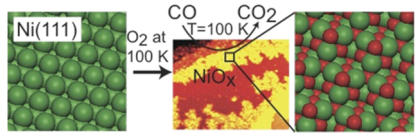
Cool Catalysis: Analyzing CO Oxidation at Low Temperatures

Though Au and Ni are immiscible in the bulk, Au can be deposited on low-index surfaces of Ni. These AuNi surface alloys have been shown to act as catalysts in the important industrial steam-reforming reaction in which hydrogen is derived from methane, with Au preventing carbon deposition and coke formation. Previous research using high-resolution electron energy loss spectroscopy and mass spectrometry has also shown that this alloy can catalyze low-temperature CO oxidation, with adsorbed oxygen on a Au/Ni(111) surface reacting easily with CO at 100 K.

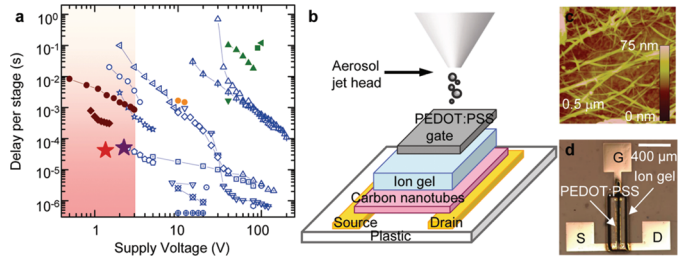


To explore low-temperature oxidation in this system, Knudsen *et al.* (p 4380) used a variety of methods, including scanning tunneling microscopy (STM), X-ray photoelectron spectroscopy (XPS), temperature-programmed desorption (TPD), and density functional theory (DFT) calculations to study CO oxidation on Ni(111), nickel oxide, and Au/Ni(111) surfaces. High-resolution STM as well as TPD and XPS spectra show that both Ni(111) and Au/Ni(111) oxidize when exposed to various amounts of O_2 at temperatures close to 100 K. Subsequently, when these oxidized surfaces are exposed to CO, XPS and TPD results show that weakly bound oxygen in the nickel oxide reacts with the CO, leading to the formation of CO_2. On Ni(111), the researchers found that a portion of the CO molecules form carbonate. However, on the Au/Ni(111) surface, high levels of Au coverage appear to block the formation of carbonate, leading to more CO_2 being released at 100 K. The authors suggest that nickel oxide appears to play a central role in catalyzing CO oxidation at low temperatures and suggest that these findings shed further light on the role of gold in these mixed-metal catalytic surfaces.

All the Circuits Fit to Print?

Applications such as bendable displays and large-area sensors continue to be important goals in electronics research. One strategy suggested for meeting these goals is using functional inks containing electronic components to enable printing circuits on flexible substrates, such as foils or paper. However, research on printed electronics has yet to produce high-performance circuits, with previous attempts having low carrier mobilities, leading to slow switching frequencies and high supply voltages that have prevented widespread application.

Seeking a novel solution to these challenges, Ha *et al.* (p 4388) printed circuits on flexible plastic and rigid SiO_2 substrates using liquid ink composed of 98% semiconducting carbon nanotubes (CNTs). This high-purity semiconducting CNT ink ensures high ON/OFF ratios without the need for further processing to remove metallic CNTs. The researchers created individual transistors by layering a CNT network, ion gel dielectric, and conducting polymer gate electrode on top of Au electrodes on each substrate using aerosol jet printing. Tests showed that these printed CNT transistors displayed clear ambipolar behavior.

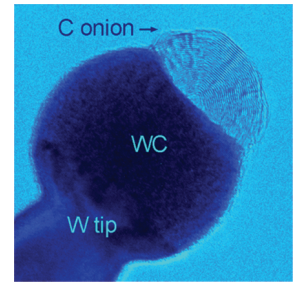


By combining identical ambipolar transistors together, the researchers were able to create a variety of circuits including inverters, NAND gates, and ring oscillators. Their results show that these circuits operate at supply voltages lower than 3 V and signal delays between 40 and 60 μs, performing significantly better than previous circuitry printed with functional inks. The authors suggest that continued improvements for printed circuits are entirely possible, lending new hope to the prospects of printed electronics.

First, Batteries from Potatoes—Now Electrons from Onions?

Among their many applications, researchers continue to pursue carbon nanotubes (CNTs) as electron sources that might eventually have applications in field-emission (FE) displays or high-resolution imaging apparatuses that use electron beams. For this function, the geometry of the tube is important, specifically its closed atomic cap, since the end emits the majority of electrons. As for the shank, keeping nanotubes shorter rather than longer has several advantages for FE, namely, better emission stability, less danger of damage from Joule heating induced by resistance, and lower thermal vibration amplitude, which improves image resolution in imaging devices.

In an effort to retain the necessary function of the cap while shortening CNT length to an extreme, Wang *et al.* (p 4396) created point electron sources using carbon "onions"—snippets of capped, multiwalled CNTs. The researchers welded these onions to the ends of tungsten tips inside high-resolution transmission electron microscopes using Joule heating, with an intermediate carbide layer connecting the cap and tungsten tip. Compared to the plain tip, which showed no FE current after a voltage sweep of 140 V, the onion-capped tip exhibited significant FE current at 70 V. Further tests showed that this novel onion emitter was able to sustain a FE current of more than 100 μA, compared to documented currents of only about 1 μA for longer CNTs due to the effects of Joule heating. These new emitters showed excellent long-term stability, which was further increased by increasing the circuit resistance. The authors suggest that carbon-onion emitters might serve as point electron sources for a variety of future applications.



