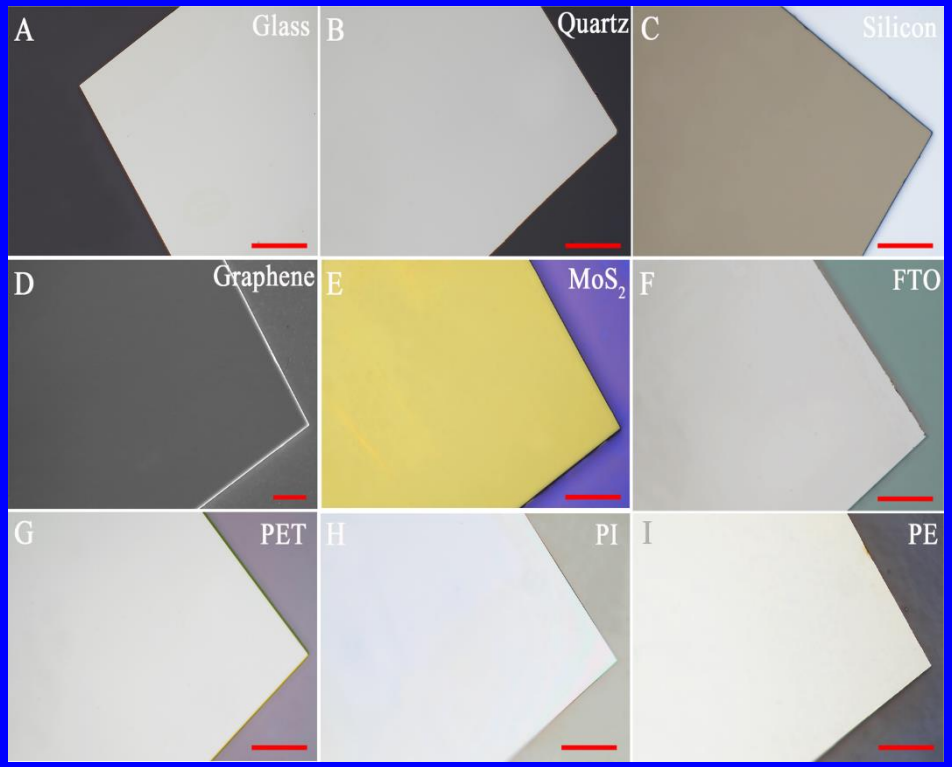


Small, 2017, 13, 1603217.

从活字印刷到活性印刷



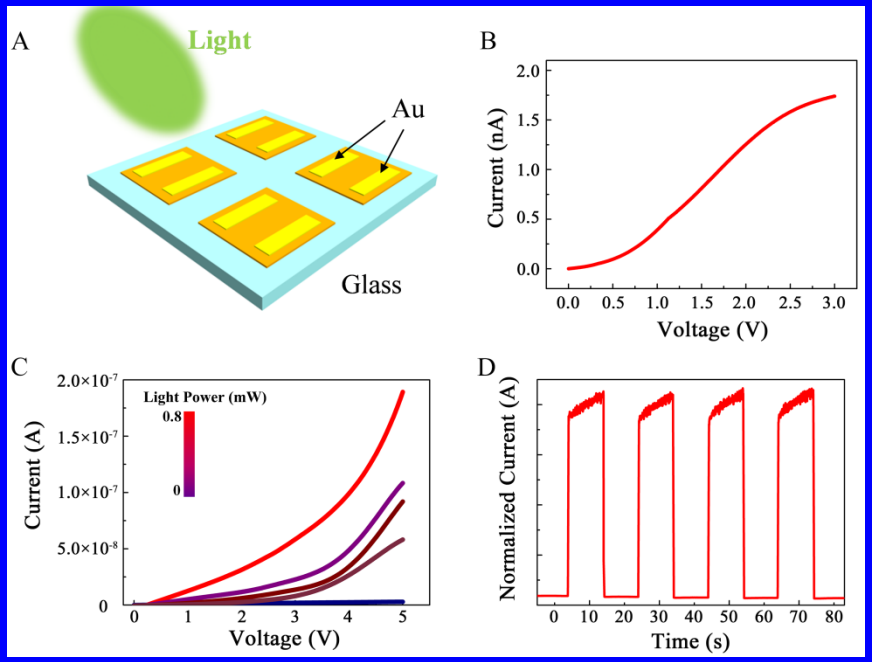


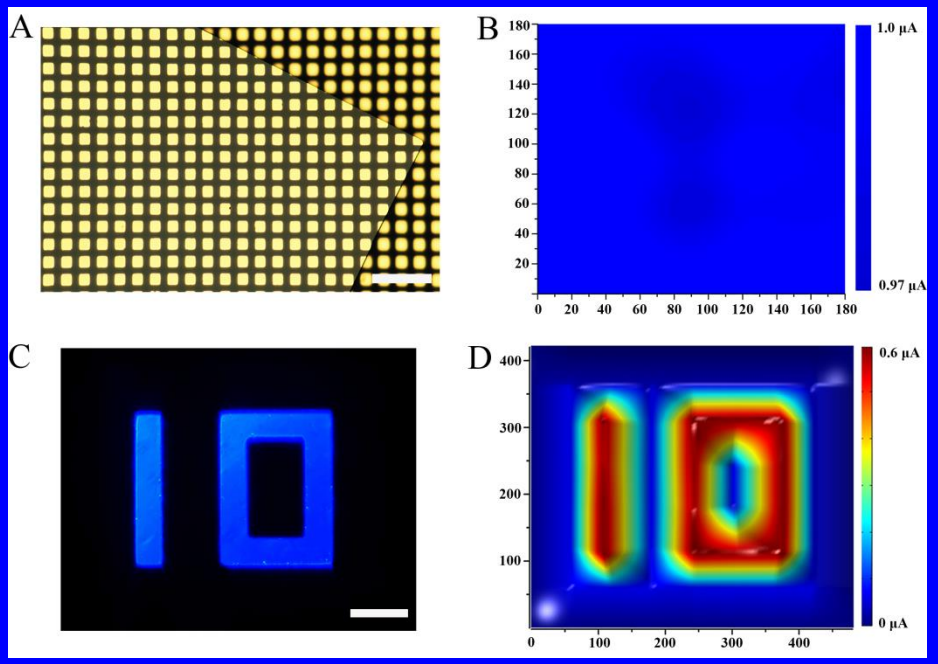


Printing perovskite single-crystal films on various kinds of substrates

***Sci. Adv.* 2018, 4, eaat2390.**

印刷钙钛矿光电探测器



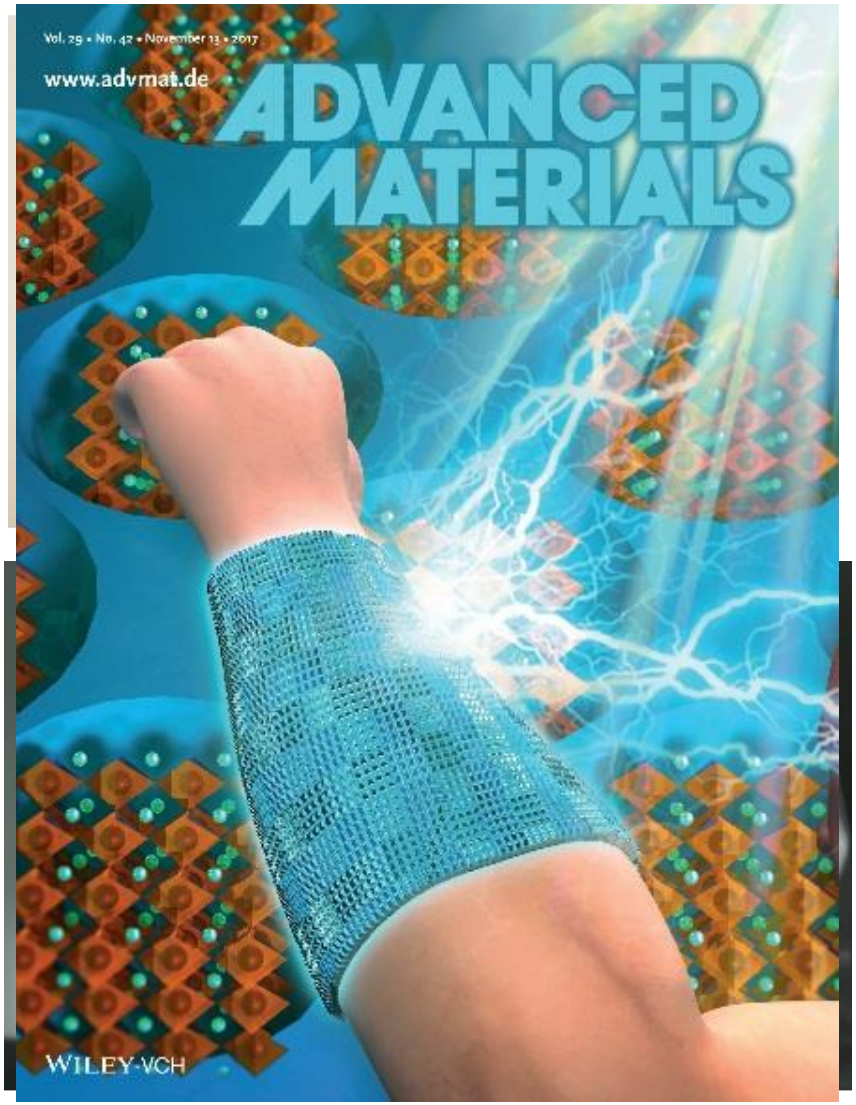


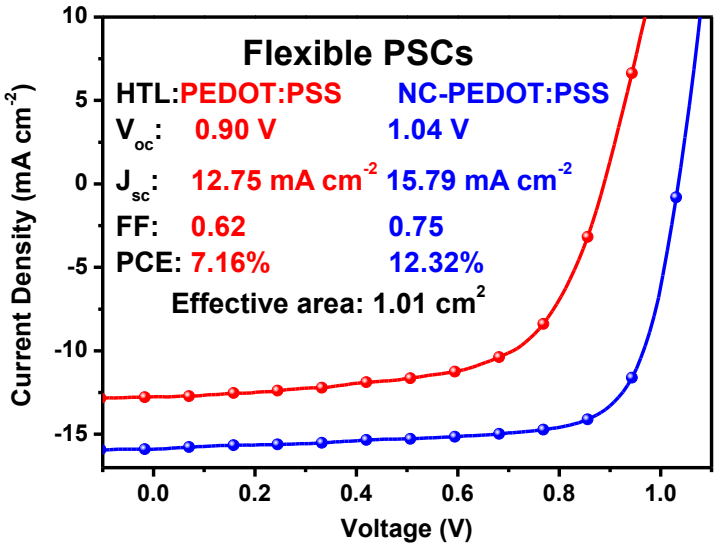
Photodetectors

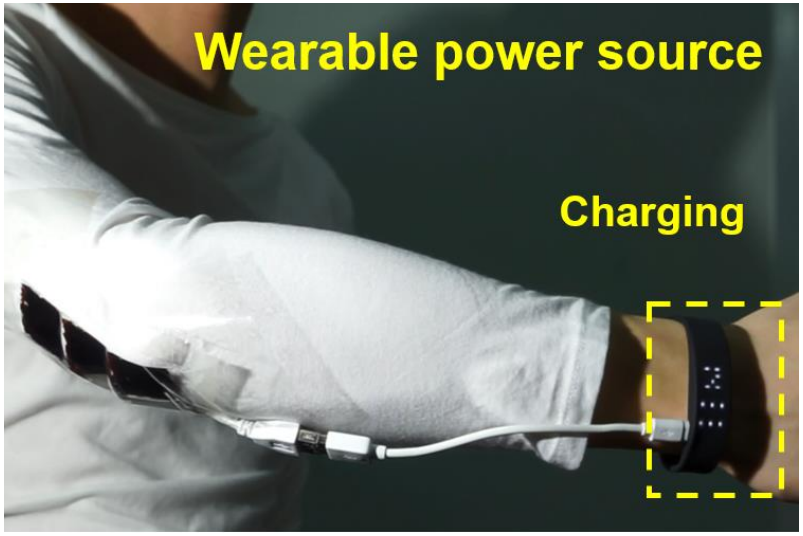
Image sensors

Sci. Adv. 2018, 4, eaat2390.

