Engineered Science

EDITORIAL

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Introducing *Engineered Science*

Hongbo Gu,[1] Dapeng Cao,[2] Jie Kong,[3] Junwei Gu,[3] Qinglong Jiang,[4] Ying Li,[5] Bin Wang,[6] Xingru Yan,[7] Yuan Chen,[8] Jong Eun Ryu,[9] Matthew Hu,[10] Yajun Yan,[11] Zhanhu Guo,[7] Brian J. Edwards[12] and David P. Young[13]

Human beings have struggled for thousands of years to understand the natural world. Throughout history, *Science*, the body of accumulated knowledge for testable explanations and predictions with regard to the physical and natural world, has driven the development and progress of human society. Science covers many multidisciplinary fields such as including physics, chemistry, biology, astronomy, geology, oceanography, ecology, meteorology, and many more, as shown in Figure 1. Mankind applies such broad branches of knowledge to advance human development and explore the unknown world. Science guides people in exploring the very large, such as the stars and the universe, in understanding the very small, such as subatomic particles and molecules, and in improving the human condition with advances in medicine and materials science.

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From the bow drill for making fire to the rocket for launching satellites, *engineering* is the creative application of science in an effort to design structures, materials, devices, and systems. For instance, genetic engineering applies the techniques of biotechnology to manipulate an organism's genes, resulting in improved or novel traits.[1,2] Chemical engineering can synthesize specialty and commodity chemicals, refined petroleum, and renewable fuels by utilizing physics, chemistry, biology, and engineering principles.

As another example, engineering can serve as a tool to facilitate the applications of science in the areas of bio detectors,[3,4] artificial muscles,[5,6] and sensors.[7,8] Electrochromic glass is based on the chemical science arising from the reversible optical color change induced by reduction or oxidation[9] after the application of an appropriate electric potential on the material.[10,11] This can be applied in variable-transmittance windows for energy-efficient architectures, smart displays,[12] energy storage devices,[13] and variable-reflectance mirrors.[14] Based on this scientific understanding, people have employed engineering approaches to study the relationship among color changes, the electric potential, and the structure variation of the materials. Take the conjugated polymer polyaniline (PANI), as an example. Normally, PANI has three different oxidation states termed as "leucoemeraldine base"

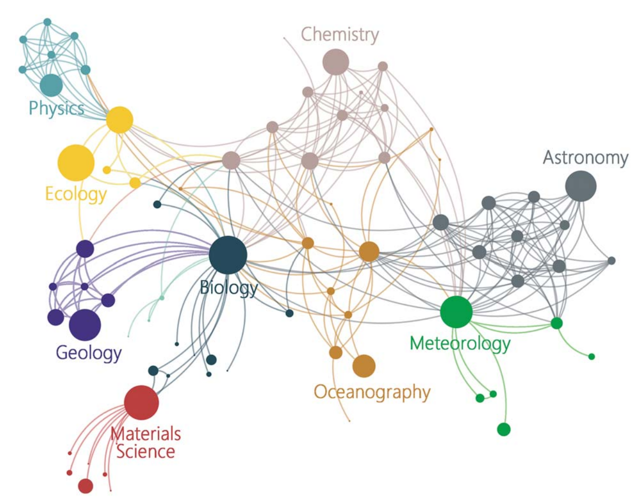

Fig. 1 Multidisciplinary fields of science.

[1] *Shanghai Key Lab of Chemical Assessment and Sustainability, Department of Chemistry, Tongji University, Shanghai 200092, China*
[2] *State Key Laboratory of Organic–Inorganic Composites, Beijing University of Chemical Technology, Beijing 100029, China*
[3] *Shaanxi Key Laboratory of Macromolecular Science and Technology, Department of Applied Chemistry, School of Science, Northwestern Polytechnical University, Xi' an, 710072, China*
[4] *Materials Science Division, Argonne National Laboratory, Lemont, Illinois 60439, United States*
[5] *Department of Mechanical Engineering, Texas A&M University, College Station, Texas 77843, USA*
[6] *Engineered Multifunctional Composites, LLC, Knoxville, Tennessee 37934, USA*
[7] *Integrated Composites Laboratory (ICL), Department of Chemical and Biomolecular Engineering, University of Tennessee, Knoxville, Tennessee 37996, United States*
[8] *School of Chemical and Biomolecular Engineering, The University of Sydney, Sydney, New South Wales, 2006, Australia*
[9] *Department of Mechanical Engineering and Integrated Nanosystems Development Institute, Indiana University-Purdue University Indianapolis, Indianapolis, IN 46202, USA*
[10] *School of Materials Science and Engineering, Nanyang Technological University (Singapore), 639798, Singapore*
[11] *College of Engineering, The University of Georgia, Athens, GA 30602, USA*
[12] *Materials Research and Innovation Laboratory (MRAIL), Department of Chemical and Biomolecular Engineering, University of Tennessee, Knoxville, Tennessee 37996, USA*
[13] *Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803, USA*

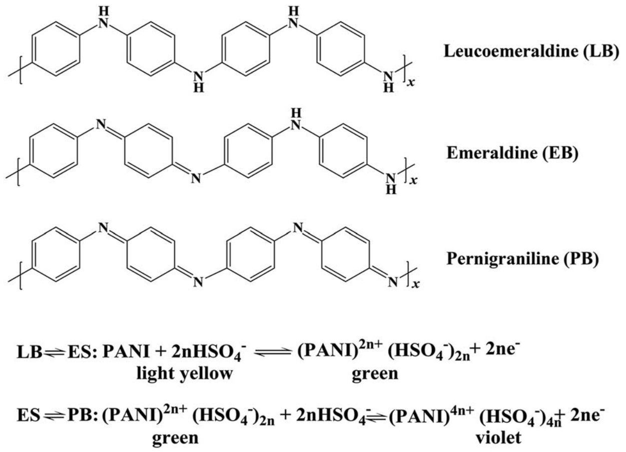

Fig. 2 Chemical structures of different PANI states and corresponding chemical reactions leading to the indicated color changes.

