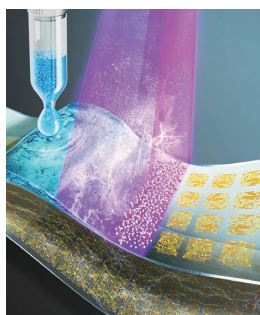


# ADVANCED FUNCTIONAL MATERIALS

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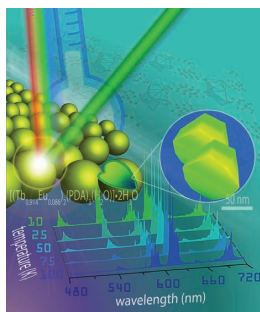
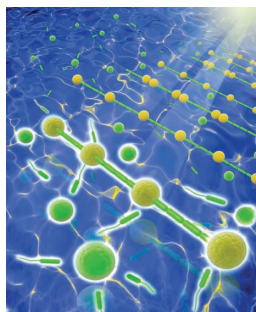


## Sol-Gel Metal Oxides

The front cover demonstrates the fabrication of sol-gel derived metal oxide electronic devices and circuits by low-temperature photochemical activation via in-situ radical-mediated reactions. On page 2807, M.-H. Yoon, S. K. Park, and colleagues show that the rapid photo-activation process enables the conversion of the sol-gel precursors into metal oxide electronic materials directly on ultra-flexible plastic substrates, which will serve as a general methodology in a rapid, scalable, and economic manner.

## Cell Patterning

Cells of different types can be patterned into periodic cell structures with controlled lengths and configurations at single-cell patterning control via direct cell-cell contact, using an optical assembly method. Light can propagate along the patterned cell structures, and the propagating signal can be detected in real-time. The patterning method demonstrated by B. Li and co-workers on page 2816 is also applicable for mammalian/human cells.

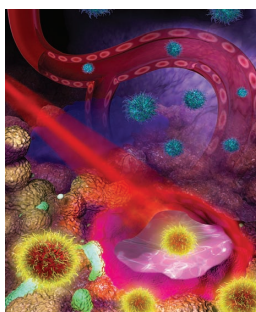


## Metal-Organic Frameworks

Nanoparticles of the first lanthanide-organic framework prepared by a spray-drying method are used by J. Rocha, L. D. Carlos, and team as luminescent thermometers operating in the 10–325 K range (emission quantum yield of 0.25). The system presented on page 2824 is the most sensitive cryogenic nanothermometer reported so far, combining high thermal sensitivity ( $5.96\% \cdot K^{-1}$  at 25 K), repeatability (99%), and low-temperature uncertainty (0.02 K at 25 K).

## Photothermal Therapy

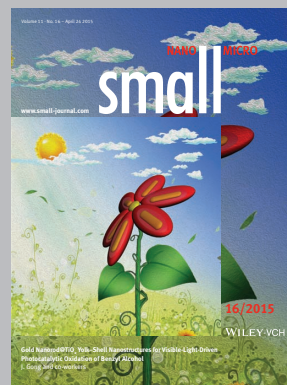
A deep tumor-penetrating photothermal nanotherapeutic is developed on page 2831 by Z. Zhang, Y. Li, and co-workers by loading a near-infrared (NIR) probe into nanoscaled polymeric carrier for simultaneous inhibition of tumor growth and metastasis. The nanotherapeutic can produce high levels of heat when exposed to NIR light. Moreover, it can penetrate into the deep interior of tumor tissues and be changed into firebombs under NIR light, surprisingly suppressing tumor growth and lung metastases of breast cancer in a single treatment.



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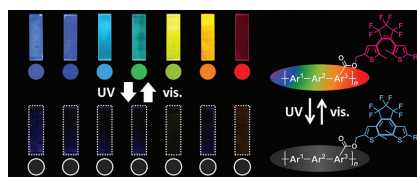
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## FULL PAPERS

A series of photoresponsive and full-colored fluorescent conjugated polymers are synthesized by combining phenylene- and thienylene-based main chains with photochromic dithienylethene side chains. In chloroform solution, nanosphere solution, and solid film, the full-colored fluorescence is reversibly switchable between emission and quenching through photoisomerization of dithienylethene side chains regardless of the fluorescent colors and the polymer chain aggregation.