印刷可穿戴太阳能电池





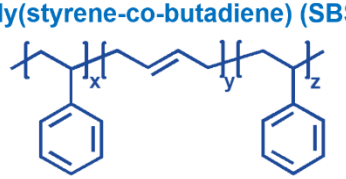


Adv. Mater. 2017, 29, 1703236.

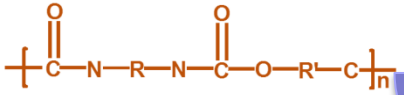
可穿戴钙钛矿太阳能电池

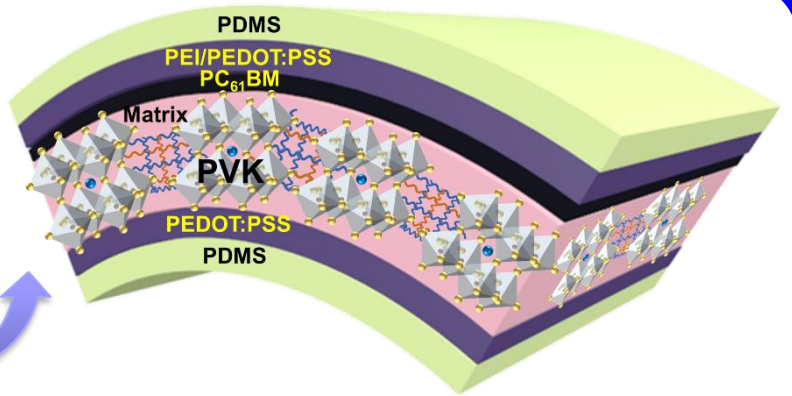
弹性砖泥结构构筑

Insoluble matrix
Poly(styrene-co-butadiene) (SBS)



Soluble matrix
Polyurethane (PU)

