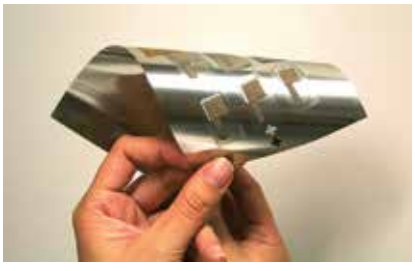
Ultrathin and Flexible Zinc Batteries to Power Tomorrow's Electronics

Emerging applications, from wearable electronics to robotics, and advances in electronics allowing designers to pack more components into ever-more-compact space are driving demand for thin, flexible, high-performance batteries with low toxicity and green chemistries.

Batteries typically occupy the largest real estate inside a portable device, dictating its shape and mechanical properties. Product designers have tried to push batteries toward thinner form factors (<1 mm), but commercially available battery chemistries have severe performance and safety limitations. For example, lithium-based chemistries require substantial hermetic packaging to protect active materials from harmful ambient moisture and oxygen.

As batteries become thinner, the space dedicated to packaging can dominate the battery-housing volume, reducing the battery's overall volumetric energy density. Currently available thin batteries struggle to achieve sufficient power density — a severe limitation, especially for powering wireless devices that rely on large pulse currents to transmit data. Curving or dynamically bending these batteries further aggravates their performance and introduces potential safety issues, such as leakage of toxic or flammable materials, gas expansion, and even explosions. But this is about to change.



▲ Imprint Energy's ultrathin batteries (shown here printed on foil) offer high volumetric energy and power densities, rechargeability, low materials and manufacturing costs, inherent safety, printability, and form-factor flexibility that exceed those of any other commercial batteries with a thickness of <1 mm. Image courtesy of Imprint Energy.

With support from the National Science Foundation, Imprint Energy, Inc., a spinout of the Univ. of California, Berkeley, is commercializing a zinc-based printed, flexible battery (ZincPoly). The innovative feature of this new battery is its highly conductive solid electrolyte, which is composed of air-stable, low-toxicity, earth-abundant non-lithium materials. This electrolyte is an ionic liquid swelled into a polymer to form a gel. The polymer electrolyte exhibits solid-like mechanical strength and liquid-like ion-transport properties, enabling the fabrication of layered microbattery structures.

Zinc batteries offer several advantages over lithium-based batteries. The materials used in zinc batteries are inherently safer and nontoxic, and can be handled in ambient environments; and, zinc batteries have high theoretical energy and power densities. Traditional zinc batteries, however, are hampered by their short cycle life — the result of branch-like dendrites that grow from the zinc electrode after repeated cell charges, as well as severe electrode shape change due to unstable electrode-electrolyte interactions.

Unlike most traditional zinc alkaline batteries, ZincPoly can be stably recharged. Because of the gel-like structure of the ZincPoly electrolyte, the electrode-electrolyte interactions are more stable than those in batteries with aqueous-based electrolytes, promoting even distribution of zinc electrodeposition at the interface and fewer shape change issues. Furthermore, the polymer electrolyte's mechanical properties limit dendrite propagation across the electrolyte, ultimately allowing this chemistry to be sustainably rechargeable.

Imprint Energy's nonaqueous polymer electrolyte maintains high ion transport and good mechanical strength — enabling the necessary physical separation between the two electrodes, says Christine Ho, CTO at Imprint Energy. "Good interfacial contact between the electrodes and electrolyte is maintained, so the battery is stable when flexed or bent."

All layers within a ZincPoly battery start as inks that are patterned using common screen-printing equipment. Imprint has printed batteries of different shapes and sizes on various substrates, including foils, plastics, and fabrics. These batteries have been dynamically flexed over a few thousand cycles with good capacity retention. They have undergone testing in several bend configurations and multi-axis dynamic bending, and they are stable when curved to various bend radii and even when creased. The ability to be safely coiled or even punctured greatly expands the potential application opportunities, and gives product designers unprecedented freedom to rethink battery shapes, form factors, and applications in portable electronics.

Imprint Energy is currently producing several hundred batteries a day for research and development purposes, and is developing the ZincPoly technology to satisfy the battery requirements of small portable electronic devices. Imprint believes the compelling capabilities of its batteries are likely to shape the battery landscape for the rapidly growing swarm of wireless accessories.

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