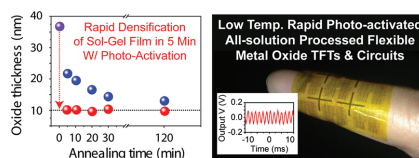
## Photoluminescence

K. Watanabe, H. Hayasaka, T. Miyashita, K. Ueda, K. Akagi\* .....2794–2806

## Dynamic Control of Full-Colored Emission and Quenching of Photoresponsive Conjugated Polymers by Photostimuli



The general physicochemical mechanisms underlying photoactivated sol-gel reactions are described, with comprehensive chemical and structural analysis inducing rapid (<5 min) fabrication of various metal oxide films at low temperatures (<150 °C), and all-solution processed high-performance electronic devices and circuitry on ultrathin polymeric substrates are demonstrated. This will open new possibilities to prepare future electronic materials in a fast, scalable, and economic manner.

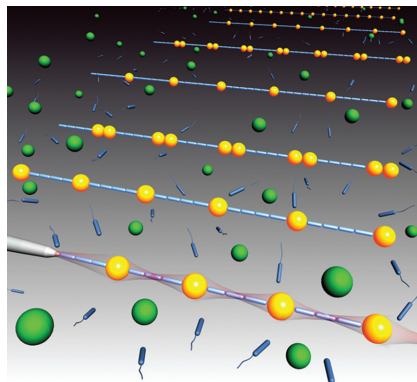


## Sol-Gel Metal Oxides

S. Park, K.-H. Kim, J.-W. Jo, S. Sung, K.-T. Kim, W.-J. Lee, J. Kim, H. J. Kim, G.-R. Yi, Y.-H. Kim, M.-H. Yoon,\* S. K. Park\* .....2807–2815

## In-Depth Studies on Rapid Photochemical Activation of Various Sol-Gel Metal Oxide Films for Flexible Transparent Electronics

Cells of different types can be patterned into periodic cell structures with controlled lengths and configurations at single-cell patterning control via direct cell-cell contact, using an optical assembly method. Light can propagate along the patterned cell structures, and the propagating signal can be detected in real-time. This patterning method is also applicable for mammalian/human cells.

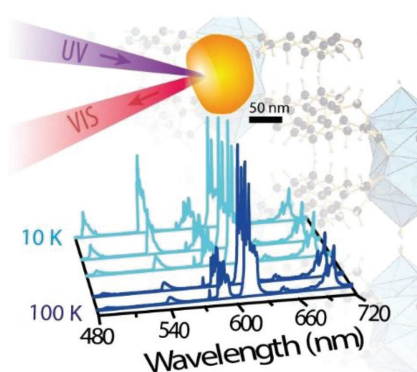


## Cell Patterning

H. Xin, Y. Li, B. Li\* .....2816–2823

## Controllable Patterning of Different Cells Via Optical Assembly of 1D Periodic Cell Structures

One of the most sensitive cryogenic thermometers (5.96% K<sup>-1</sup> at 25 K) reported so far is described, consisting of lanthanide (Tb<sup>3+</sup>, Eu<sup>3+</sup>) organic framework nanoparticles prepared by spray-drying, exhibiting an excellent reproducibility (>99%) and low-temperature uncertainty (0.02 K at 25 K).



## Metal–Organic Frameworks

Z. Wang, D. Ananias, A. Carné-Sánchez, C. D. S. Brites, I. Imaz, D. Maspoch, J. Rocha,\* L. D. Carlos\* .....2824–2830

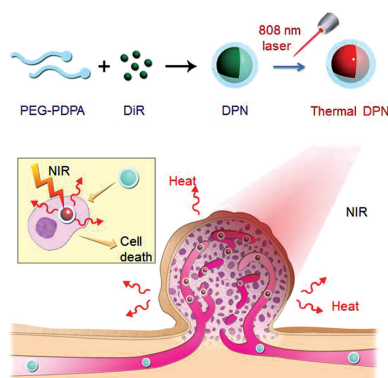
## Lanthanide–Organic Framework Nanothermometers Prepared by Spray-Drying

## FULL PAPERS

## Photothermal Therapy

X. He, X. Bao, H. Cao, Z. Zhang,\*  
Q. Yin, W. Gu, L. Chen,  
H. Yu, Y. Li\* ..... 2831–2839

**Tumor-Penetrating Nanotherapeutics Loading a Near-Infrared Probe Inhibit Growth and Metastasis of Breast Cancer**



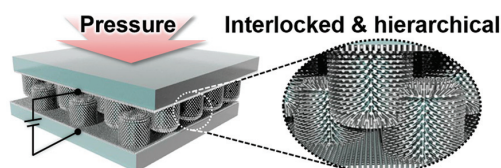
**A deep tumor-penetrating photothermal nanotherapeutics** loading a lipophilic near-infrared (NIR) probe of 1,1-dioctadecyl-3,3,3,3-tetramethylindotricarbocyanine iodide (DiR) (DiR-loaded photothermal nanotherapeutics (DPN)) is first developed, and can generate high levels of thermal energy upon NIR irradiation for efficient photothermal therapy of tumor growth and metastasis of breast cancer.