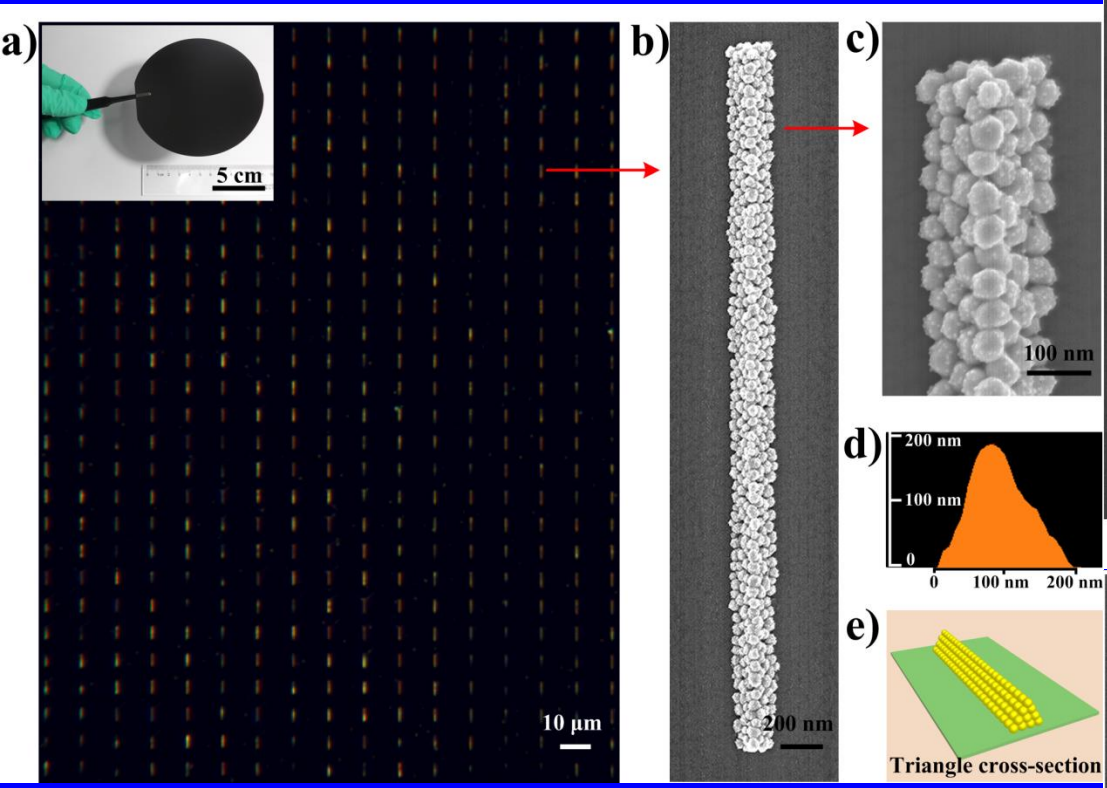


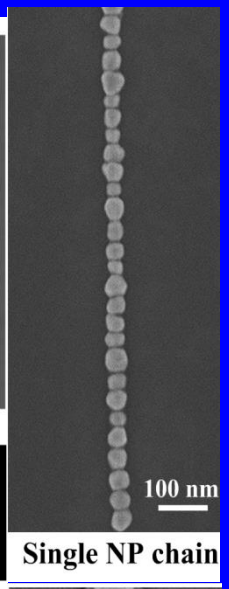


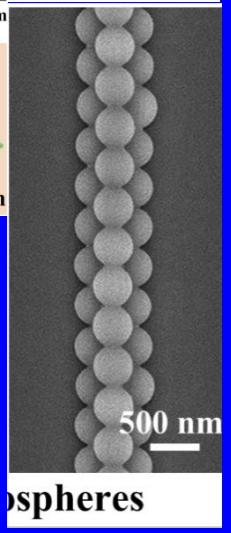
可穿戴电源

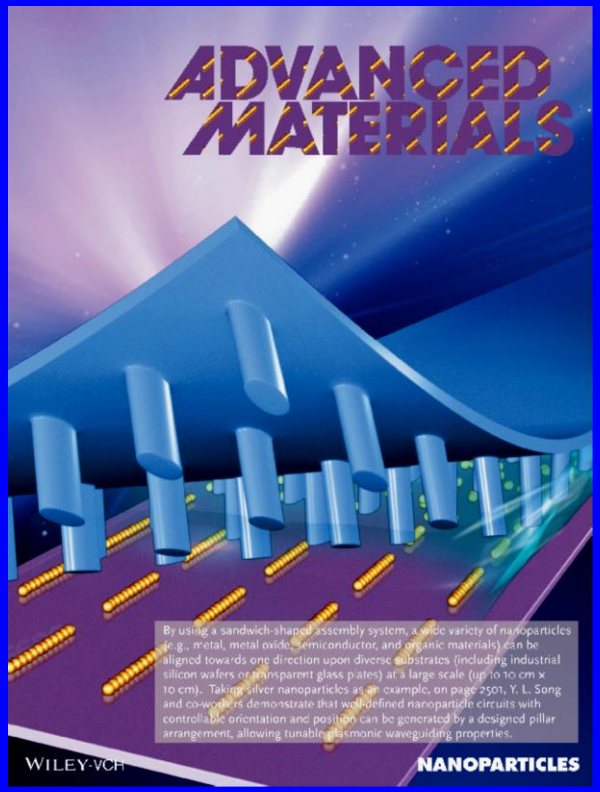
Energy Environ. Sci. 2019, 12, 979-987

印刷制造纳米精度电路





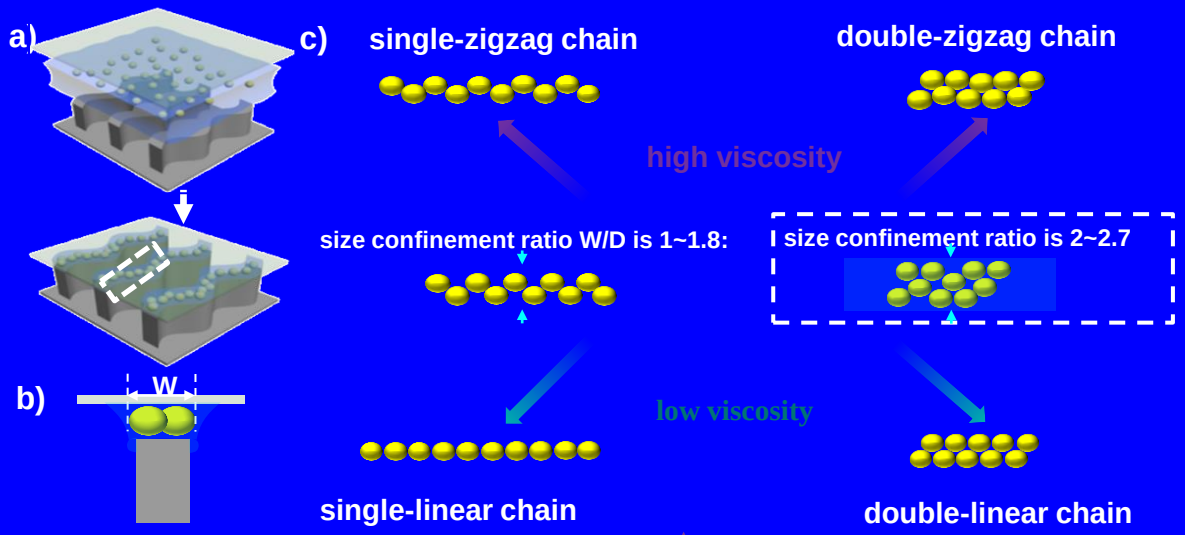


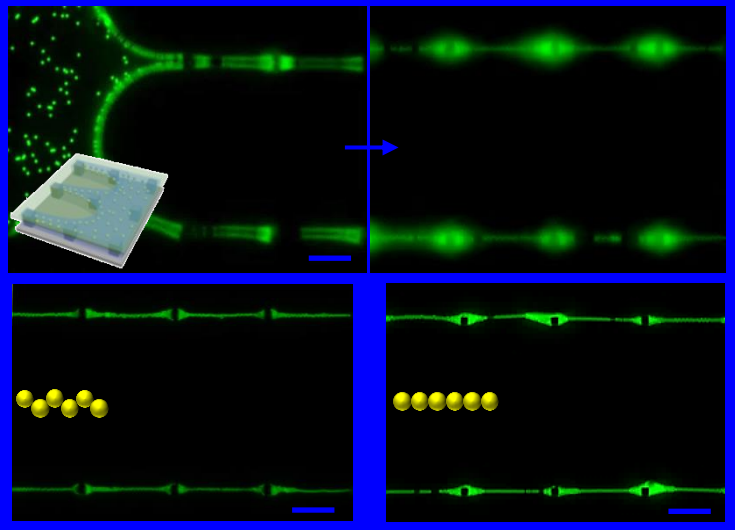


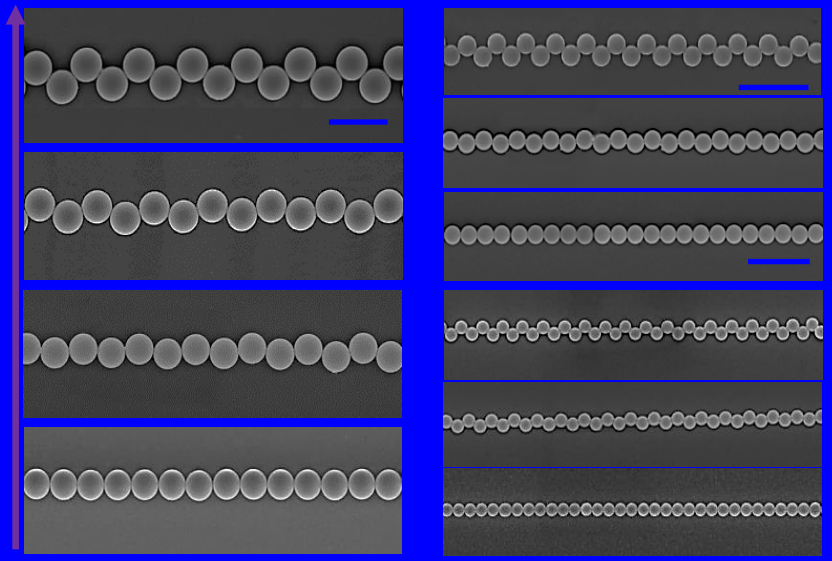
Adv. Mater. 2014, 26, 2501-2507

Small 2013, 9, 722-726

精确可控的微纳米粒子印刷组装

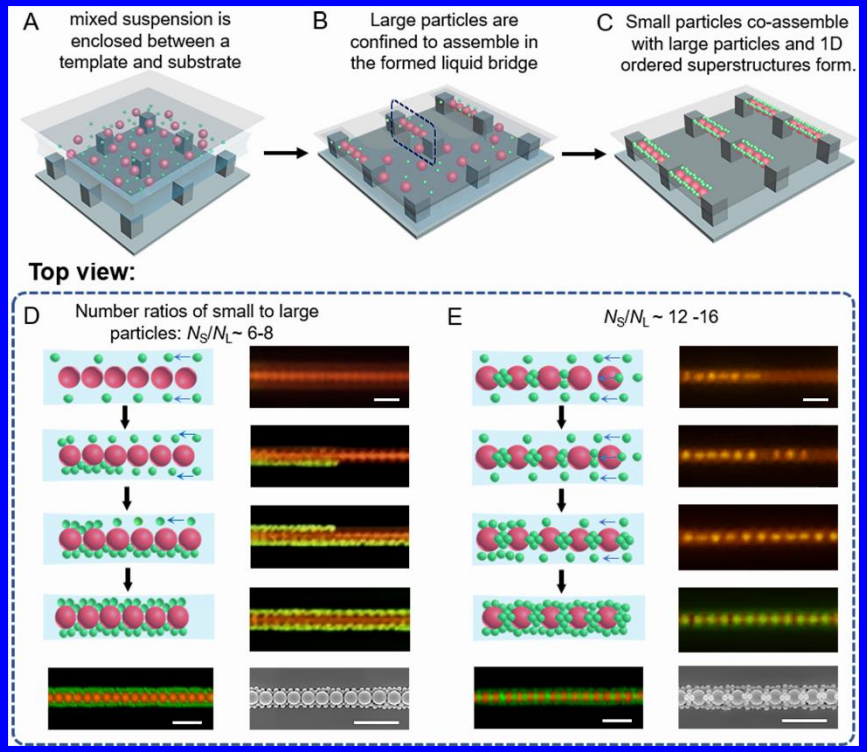


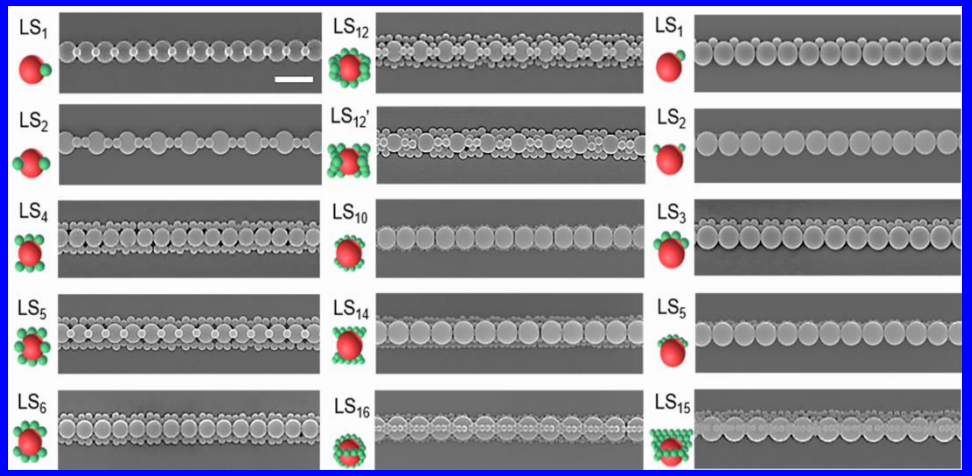


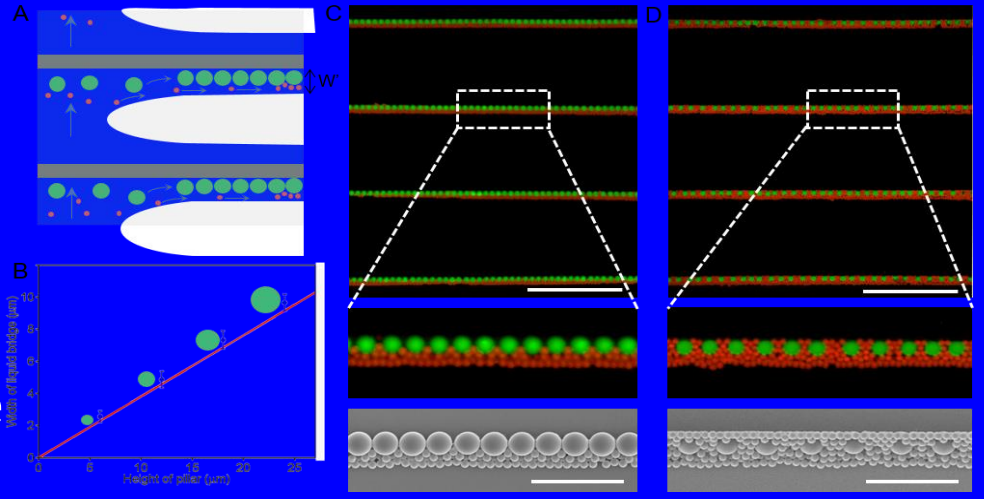


Angew. Chem. Int. Ed., 2017, 56, 15348.

精确可控的微纳米粒子印刷组装



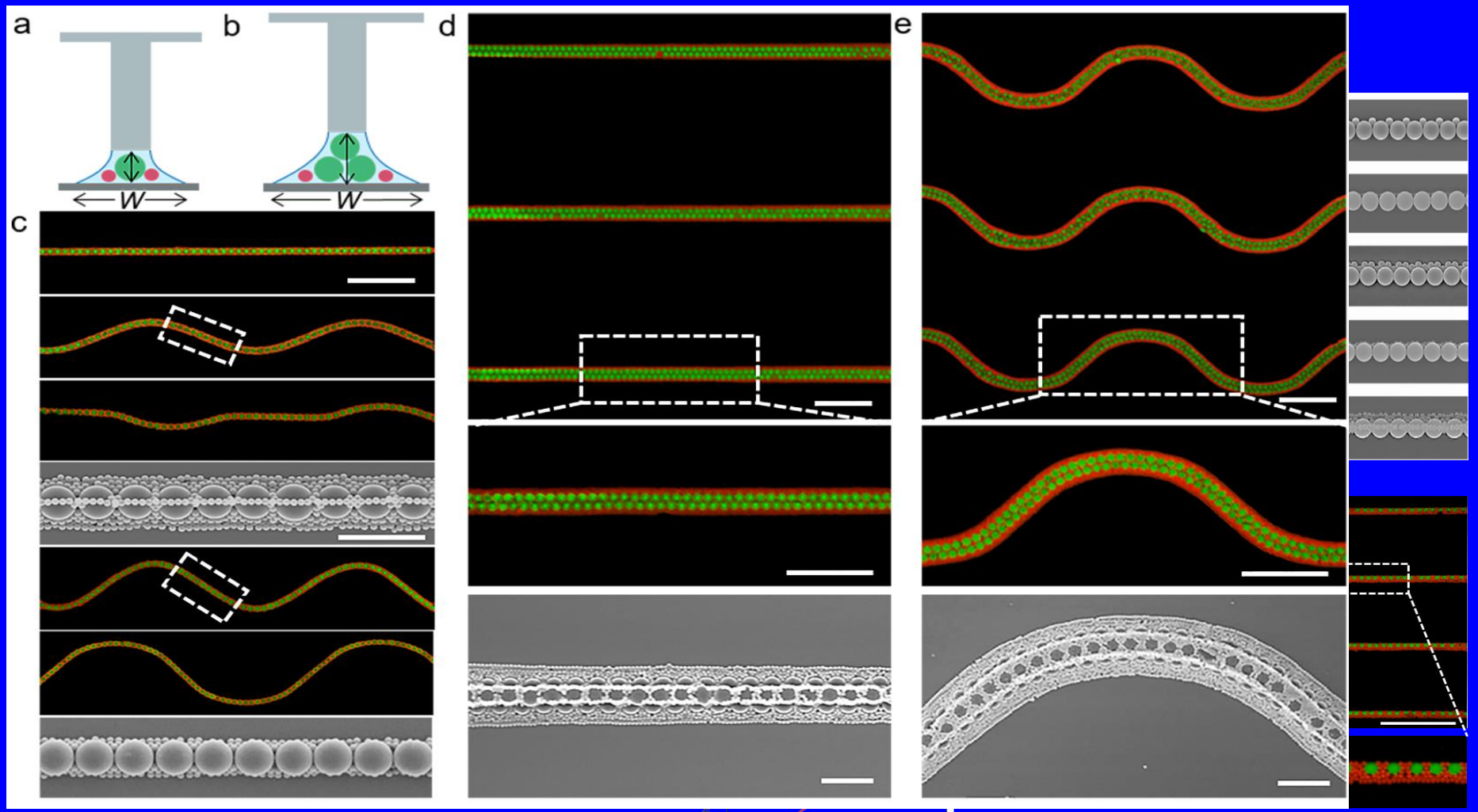




Symmetric or asymmetric 1D co-assembly by dividing the capillary confinement and quantification of the relation between width of capillary confinement (W') and H.

JACS 2017, DOI:10.1021/jacs.7b09738.

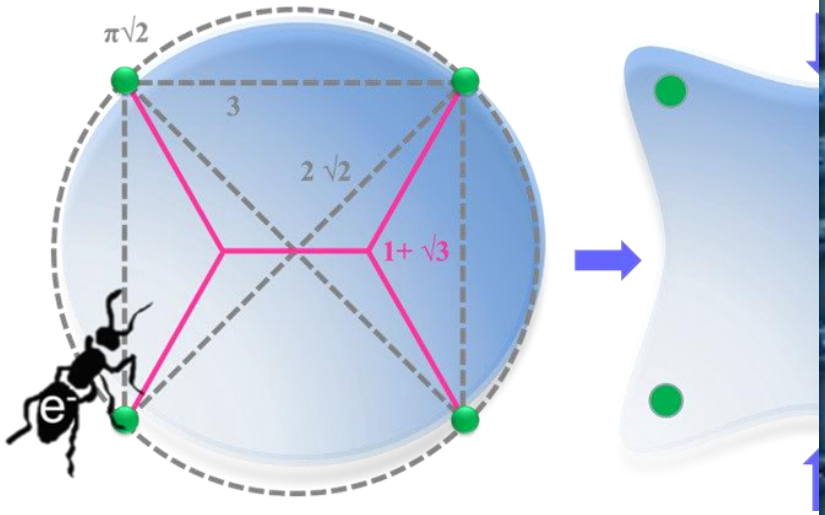
精确可控的微纳米粒子印刷组装



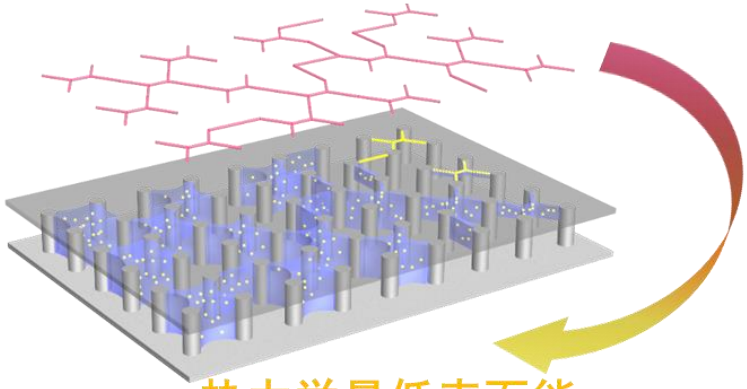
JACS 2017，DOI:10.1021/jacs.7b09738.