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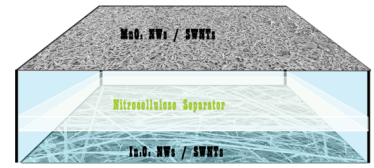
Super Performance from Novel Asymmetric Supercapacitors

Electrochemical capacitors, also known as supercapacitors, have several advantages over conventional batteries, such as greater power density, faster charging, and excellent cycling ability. Commercially available supercapacitors do not yet provide sufficient energy/power densities or efficiencies for some desirable applications, such as propelling hybrid vehicles. Thus, researchers are currently focused on trying to increase energy density without affecting power density or cycle life. One way to accomplish this goal is through asymmetric supercapacitors, which use different active materials in the system's two electrodes. Researchers have tried several different combinations of materials to create these devices, but performance has not reached the level of electrical double-layer capacitors that use single-walled carbon nanotubes (SWNTs) as the active layers.

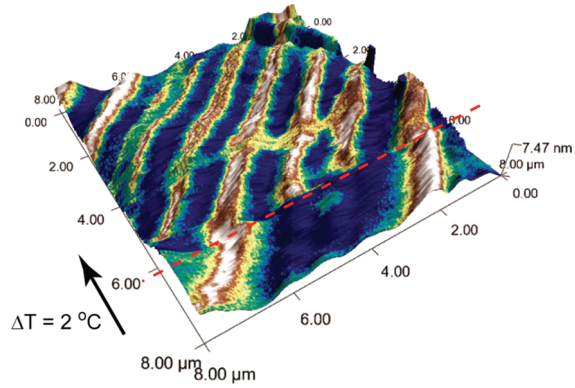
Hoping to improve performance, Chen *et al.* (p 4403) integrated SWNTs with transition-metal-oxide nanowires in thin films that act as the electrodes of a novel asymmetric supercapacitor. The cell used a combination of MnO_2 and SWNTs as the positive electrode and In_2O_3 with SWNTs as the negative electrode, with an aqueous Na_2SO_4 electrolyte. Tests showed that this cell system operated stably up to 2 V due to an optimized mass balance between the two electrodes. The researchers showed that the specific capacitance of these novel asymmetric supercapacitors was 184 F/g, their power density was 50.3 kW/kg, and their energy density was 25.5 Wh/kg—performance far better than symmetric SWNT capacitors or earlier reported asymmetric supercapacitors. The authors suggest that their improved asymmetric supercapacitors might eventually find a home in applications such as portable electronics or electric vehicles.



A New Ripple in Ferroelastic Phase Transition

At their critical temperature, ferroic materials undergo phase changes that can alter the shape or orientation of individual unit cells, breaking symmetry and leading to changes in the materials' electronic and magnetic properties. At the nanoscale, this behavior can give rise to interesting mesoscopic phenomena at the domain interfaces within the material, including superconductivity and unusual magnetic behavior. Thus, these domain interfaces provide a useful system to research the effects of symmetry breaking on various materials' behavior directed solely by these often small but significant changes in structure.

Seeking more insight into one such ferroic material, Tselev *et al.* (p 4412) systematically studied phase changes and resulting domain formation in the improper ferroelastic vanadium oxide (VO_2). The researchers conducted their experiments using VO_2 nanoplatelets on Si/SiO_2 substrates, structures that remained mechanically stable after repeated cycles of domain formation and disappearance. Using scanning microwave microscopy, the researchers found that upon heating the nanoplatelets above 55 °C, this material undergoes a metal−insulator transition. Though semiconducting at room temperature, the nanoplatelets formed metallic domains extending along their lengths. As the phase transition progressed at slightly higher temperatures, the material formed a corrugated structure, with 1 μm wide metallic domains nucleating at the ridges and growing into the furrows. These metallic domains showed dramatically higher conductivity compared to the surrounding material and could function as conductive channels within the material. Density functional theory calculations suggest that these structures form due to lowering of the energy barrier caused by band gap closure near domain walls. The researchers suggest that harnessing this behavior could eventually lead to tunable electronics that take advantage of the strain-dependent transport properties of ferroelastic materials.



Big Solar Power Conversion Efficiency from Tiny TiO_2 Beads

Titanium dioxide's unique optoelectronic properties have made it a subject of intense focus for a variety of applications, including photoanodes for dye-sensitized solar cells (DSSCs). The performance of these devices depends not only on the light-harvesting capacity of the sensitizing dye adsorbed onto the TiO_2 particles used but also on the transport of photoinjected electrons through the semiconductor electrode. To achieve a high-performance DSSC, fast electron diffusion is necessary. However, the loosely packed areas of traditional TiO_2 electrode films and low surface area of TiO_2 nanorods and nanotubes on transparent conducting electrodes impedes device performance by increasing the chances for interfacial losses.

Seeking a new way to improve power conversion efficiency in TiO_2-based solar cells, Sauvage *et al.* (p 4420) designed a single-layer film of mesoporous TiO_2 beads ~830 nm in diameter. The beads' large size gives the film a light-scattering ability typically achieved through adding an additional layer of smaller particles, a step that can add to manufacturing complexity and cost, and the particles' pores provide a structure for dye attachment. Transmission electron microscopy images show that TiO_2 nanocrystals inside the beads were densely packed, each having contacts with multiple neighboring grains. To determine if these features increased device efficiency, the researchers created cells incorporating the novel TiO_2 films and one of two sensitizing dyes. Results showed power conversion efficiencies (PCEs) greater than 10%, higher than other reported single-layer titania films. The authors suggest that even greater PCEs are achievable through further tweaks in their design, which they are currently testing in ongoing research.