## Electronic Skin

M. Ha, S. Lim, J. Park, D.-S. Um,  
Y. Lee, H. Ko\* ..... 2841–2849

**Bioinspired Interlocked and Hierarchical Design of ZnO Nanowire Arrays for Static and Dynamic Pressure-Sensitive Electronic Skins**

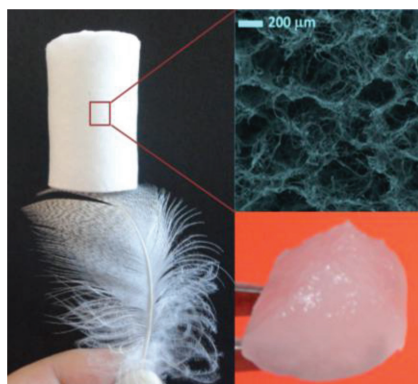
**Flexible electronic skins (e-skins)** with static and dynamic tactile sensing capabilities are demonstrated based on the interlocked geometry of hierarchical polydimethylsiloxane micropillar arrays decorated with ZnO nanowire forests. While the e-skin in a piezoresistive mode enables a static pressure detection with a high sensitivity, the piezoelectric e-skin mode permits the dynamic sensing of high frequency vibrations.



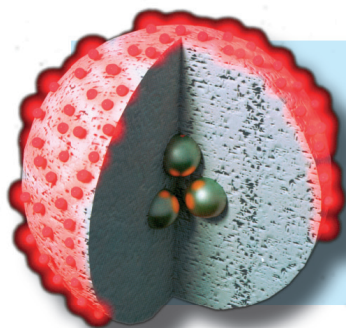
## Hierarchical Structures

G. Duan, S. Jiang, V. Jérôme,  
J. H. Wendorff, A. Fathi, J. Uhm,  
V. Altstädt, M. Herling, J. Breu,  
R. Freitag, S. Agarwal,  
A. Greiner\* ..... 2850–2856

**Ultralight, Soft Polymer Sponges by Self-Assembly of Short Electrospun Fibers in Colloidal Dispersions**



**Ultralight 3D electrospun polymer sponges** with densities below  $3 \text{ mg cm}^{-3}$  are obtained by freeze-drying of dispersions of short electrospun fibers. This sponge is soft but reversibly compressible, which accounts to a hierarchical pore structure. It is hydrophobic and shows extremely high hydrophobic liquid absorption ability because of pore filling rather than surface wetting. These polymer sponges are of interest for cell culturing.



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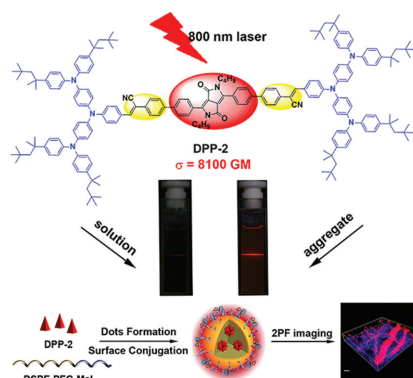
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## FULL PAPERS

### Design and synthesis of two novel red/NIR emissive DPP-based compounds

with large two-photon absorption cross-sections and aggregation-induced emission properties are reported. After being fabricated by DSPE-PEG-Mal and CPP, DPP-2-CPP nanoparticles are used for cell imaging and two-photon imaging, with clear visualization of blood vasculature inside mouse ear skin.

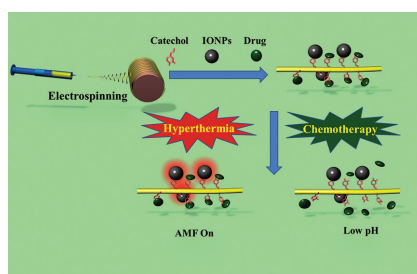


### Nanoparticles

Y. Gao, G. Feng, T. Jiang, C. Goh, L. Ng, B. Liu,\* B. Li, L. Yang, J. Hua,\* H. Tian .....2857–2866

### Biocompatible Nanoparticles Based on Diketo-Pyrrolo-Pyrrole (DPP) with Aggregation-Induced Red/NIR Emission for In Vivo Two-Photon Fluorescence Imaging

**Drug-loaded magnetic nanofibers** are designed for a synergistic anticancer treatment that combines hyperthermia treatment and chemotherapy. A mussel-inspired binding is used to incorporate iron oxide nanoparticles (IONPs) and the drug onto the nanofibers. The smart nanofibers are capable of pH-dependent drug delivery to cancer cells, and their IONPs enable multiple cycles of hyperthermia therapy with the application of an alternating magnetic field (AMF).