集成电路的串线问题：
最优微纳线路印刷制造

液滴自发收缩成型

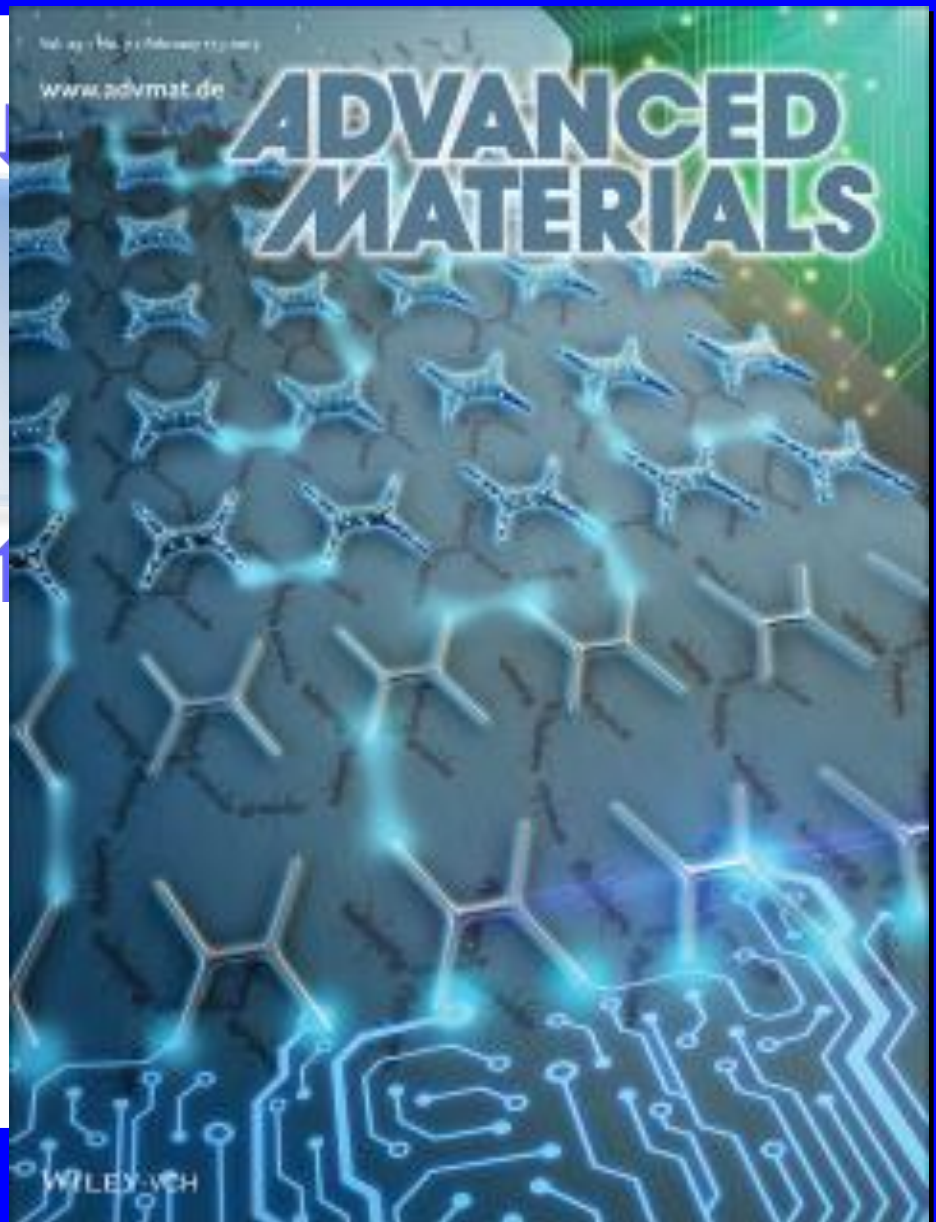


数学上最短路径

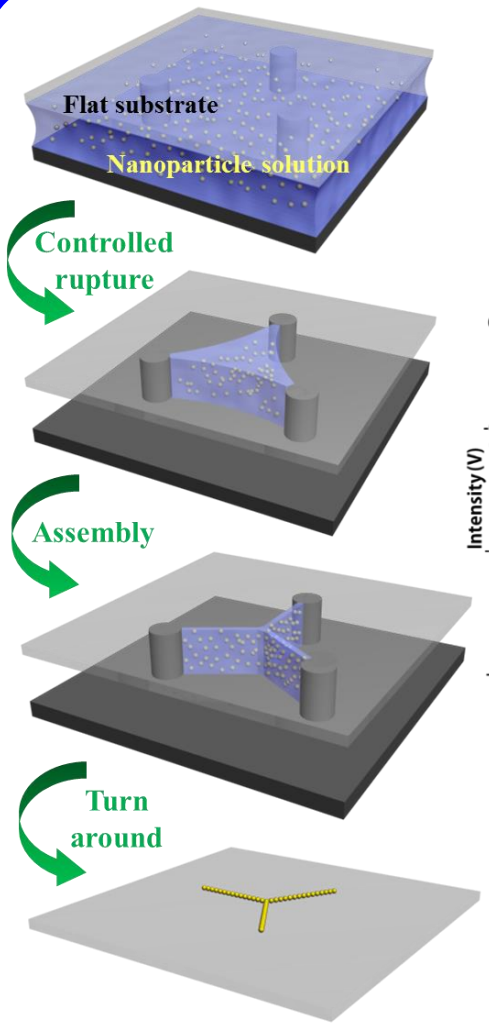


热力学最低表面能

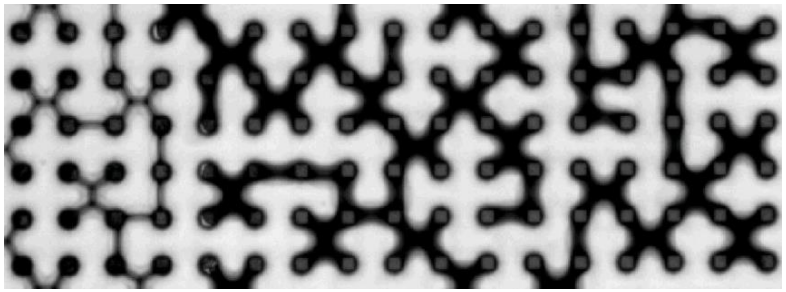
Adv. Mater. 2017, *29*, 1605223.

