Electrodes with hollow nanotubes improve performance of potassium-ion batteries

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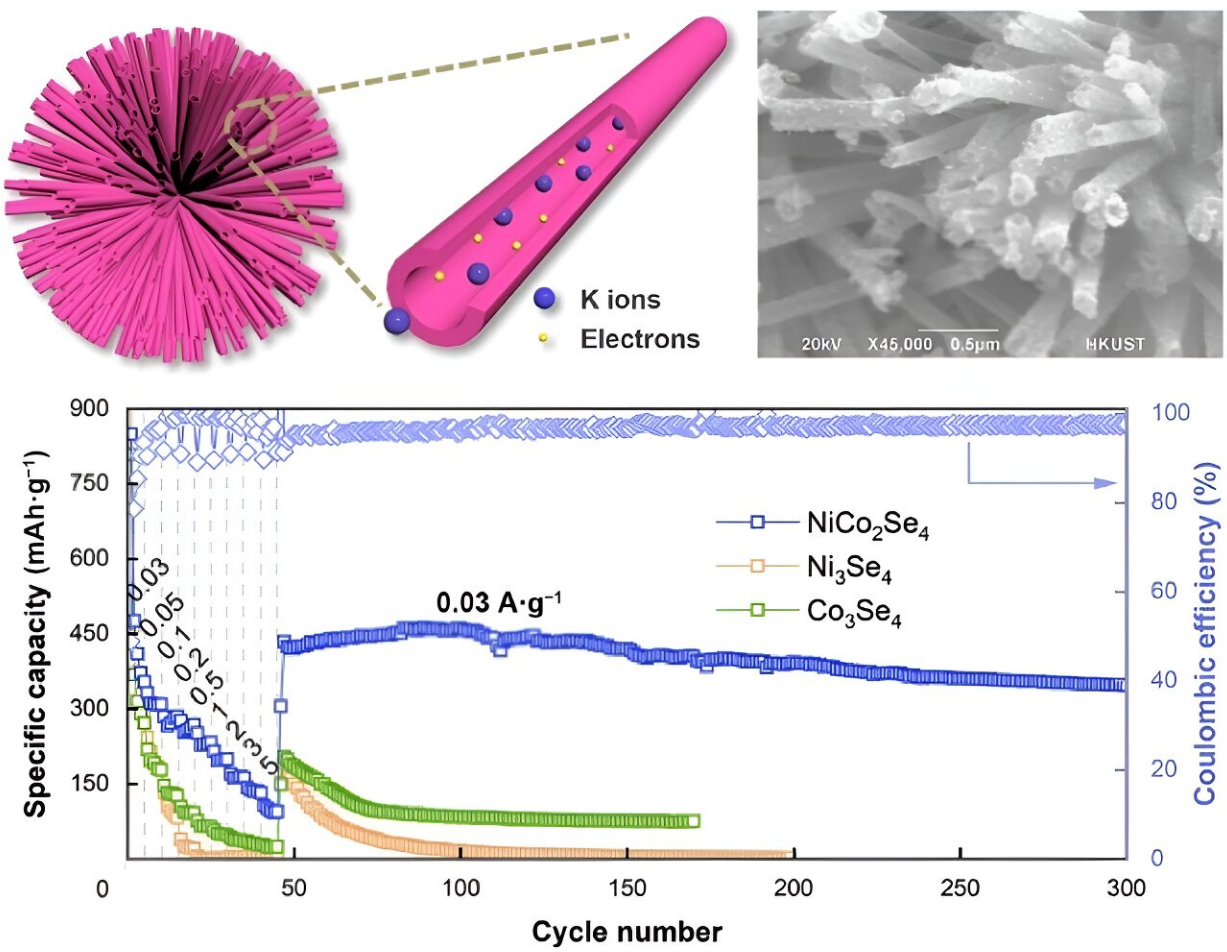

This graphic includes a diagram showing the structure of $NiCo_2Se_4$ nanotube spheres that have been used to create anodes for potassium-ion batteries. It also includes a graph showing the improved performance of the potassium-ion batteries constructed with the $NiCo_2Se_4$ nanotube spheres. Credit: *Energy Materials and Devices* (2023). DOI: 10.26599/EMD.2023.9370001

Researchers who are working to find alternatives to lithium-ion batteries have turned their attention to potassium-ion batteries. Potassium is an abundant resource, and the technology functions in much the same way as lithium-ion batteries, but these batteries have not been developed at a large scale because the ionic radius causes problems in energy storage and substandard electrochemical performance.

To solve this problem, researchers are considering $NiCo_2Se_4$, a bimetallic selenide, to create sphere-shaped electrodes. The spheres are constructed with $NiCo_2Se_4$ nanotubes, which improve the electrochemical reactivity for faster transfer and storage of potassium ions.

The research was presented in a paper published in *Energy Materials and Devices* on 14 September.

"Bimetallic selenides combine the ameliorating features of two metals, which synergize by showing rich redox reaction sites and high electrochemical activities. One bimetallic selenide, $NiCo_2Se_4$, was previously studied for sodium storage, supercapacitors, and electrocatalysts and presents considerable potential for potassium ion storage.

"By synthesizing $NiCo_2Se_4$ using a two-step hydrothermal process, a nanotube structure with flower-like clusters develops, creating convenient channels for potassium ion/electron transfer," said Mingyue Wang, a researcher at the Engineering Research Center of Energy Storage Materials and Devices at Xi'an Jiaotong University in Xi'an, China.

Initially, Ni-Co precursor spheres with solid nanoneedles are prepared.

These spheres have a well-defined crystalline structure that is then exposed to selenide during a process called selenization. This process introduces selenium to the Ni-Co precursor, developing the $NiCo_2Se_4$ nanotube shell.

The hollow tubes form because of a phenomenon called the Kirkendall effect, which is when two metals move because of the difference in the diffusion rates of their atoms. These nanotubes are around 35 nanometers wide, giving enough space for the potassium ions and electrons to transfer.

Through a variety of tests and analysis, the researchers were able to confirm how well the $NiCo_2Se_4$ anodes could move and store potassium ions and electrons. They found that $NiCo_2Se_4$ has more active sites than other electrode materials, had uniformly distributed elements, and outperformed other electrodes that were tested during research.

"The $NiCo_2Se_4$ nanotube electrode presented a much better electrochemical performance in terms of cyclic stability and rate capability than other tested electrodes, including Ni_3Se_4 and Co_3Se_4. This is because the unique nanotube structure of $NiCo_2Se_4$ and the synergy offered by the co-presence of two metals," said Wang.

These monometallic counterparts, Ni_3Se_4 and Co_3Se_4 were not as successful as the bimetallic $NiCo_2Se_4$, simply because of the way the two metals (Ni and Co) interact together. $NiCo_2Se_4$ also had a higher capacity, which is very beneficial for maintaining cyclic stability and high-rate performance.

"This work offers new insights into the design of micro/nano-structured binary metal selenides as anodes for potassium-ion batteries with extraordinary potassium ion storage performance," said Wang.

More information: Mingyue Wang et al, Conversion mechanism of NiCo 2Se 4 nanotube sphere anodes for potassium-ion batteries, *Energy Materials and Devices* (2023). DOI: 10.26599/EMD.2023.9370001

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