Nanocomposites and nanomaterials

Hard carbon nanomaterials for next-generation energy storage

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Today's graphitic carbon anode of lithium-ion batteries (LIBs) suffers from relatively low capacity and sluggish rate performance (Fig., curves 1&1'). With large-scale battery markets of electric vehicles and energy storage systems (as a part of smart grids or for utilizing renewable energies) future LIBs must meet the challenges of these emerging sectors, necessitating a move to alternative materials with increased capacity, cycle life and rate performance, together with a consideration of production cost and environmental impact.

Hard carbon (HC) nanomaterials hold the key to new generations of LIBs. The high capacity and low polarizability of novel HC electrode (Fig., curves 2&2') are due to diversity of positions accessible to lithium atoms in its structure: sites of Li+ adsorption with partial charge transfer; intercalation sites between aromatic molecules in the clusters; spaces between the edges of the hexagonal clusters; voids between the randomly arranged clusters; sites in defects created by heteroatoms (Si, P).

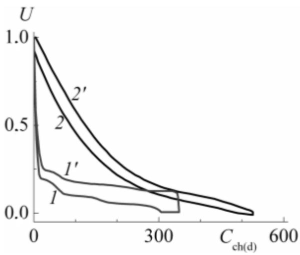

Fig. Charge–discharge curves (second cycle) of half-cells with lithium counter electrode and working electrodes based on artificial graphite (*1*, *1'*) and hard carbon (*2*, *2'*) in the *cc/cv* and *cc* modes. *U* is the half-cell voltage (V), $C_{ch(d)}$ is the working electrode specific charge (discharge) capacity per unit weight of active material (mA h/g).

Also we report excellent performance anodes for LIBs made with a ceramic frame-ordered composite ″nano-Si@HC″ [1,2], using the hard carbon as a structurally reinforcing and electrochemical-enhancing backbone for silicon.

1. *Kuksenko S.P.* Silicon-Containing Anodes with Low Accumulated Irreversible Capacity for Lithium–Ion Batteries // Russ. J. Appl. Chem.-2013.-**86**, N 5.-P. 703-712.
2. *Kuksenko S.P.* Silicon-Containing Anodes with High Capacity Loading for Lithium–Ion Batteries // Russ. J. Electrochem.-2014.-**50**, N 6.-P. 537-547.