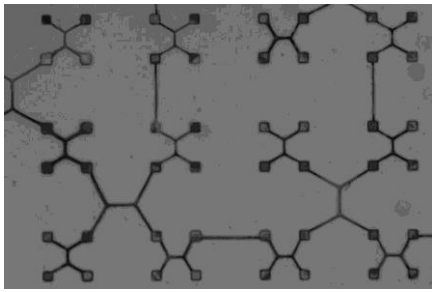


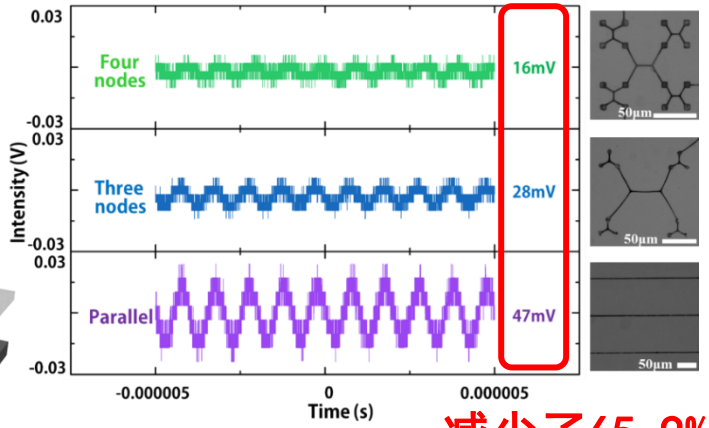
最优串线的印刷线路及性能测试

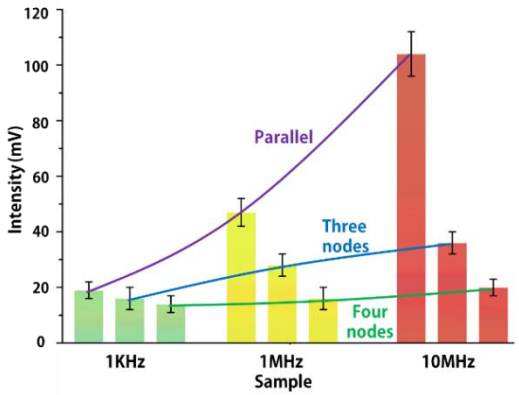


液体可控收缩









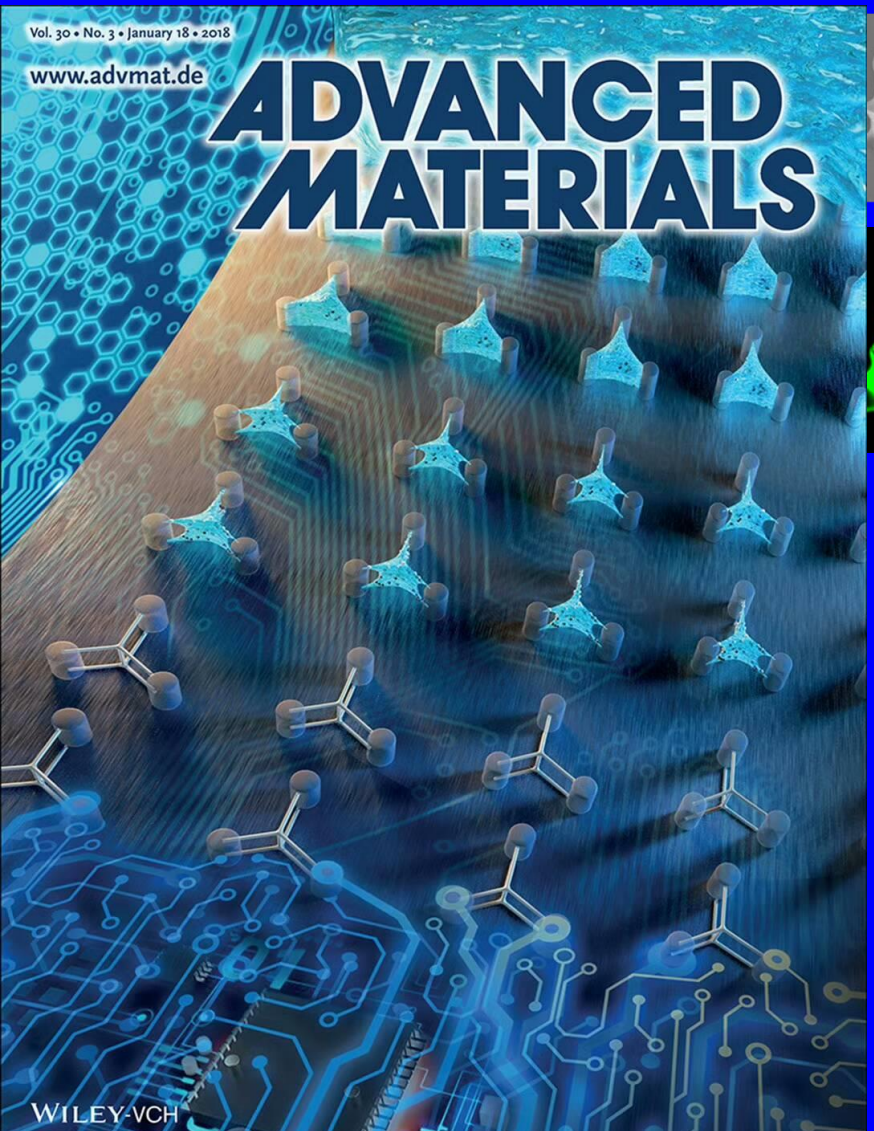
减少了65.9%的电磁干扰

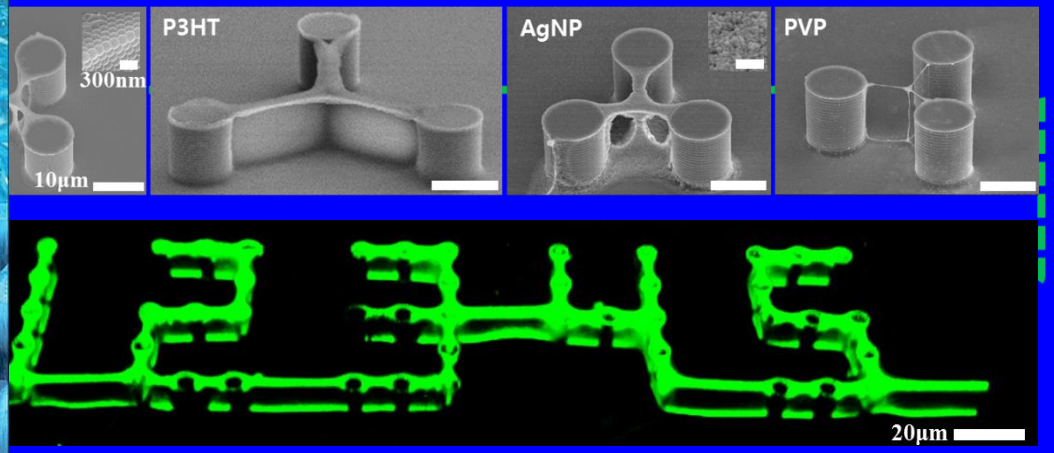
Interconnect Patten	Length (=L)	Delay ($\sim L^2$)	Energy-delay ($\sim L^3$)
The optimal interconnect	$\frac{3}{2}\cdot 2^n(2^n-1)$	$\frac{9}{4}\cdot 2^{2n}(2^n-1)^2$	$\frac{27}{8}\cdot 2^{3n}(2^n-1)^3$
The Manhattan interconnect	$\frac{1+\sqrt{3}}{2}\cdot 2^n(2^n-1)$	$\frac{(1+\sqrt{3})^2}{4}\cdot 2^{2n}(2^n-1)^2$	$\frac{(1+\sqrt{3})^3}{8}\cdot 2^{3n}(2^n-1)^3$
Decrease	**8.9%**	**17.1%**	**24.5%**

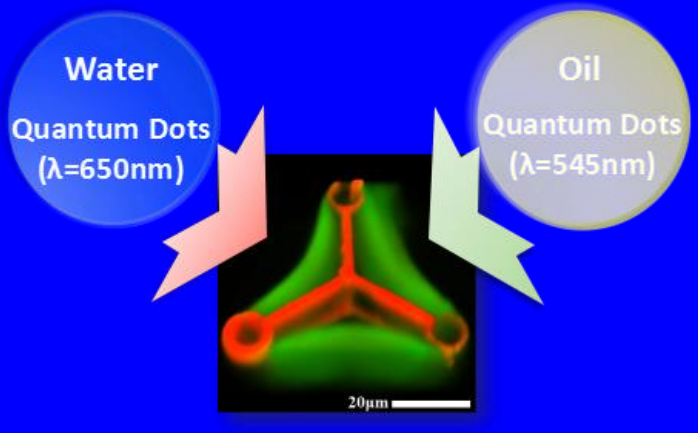
对线长、能耗（减少24.5%）和信号延迟的显著改善

Adv. Mater. 2017, *29*, 1605223.

印刷术突破：多层纳米电路的3D印刷



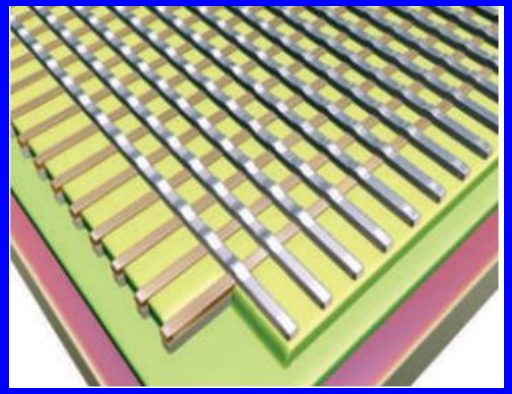




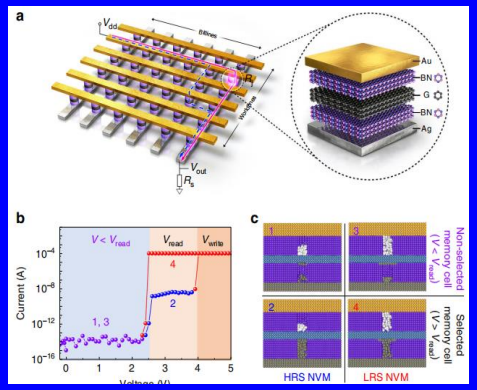
Multi-materials combination

Adv. Mater. 2018, 30, 1703963.

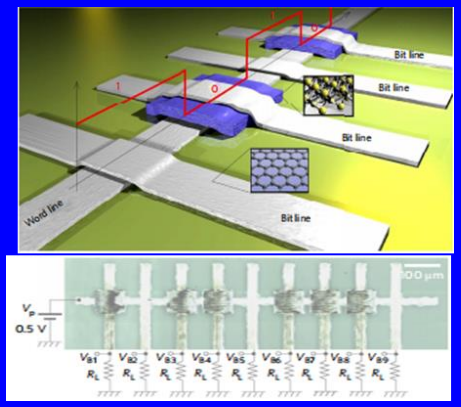
全印刷制备交叉线忆阻器阵列



Crossbar structure

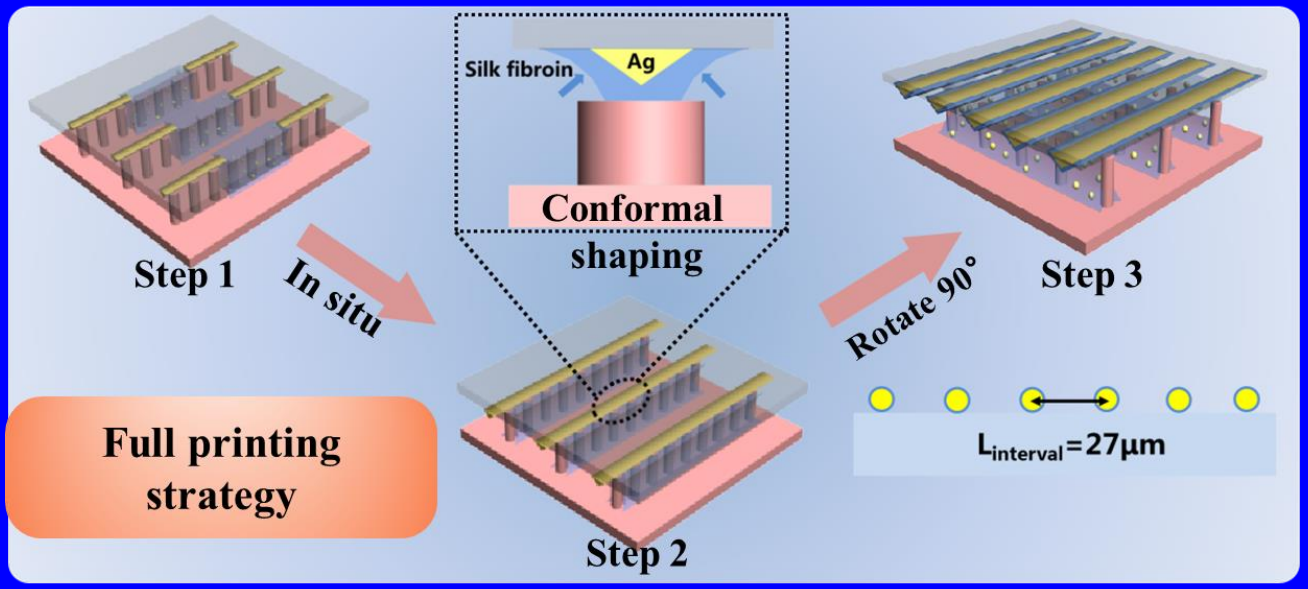


Nat. Commun. 2019, ***10,*** 3161.



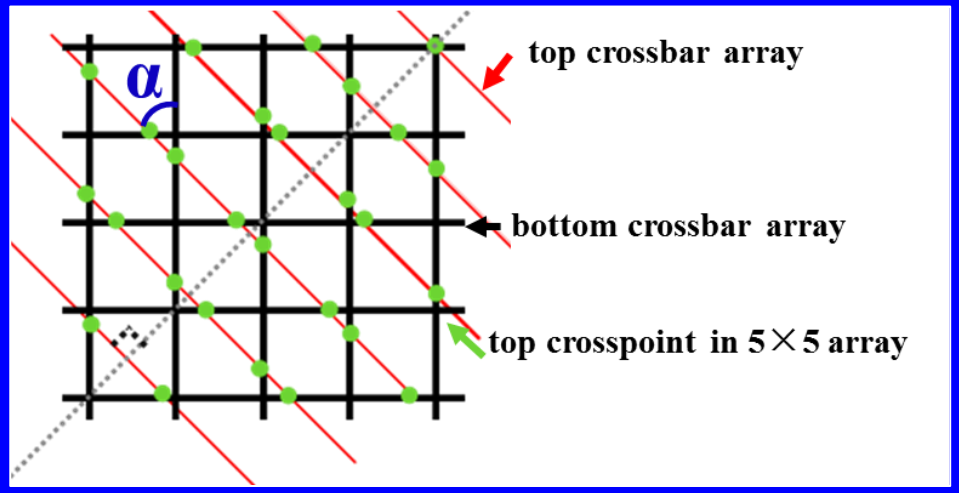
Nat. Nanotech. 2017, ***12,*** 343-350.