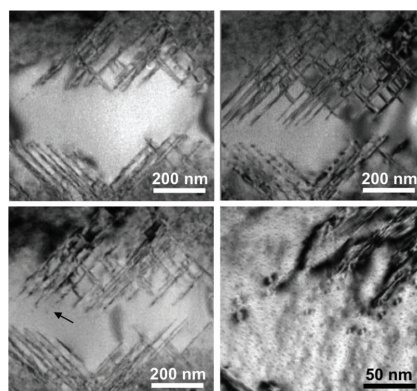


### Drug Delivery

A. GhavamiNejad, A. R. K. Sasikala, A. R. Unnithan, R. G. Thomas, Y. Y. Jeong, M. Vatankeh-Varnoosfaderani, F. J. Stadler,\* C. H. Park,\* C. S. Kim\* .....2867–2875

### Mussel-Inspired Electrospun Smart Magnetic Nanofibers for Hyperthermic Chemotherapy

**Structural changes** induced by in situ biasing of TiN/single-crystal rutile TiO<sub>2</sub>/Pt resistive switching structures are monitored by TEM. Three elementary processes essential for resistive switching are documented: i) creation of oxygen vacancies by electrochemical reactions at low temperatures, ii) their drift in the electric field, and iii) their coalescence into (and dissociation from) planar faults.

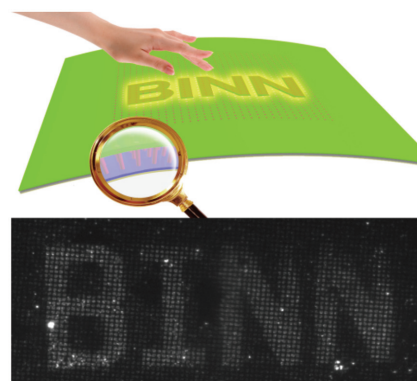


### Resistive Switching

J. Kwon, A. A. Sharma, J. A. Bain, Y. N. Picard, M. Skowronski\*...2876–2883

### Oxygen Vacancy Creation, Drift, and Aggregation in TiO<sub>2</sub>-Based Resistive Switches at Low Temperature and Voltage

The piezo-phototronic effect is applied to prepare a flexible LED array composed of PEDOT:PSS and patterned ZnO NWs for mapping of spatial pressure distributions. The spatial resolution achieved is as high as 7 μm by fabricating ZnO nanowires on flexible substrates. By controlling the growth conditions of the ZnO nanowire array, a wide range of pressure measurements from 40 to 100 MPa are derived under different ZnO morphologies.



### Tactile Sensing

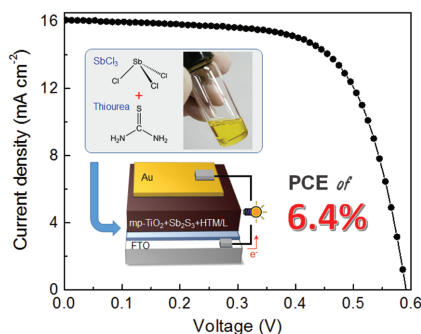
R. Bao, C. Wang, L. Dong,\* R. Yu, K. Zhao, Z. L. Wang,\* C. F. Pan\* .....2884–2891

### Flexible and Controllable Piezo-Phototronic Pressure Mapping Sensor Matrix by ZnO NW/p-Polymer LED Array

## FULL PAPERS

## Solar Cells

Y. C. Choi, S. I. Seok\* ..... 2892–2898

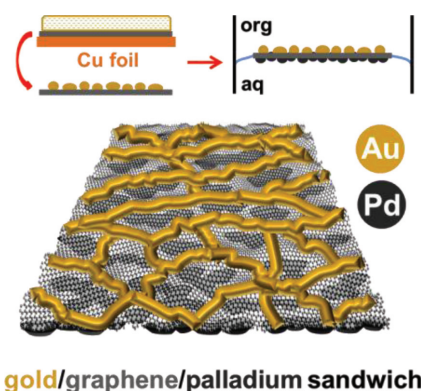
Efficient  $\text{Sb}_2\text{S}_3$ -Sensitized Solar Cells Via Single-Step Deposition of  $\text{Sb}_2\text{S}_3$  Using S/Sb-Ratio-Controlled  $\text{SbCl}_3$ -Thiourea Complex Solution

A single-step solution approach based on  $\text{SbCl}_3$ -thiourea complex solution processing is introduced for high-efficiency  $\text{Sb}_2\text{S}_3$ -sensitized solar cells. The  $\text{Sb}_2\text{S}_3$  is easily deposited on substrates using S/Sb-ratio-controlled  $\text{SbCl}_3$ -thiourea complex solution. The champion device exhibits an overall power conversion efficiency of 6.4% under standard 1.5G conditions.

