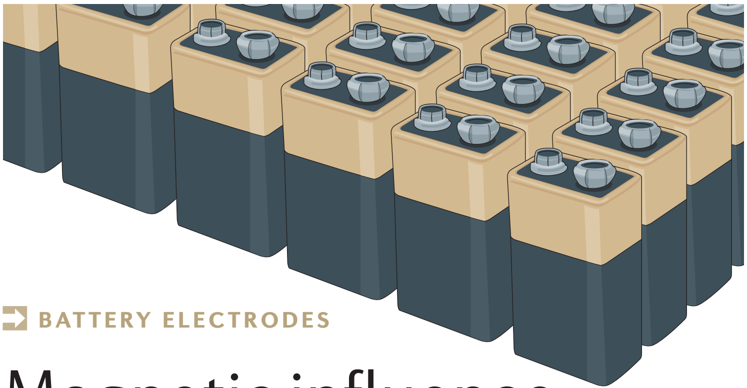

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BATTERY ELECTRODES

Magnetic influence

Better electrodes are needed to meet the increasing demand for low-cost, long-life batteries. Much effort is devoted to identifying new electrode materials, but a simpler, promising route is improving existing electrode designs. Two studies recently published in *Nature Energy* — one focusing on the anode, the other on the cathode — demonstrate the use of weak magnetic fields to obtain aligned pores in electrodes for Li-ion batteries, overcoming the problem of tortuosity in the diffusion paths in the electrodes.

The first study, led by André Studart and Claire Villevieille, demonstrates the optimization of a graphite anode through the magnetic alignment of the graphite flakes that constitute the electrode. Graphite is a widely used anode material, because of its high energy density, good reversibility, non-toxicity and low cost, but it is highly tortuous. The insertion and extraction of Li ions is further impeded because these processes occur only in a particular crystallographic plane. If the flakes are aligned in the transport direction, the ions experience shorter diffusion paths and easier access to the preferential insertion and extraction sites. "Our focus in this work was to exploit a colloidal assembly approach that would benefit from the anisotropic nature of this highly abundant and cheap anode material, without the need of incorporating major additional ingredients and processing steps," says Studart.

To make the graphite flakes sensitive to the applied magnetic field, they are coated with superparamagnetic iron oxide nanoparticles (SPIONs). The coated flakes, suspended in solution, align in the transport direction under the influence of the magnetic field. The enhanced performance of the aligned electrodes reaches specific charge values that are up to three times higher than those of a non-magnetically aligned electrode. Moreover, the overpotential is much lower and increases more slowly with increasing discharge rate. Further tests with highly loaded electrodes and higher discharge rates reveal, after 50 cycles, a specific charge 1.6 times higher than that of the conventional anodes.

In the second study, Yet-Ming Chiang and colleagues explore two methods for exploiting a magnetic field to align the pore channels in $LiCoO_2$ cathodes. In one case, sacrificial nylon microrods coated with SPIONs are dispersed in a suspension of electrode particles. They are then uniformly aligned by the magnetic field, the solvent is evaporated leaving a solid electrode and the rods are removed by pyrolysis. The second method uses emulsion droplets of SPIONs, which align in linear chains when exposed to the magnetic field. After electrode solidification, the emulsion phase is removed by drying. In both cases, highly aligned pore channels are obtained. The microrods give a more uniform pore diameter, but the emulsion droplets have the advantage of adapting to different electrode thicknesses. In both approaches, the pore diameter and the density of the pores can be easily controlled and anisotropic particles are not needed. "We were inspired by earlier work with shaped particles by Vanessa Wood and Martin Ebner. However, because spherical particles are generally preferred in commercial production for better handling and packing, one of our motivations was to develop an approach that did not require the use of shaped particles. Graphite is an exception amongst active materials, because natural graphite comes in platelet form," explains Chiang.

As observed for the anodes, the two magnetically aligned cathodes show superior performance, reaching an areal capacity three times higher than that of conventional cathodes for the microrod-based electrodes. Both cathodes were tested in a drive-cycle test using dynamic discharge profiles to determine their performance in electric vehicle applications. The measured areal capacity under these conditions is twice that of a non-magnetically aligned cathode. The cathodes produced using the emulsion droplets are more promising, because they are more flexible than the microrod-based cathodes and do not require polymer pyrolysis, thus they are compatible with room-temperature processing.

"These two studies demonstrate the potential of directed colloidal assembly approaches, which are inexpensive and scalable, in generating architectured electrodes for improved battery performance," concludes Studart.

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Giulia Pacchioni

ORIGINAL ARTICLES Billaud, J. *et al.* Magnetically aligned graphite electrodes for high-rate performance Li-ion batteries. *Nat. Energy* http://dx.doi.org/10.1038/nenergy.2016.97 (2016) | Sander, J. S. *et al.* High-performance battery electrodes via magnetic templating. *Nat. Energy* http://dx.doi.org/10.1038/nenergy.2016.99 (2016)