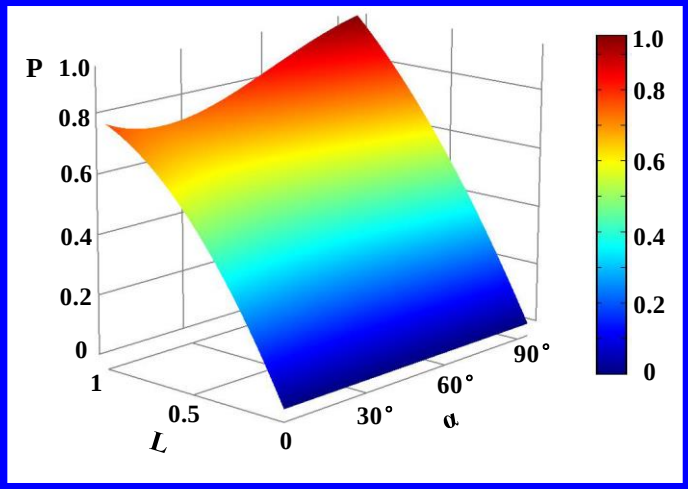
挑战：多材料器件的印刷密度和精度

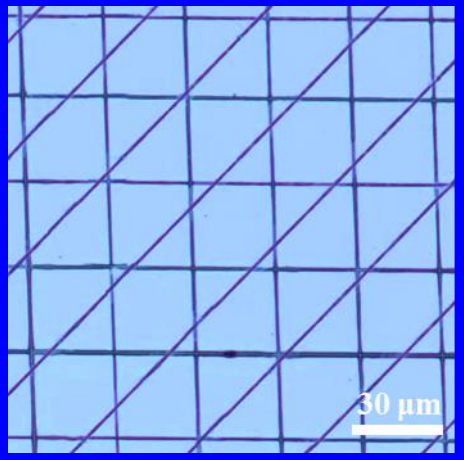


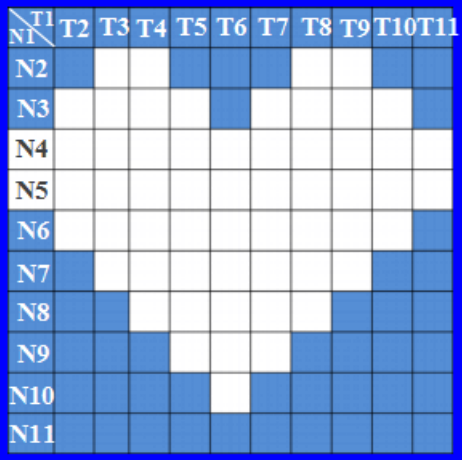
全印刷交叉线忆阻器阵列

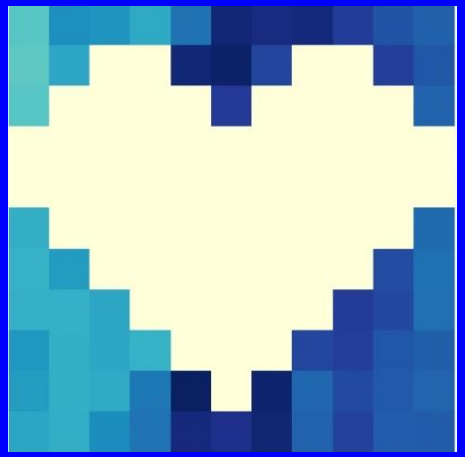
全印刷高密度忆阻器







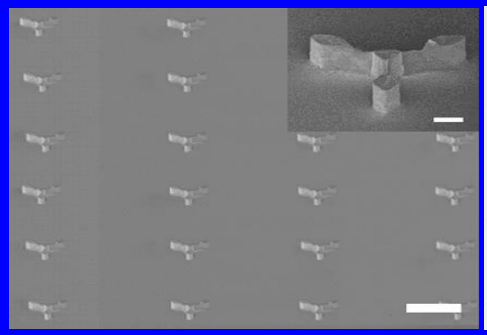


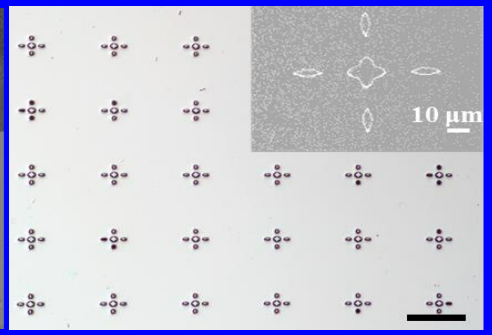


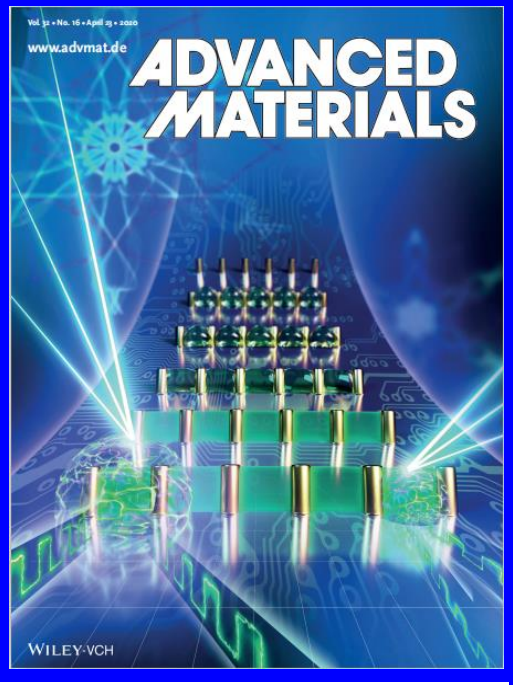
存储密度：2×10^5 bits/cm^2　　图像显示

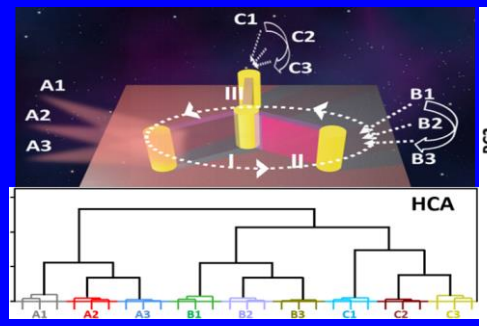
Adv. Electron. Mater. 2019, 1900131.

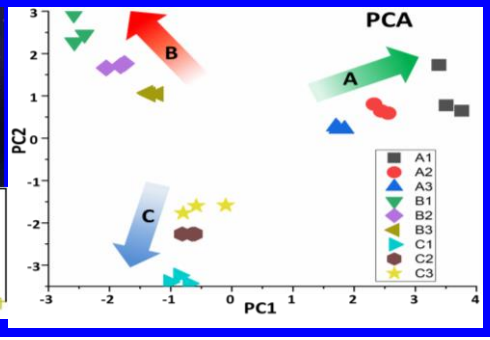
立体光探测器

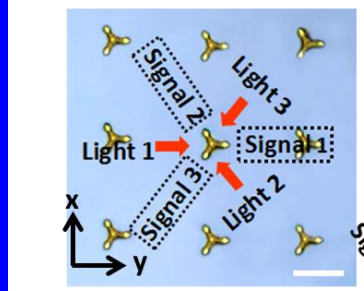


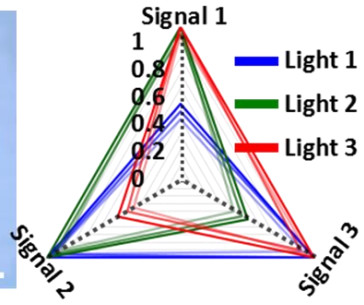


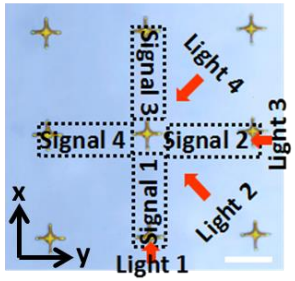


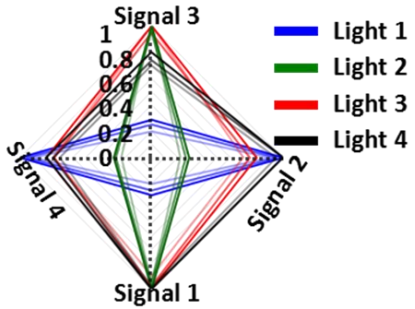










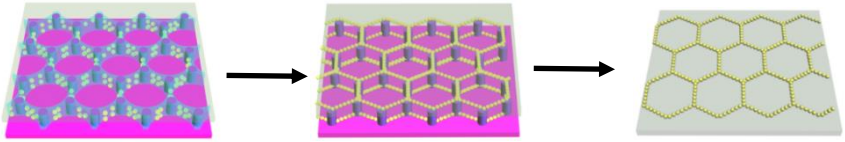


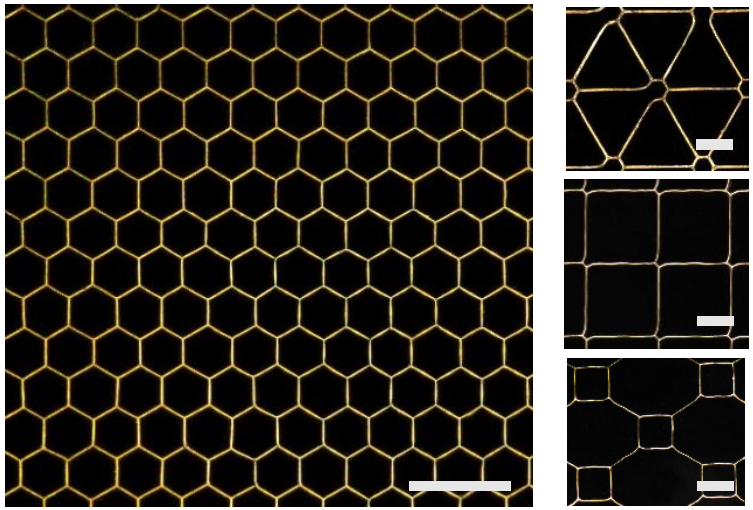
空间全向光角度的识别（自动驾驶）

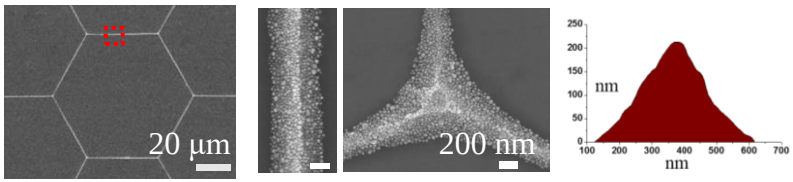
Adv. Mater. 2020, 1907280.

