New approach may accelerate design of high-power batteries

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Credit: Skylar Kang from Pexels

Research led by a Stanford scientist promises to increase the performance of high-power electrical storage devices, such as car batteries.

In work published this week in *Applied Physics Letters*, the researchers describe a mathematical model for designing new materials for storing electricity. The model could be a huge benefit to chemists and materials scientists, who traditionally rely on trial and error to create new materials for batteries and capacitors. Advancing new materials for energy storage is an important step toward reducing carbon emissions in the transportation and electricity sectors.

"The potential here is that you could build batteries that last much longer and make them much smaller," said study co-author Daniel Tartakovsky, a professor in the School of Earth, Energy & Environmental Sciences. "If you could engineer a material with a far superior storage capacity than what we have today, then you could dramatically improve the performance of batteries."

Lowering a barrier

One of the primary obstacles to transitioning from fossil fuels to renewables is the ability to store energy for later use, such as during hours when the sun is not shining in the case of solar power. Demand for cheap, efficient storage has increased as more companies turn to renewable energy sources, which offer significant public health benefits.

Tartakovsky hopes the new materials developed through this model will improve supercapacitors, a type of next-generation energy storage that could replace rechargeable batteries in high-tech devices like cellphones and electric vehicles. Supercapacitors combine the best of what is currently available for energy storage – batteries, which hold a lot of energy but charge slowly, and capacitors, which charge quickly but hold little energy. The materials must be able to withstand both high power and high energy to avoid breaking, exploding or catching fire.

"Current batteries and other storage devices are a major bottleneck for transition to clean energy," Tartakovsky said. "There are many people working on this, but this is a new approach to looking at the problem."

The types of materials widely used to develop energy storage, known as nanoporous materials, look solid to the human eye but contain microscopic holes that give them unique properties. Developing new, possibly better nanoporous materials has, until now, been a matter of trial and error – arranging minuscule grains of silica of different sizes in a mold, filling the mold with a solid substance and then dissolving the grains to create a material containing many small holes. The method requires extensive planning, labor, experimentation and modifications, without guaranteeing the end result will be the best possible option.

"We developed a model that would allow materials chemists to know what to expect in terms of performance if the grains are arranged in a certain way, without going through these experiments," Tartakovsky said. "This framework also shows that if you arrange your grains like the model suggests, then you will get the maximum performance."

Beyond energy

Energy is just one industry that makes use of nanoporous materials, and Tartakovsky said he hopes this model will be applicable in other areas, as well.

"This particular application is for electrical storage, but you could also use it for desalination, or any membrane purification," he said. "The framework allows you to handle different chemistry, so you could apply it to any porous materials that you design."

Tartakovsky's mathematical modeling research spans neuroscience, urban development, medicine and more. As an Earth scientist and professor of energy resources engineering, he is an expert in the flow and transport of porous media, knowledge that is often underutilized across disciplines, he said. Tartakovsky's interest in optimizing battery design stemmed from collaboration with a materials engineering team at the University of Nagasaki in Japan.

"This Japanese collaborator of mine had never thought of talking to hydrologists," Tartakovsky said. "It's not obvious unless you do equations – if you do equations, then you understand that these are similar problems."

More information: Xuan Zhang et al. Optimal design of nanoporous materials for electrochemical devices, *Applied Physics Letters* (2017). DOI: 10.1063/1.4979466

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