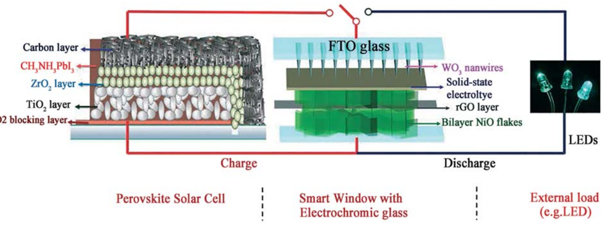

Fig. 3 Schemtic illustration for a smart window device structure and working principles.[16] Redrawn from Ref. 16. Reprinted with permission from Ref. 16.

(LEB), "emeraldine base" (EB) and "pernigraniline base" (PB), corresponding to the completely reduced state, the half-oxidized state, and the fully oxidized state, respectively, as illustrated in Figure 2.[15] After the doping/protonation process, the EB form of PANI can be converted to the emeraldine salt (ES) form. Since these different PANI states have different colors, applying an electric field would bring different structure variations, leading to further color changes, as demonstrated at the bottom of Figure 2. More recently, perovskite solar cell-powered electrochromic materials were designed for smart window applications,[16] in which the perovskite solar cell served as the power source for the electrochromic glass, and the electrochromic glass was used as a battery to light the LEDs, as shown in Figure 3. This example fully reflects the deep integration of science and engineering.

Thermochromic materials represent another example where science and engineering have come together to create new materials with novel properties and potentially countless applications. Similar to electrochromism, thermochromism refers to the color change in response to varied temperatures.[17] As an approach of engineered science, researchers have studied the mechanism for the color change with temperature based on the relationship between structure and properties.[18,19] For example, Dharmarwardana *et al*.[20] explored the thermochromic behavior of organic single crystal (SC) butoxyphenyl *N*-substituted naphthalene diimide (BNDI, Figure 4a) and found that the yellow monoclinic polymorph (α-phase, Figure 4b) BNDI underwent a reversible thermochromic structural transition to the triclinic polymorph (β-phase) upon heating, and subsequently changed to orange crystals after cooling down to room temperature (Figure 4c). They believed that this thermochromic behavior was based on the phase transition from a thermo-mechanical responsive SC-to-SC change (Figure 4d).

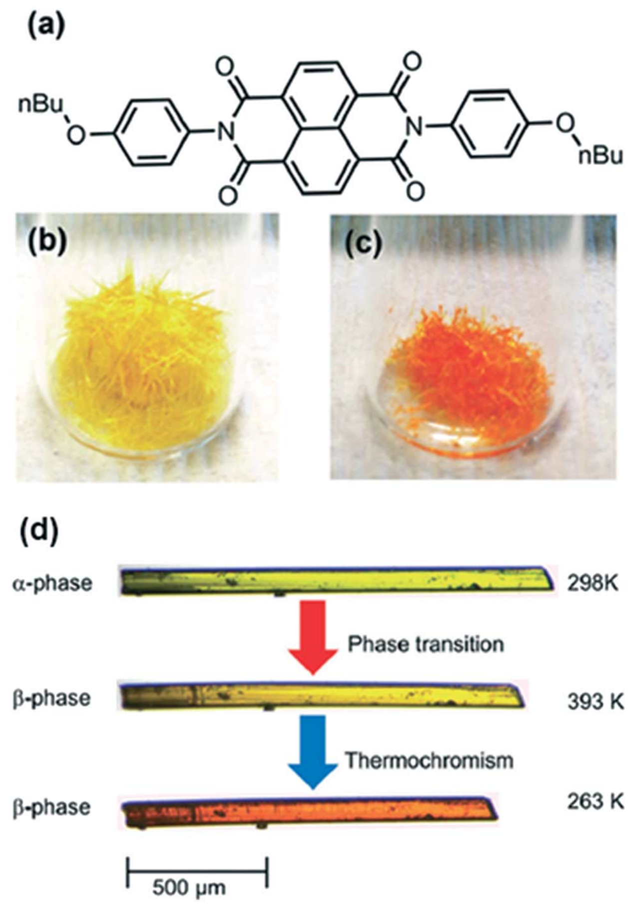

Fig. 4 (a) Chemical structure of BNDI; photographs of the two polymorphs: (b) non-thermochromic α-phase and the (c) thermochromic β-phase; (d) Changes in crystal dimensions during the α-phase to the β-phase transformation.[20] Reprinted with permission from Ref. 20.

As demonstrated from the aforementioned explanations and examples, *Engineered Science*, a new multidisciplinary journal published by Engineered Science Publishing, focuses on the understanding, manipulation, and interpretation of all aspects of science, engineering, and technology in an effort to advance the development of our society and improve the quality of human life. The aim of this journal is to connect the work of scientists and engineers from academia and industry, and to provide a platform for researchers to utilize science principles with proper engineering approaches to achieve their objectives. The complexity of science and engineering embedded in the design and construction of a bridge, as illustrated in Figure 5, is a good example of *Engineered Science* and captures the true spirit of the journal.

Fig. 5 An example of *Engineered Science* that integrates science and engineering in the design and construction of a bridge.

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