印刷最细的电路：以气泡为印板的纳米图案

Structure

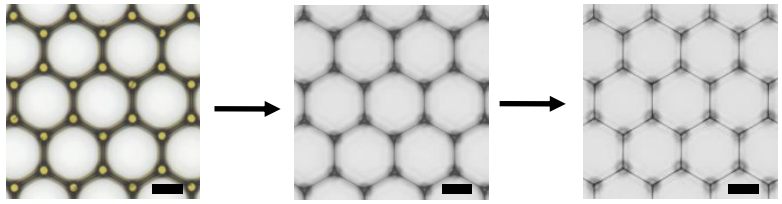






AgNP networks with different line width from 48±13 nm to 998±100 nm

Properties



奥斯瓦尔德

（Ostwald Friedrich Wilhelm，1853-1932）

1909年获诺贝尔化学奖

首次提出了反奥斯瓦尔德熟化的气泡图案化方法

以气泡为模板的印刷术

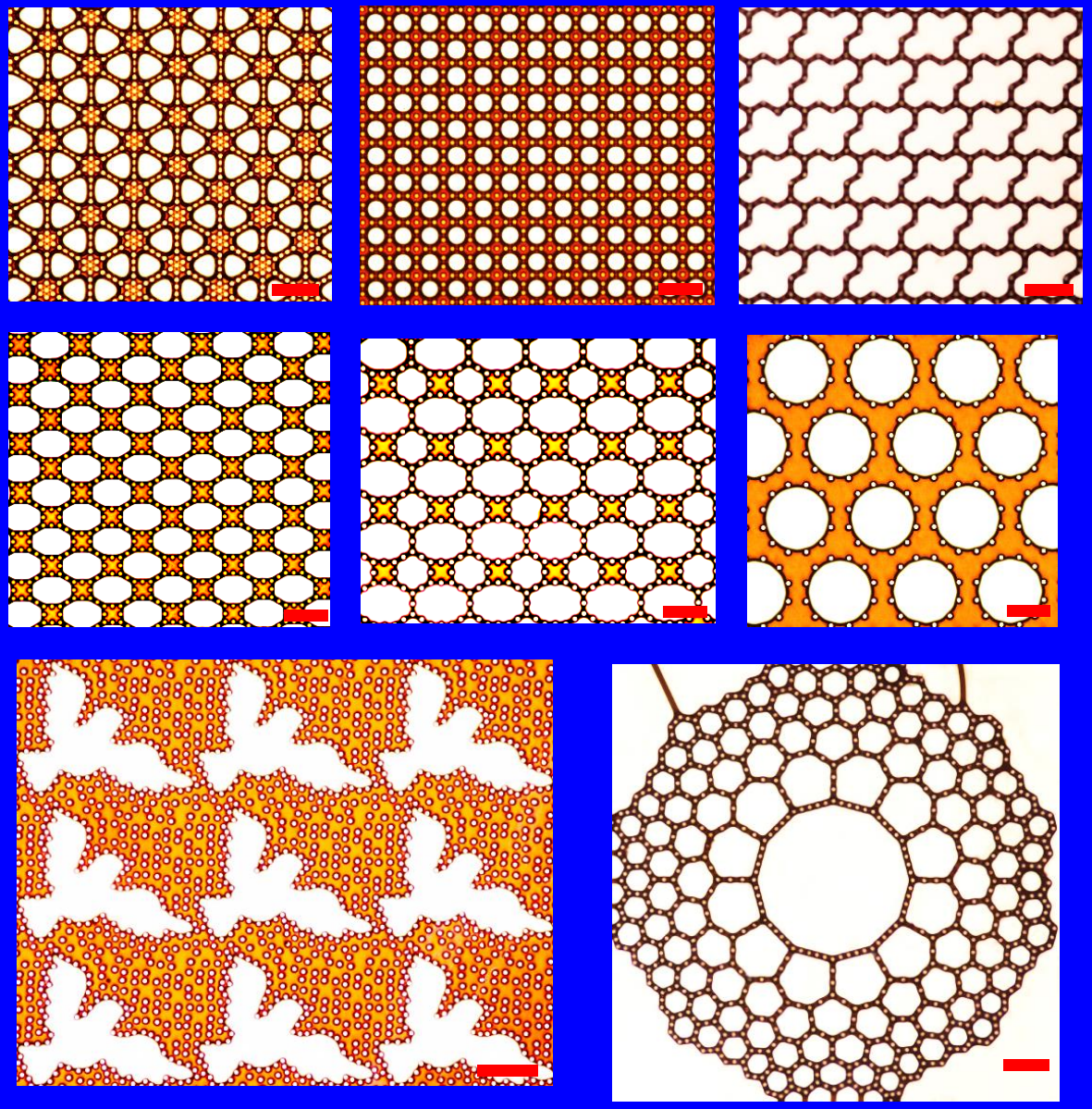
Narrow pillar interval

Special arrangement

Trapping bubbles

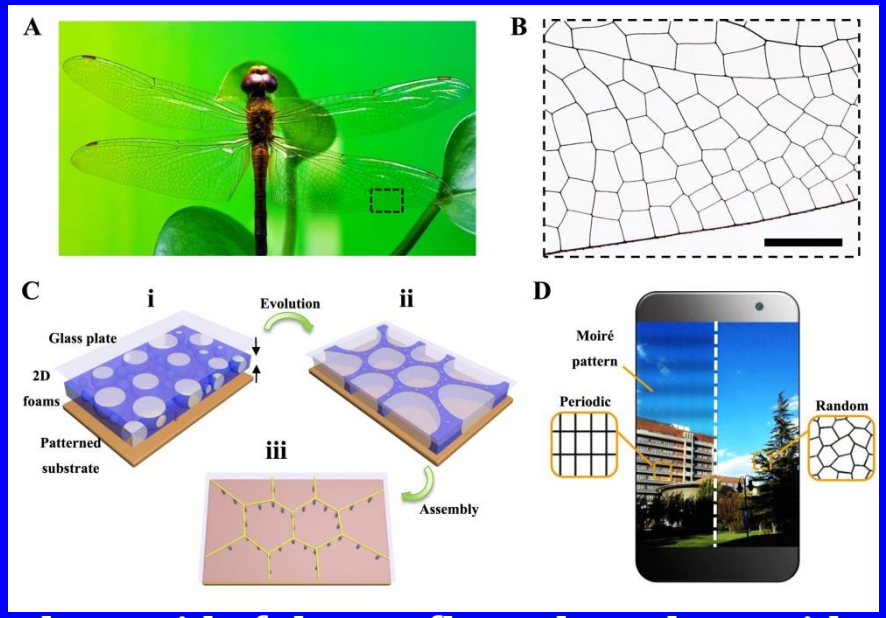
Positioning bubbles

Patterning bubbles

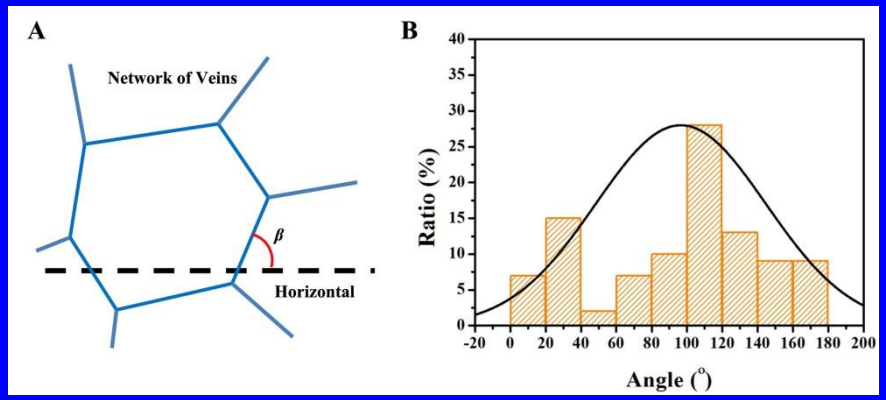


Nature Commun. 2017

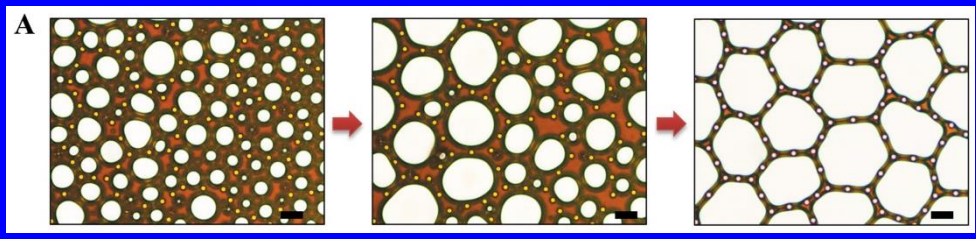
印刷无摩尔条纹的触摸屏



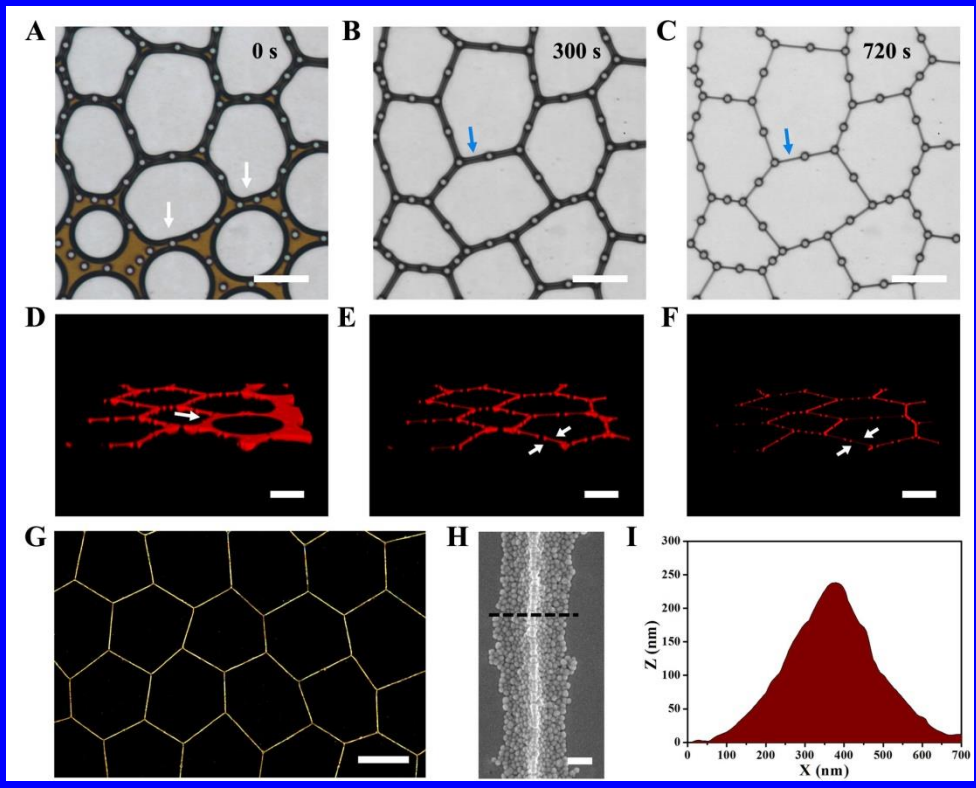
andom grid of dragonfly and random grid



Randomness of the dragonfly's grid



Patterning foams



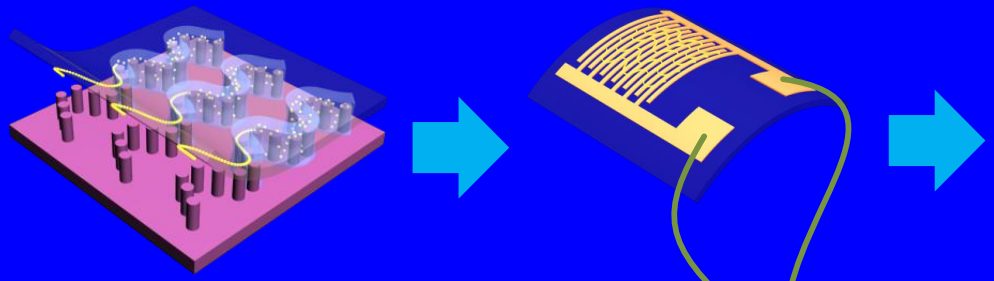
The fabrication and morphology of random grid

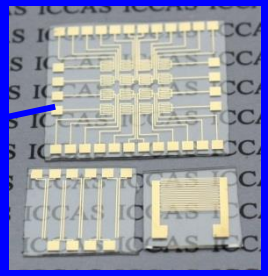
Adv. Opt. Mater. 2017,

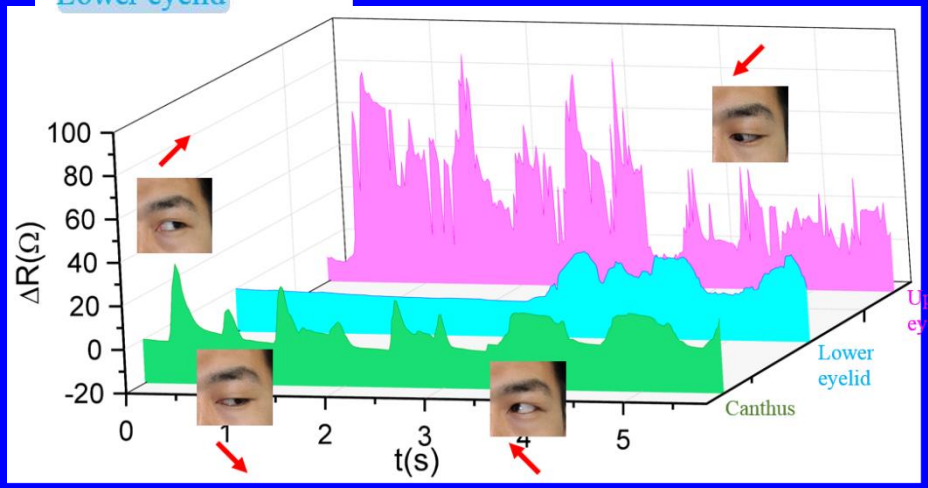
Printable Flexible Electronics for Lou Gehrig's disease or paralytic people

