Electrical Engineering | Energy Technology | Batteries | Technology offer

Macro-porous, nanocrystalline silicon layer for lithium-ion batteries

Field of application

The method according to the invention is a special 'all-in-one' processing technology for the production of anode material, made of semiconductor materials (silicon (Si) or/ and germanium (Ge)) and used in lithium-ion batteries (Li-ion batteries) with a high capacity and long lifespan.

State of the art

For the production of rechargeable batteries, it is desirable to use silicon as anode material in Li-ion batteries. Until recently, however, this was not feasible. The use of silicon anodes theoretically increases battery capacity tenfold compared to conventional graphite anodes.
However, the attempt had previously failed, since the layers would expand by 300 to 400 % due to the storage of lithium ions in the Si bulk material. This induces a high residual strain and can destroy the bulk Si after only a few charge cycles. In addition, as a consequence of the irreversible reaction between the Si anode and electrolyte a layer of solid electrolyte interphase (SEI) can develop and lead to a low coulombic efficiency.

Innovation

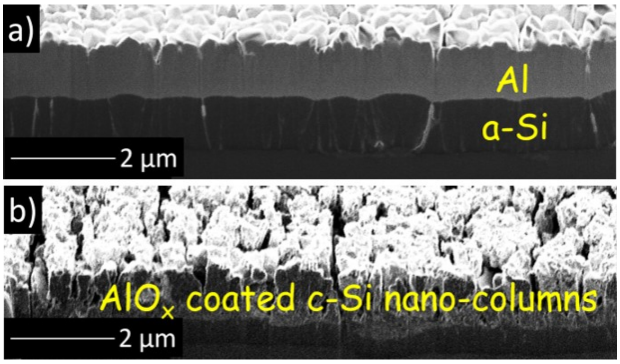
Scientists of the University of Stuttgart succeeded in developing a structure that eliminates the residual strain and can be manufactured in a continuous process. By selecting the optimal combination of process parameters (deposition process, annealing and chemical treatment) a porous semiconductor layer can be formed, which displays a pore distribution from 50 to 3000 nm.
According to the invention a semiconductor layer (e.g. silicon, germanium or their alloys) is deposited on the substrate (e.g. glass, silicon dioxide, titanium, nickel or ceramics). Onto this semiconductor layer, an additional metallic layer, e.g. aluminum, is deposited. The following heat treatment with an optimized combination of temperature and duration produces an incomplete interdiffusion between the two layers. Spontaneously, the amorphous semiconductor layer transforms at least partially into a crystalline state. In the last step, the metallic phase is removed by selective etching. A conformal layer of Al oxide can prevent the formation of an SEI layer. The porous semiconductor layer with a thickness of 300 nm to 5 µm is doped and capable of absorbing lithiation-induced strain without breaking.
Initial experiments with a laboratory model of a Li-ion battery have already shown that even after 500 charge/ discharge cycles the capacity remains stable at approx. 1650 mAh/g, without any major optimization efforts.

Patent portfolio

EP3087629B1 granted (validated in DE, FR & GB);
US2016/0322632 pending.

Your benefits at a glance

- ✓ Method for creating a mechanically stable, porous semiconductor layer for Li-ion batteries
- ✓ Stable charge capacity of 1650 mAh/g already shown in laboratory experiments
- ✓ Simple, inexpensive layer fabrication in continuous process, also for larger surface areas
- ✓ Wide range of options for controlling the production process in terms of surface topology and pore morphology
- ✓ Conformal Al-oxide layer to insure the high coulombic efficiency all the time
- ✓ Very good adhesion between the porous semiconductor layer and conductive substrate



Cross-sectional images created via FIB:
a) As-deposited status, Al/a-Si bilayers constructed onto a flexible conductive substrate; (a-Si=amorphous silicon)
b) After removal and etching, AlOx-coated, crystalline Si nanocolumns formed. (AlOx=aluminum oxide), (c-Si=crystalline silicon)

Technology transfer

TLB GmbH manages inventions until they are marketable and offers companies opportunities for license and collaboration agreements.

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