## Graphene Functionalization

P. S. Toth,\* M. Velický, Q. M. Ramasse, D. M. Kepaptsoglou, R. A. W. Dryfe\* ..... 2899–2909

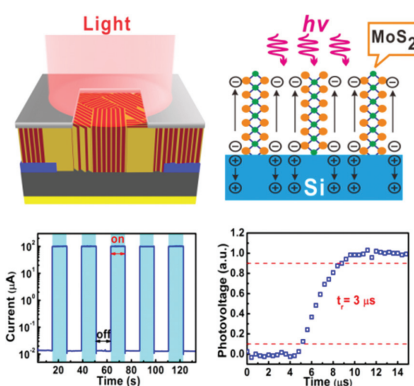
## Symmetric and Asymmetric Decoration of Graphene: Bimetal-Graphene Sandwiches



Graphene is asymmetrically functionalized with different metal nanoparticles. Such dual-decorated graphene-based metal nanoclusters are studied using various microscopic techniques and several spectroscopic methods to prove the double-side decorated monolayer graphene. The preparation of sandwich structures of graphene with two different species opens the way for further asymmetric decoration processes at the polarizable liquid/liquid interface.

## Optoelectronics

L. Wang, J. S. Jie,\* Z. B. Shao, Q. Zhang, X. H. Zhang,\* Y. M. Wang, Z. Sun, S.-T. Lee\* ..... 2910–2919

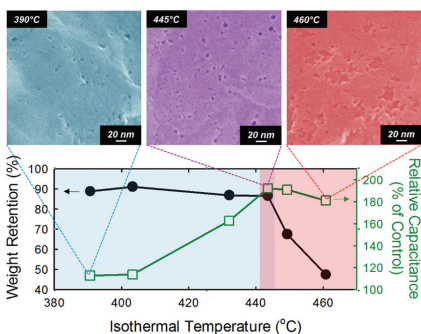
 $\text{MoS}_2$ /Si Heterojunction with Vertically Standing Layered Structure for Ultrafast, High-Detectivity, Self-Driven Visible–Near Infrared Photodetectors

A new type of visible–near infrared self-driven photodetector is developed by sputtering a layer of n-type  $\text{MoS}_2$  film with a vertically standing layered structure on p-type silicon. With the advantages of easy fabrication, wide response spectrum, extremely high detectivity ( $\approx 10^{13}$  Jones), ultrafast response speed ( $\approx 3 \mu\text{s}$ ), and good durability, this heterojunction photodetector shows great potential for optoelectronic applications.

## Graphene

Y. Lin,\* X. Han, C. J. Campbell, J.-W. Kim, B. Zhao, W. Luo, J. Dai, L. Hu,\* J. W. Connell ..... 2920–2927

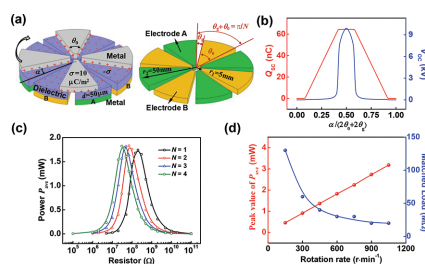
## Holey Graphene Nanomanufacturing: Structure, Composition, and Electrochemical Properties



Holey 2D materials such as holey graphene are a novel class of nanomaterials with enhanced through-plane transport enabled by holes with retained 2D-related properties. By controlling the synthesis parameters of holey graphene, optimal electrochemical capacitive properties are achieved upon hole formation and modification, which dictates the fine balance of oxidative doping, mesopore formation, and graphitic carbon gasification.

## FULL PAPER

A theoretical model for rotary freestanding triboelectric nanogenerators with a grating structure is constructed. The fundamental physics of triboelectric nanogenerators is revealed by using the finite element method, and the dynamic output characteristics are theoretically calculated through the analytical solving of governing equation.



## Triboelectric Nanogenerators

T. Jiang, X. Chen, C. B. Han, W. Tang,  
Z. L. Wang\* .....2928–2938

## Theoretical Study of Rotary Freestanding Triboelectric Nanogenerators

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