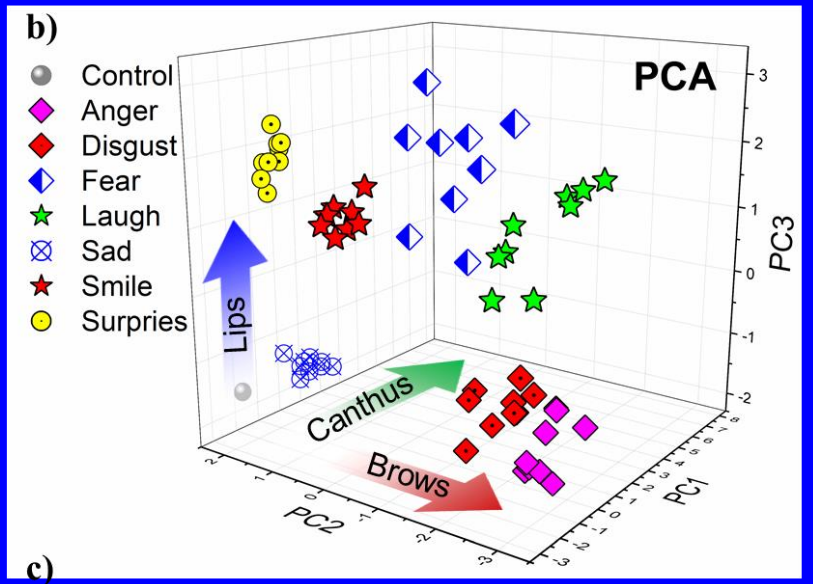
Ice bucket challenge

Printable Flexible Electronics for paralytic people

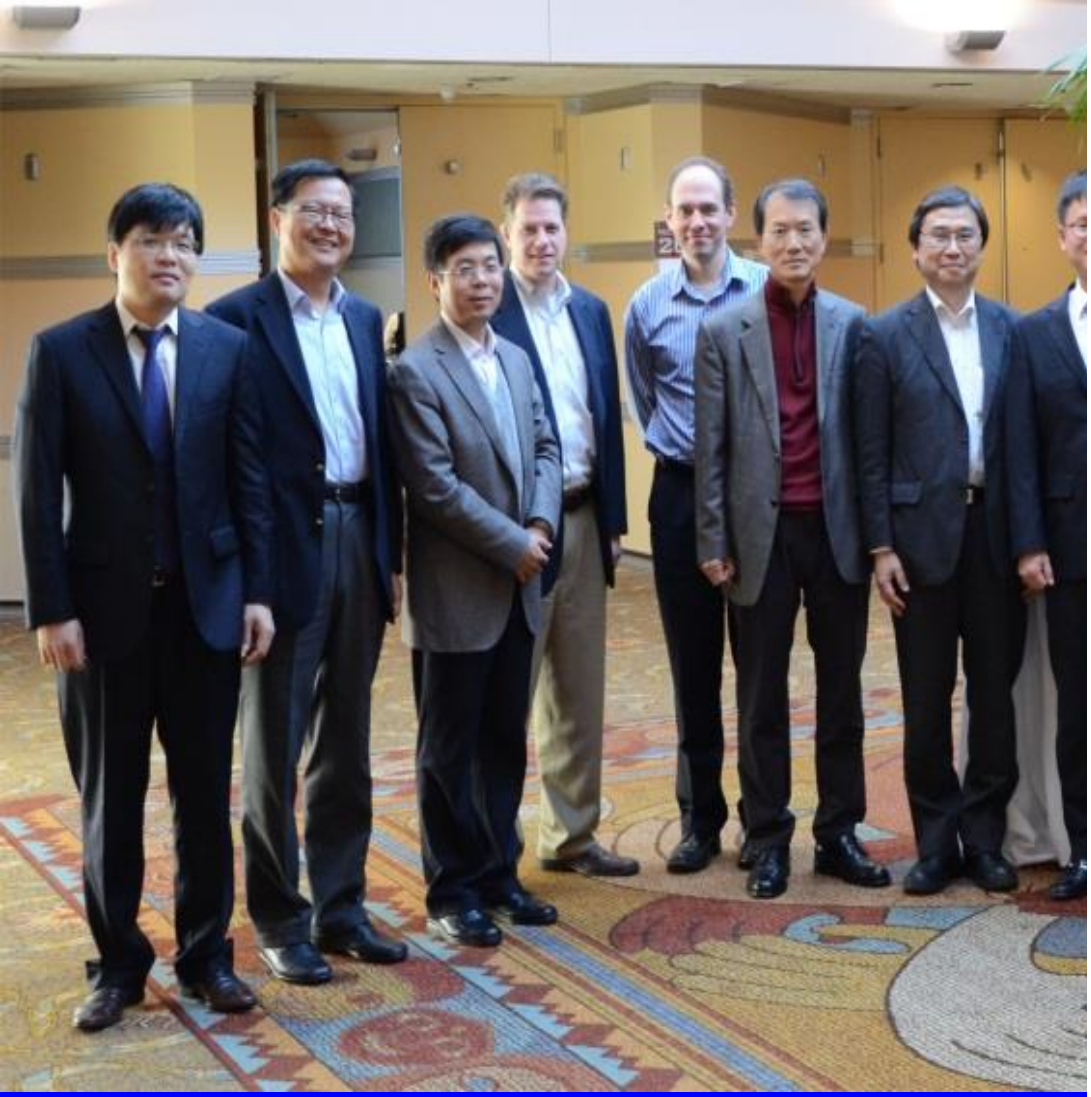








主持制定国际标准



IEC

1906 Award

The International Electrotechnical Commission
expresses its sincere appreciation of the valuable and sustainable contribution by

Yanlin Song

Expert of the IEC Technical Committee 119,
Printed electronics

Nominated by the Chair and Secretary of IEC TC 119

In recognition of his promotion of the publication of IEC 62899-402-2 of IEC TC 119 as the project leader and as expert of TC 119/WG 2, WG 3 and WG 4. This standard provides measurement methods of printed pattern edge waviness to evaluate the printability.

On behalf of the
International Electrotechnical Commission

Geneva, Switzerland, July 2019

Dr Ralph Sporer
IEC Vice-President,
Chair of the Standardization
Management Board

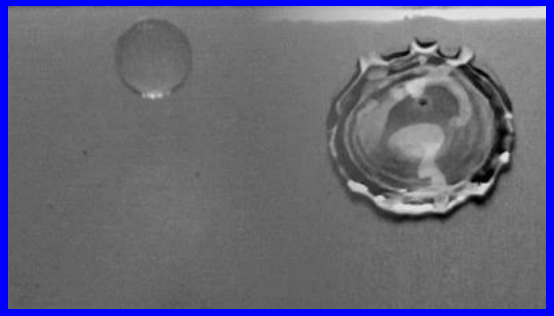
IEC 1906 AWARD

Frans Vreeswijk
IEC General Secretary and CEO

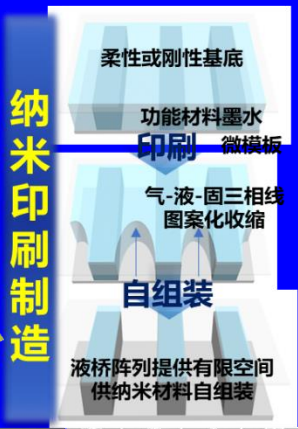
纳米绿色印刷技术发展

- 无光刻
- 无污染
- 无浪费

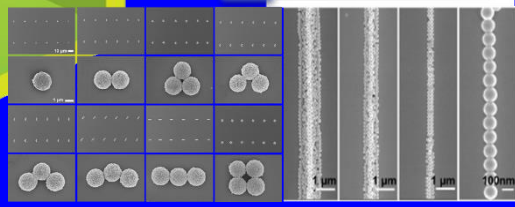
- 原理创新
- 技术突破
- 产业引领



印刷四化
绿色化 功能化
立体化 器件化

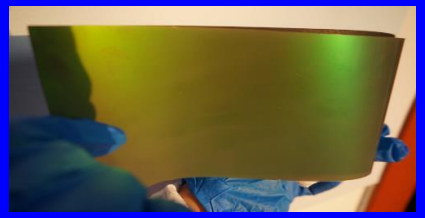


纳米印刷

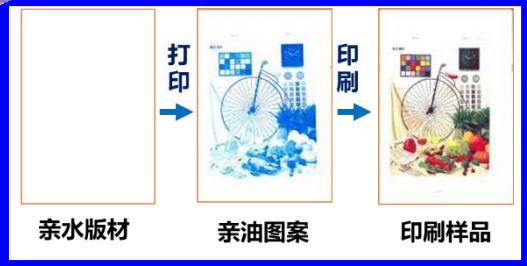


印刷光子

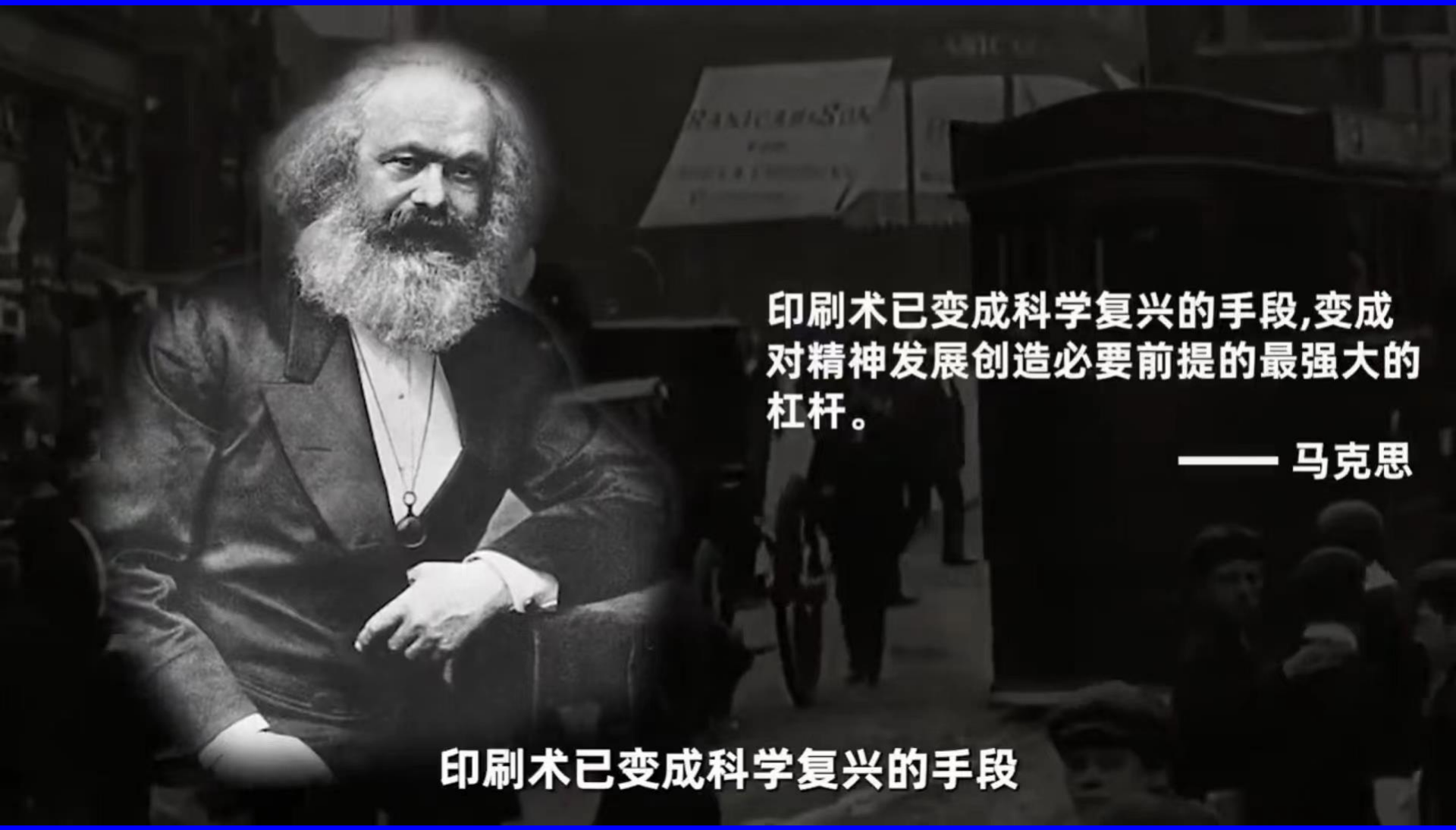
印刷电子



绿色印刷



印刷术与科技进步



致　谢