Non-flammable and leak-proof:

Sodium borohydride as an ion conductor

Arndt Remhof, Gruppenleiter in der Abteilung von Corsin Battaglia, nutzt Amid-Borohydrid-Kristalle auf der Suche nach viel versprechenden Festkörperelektrolyten. Remhof hat langjährige Erfahrung mit dieser Materialklasse: Er hat sie bereits als Wasserstoffspeicher unter die Lupe genommen. Nun steht die Ionenleitfähigkeit dieser Festkörper im Fokus seiner Arbeit.

In diesem Jahr konnte er mit seinem Team bereits viel versprechende Ergebnisse veröffentlichen: Die Leitfähigkeit des an der Empa entwickelten Festkörperelektrolyten aus Amid-Borohydrid ist bei Raumtemperatur vergleichbar mit einem Flüssigelektrolyten. Auch ist der neuartige Festkörperelektrolyt selbst bei Temperaturen von bis zu 150 Grad Celsius noch stabil – herkömmliche Flüssigelektrolyten wären bei derart hohen Temperaturen ein Sicherheitsrisiko.

Noch steckt das Projekt allerdings in den Kinderschuhen und hat mit einigen Schwierigkeiten zu kämpfen. So hält das Amid-Borohydrid bislang erst eine Spannung von gut einem Volt stand. Das ist zu wenig für eine markttaugliche Batterie. Um dieses Problem anzugehen, sind die Forschenden zurzeit dabei, alternative Borverbindungen zu entwickeln und zu untersuchen – und haben damit auch bereits eine Spannung von immerhin drei Volt erzielt. «Der erste Schritt, um in Zukunft die flüssigen Lithium-Ionen-Batterien durch Festkörper-Akkus ersetzen zu können», erklärt Empa-Forscher Léo Duchêne, der die ersten 3 Volt-Prototypen entwickelt hat.

Strong and safe:

Lithium metal anodes and solid electrolytes

No flammable electrolyte – if a material is combustible it has no place in a battery, according to Stephan Bücheler. “The battery we’re developing shouldn’t give off any hazardous substances at all while it is in operation, even if it malfunctions,” says the Empa researcher. He is a specialist for the production and characterization of thin semiconductor layers and has been conducting research and development on flexible thin-film solar cells at Empa for several years. He is now turning his expertise to batteries.

“Thin-film solar cells are a useful thing – full thin-film batteries less so. After all, efficient batteries always have a certain volume to reach high capacity,” says Bücheler. “However, fitting a battery with thin films in certain places does have clear advantages.” Bücheler’s research concerns electrolytes – i.e. the part of the battery responsible for conducting ions between the anode and the cathode, the two poles. On the one hand, electrolytes need to be stable and not have any holes to prevent short circuits; because if the anode and cathode touch each other, the battery is dead. On the other hand, the ions are supposed to move as quickly as possible during the charging and discharging process. So the shorter the distance between the poles, the more efficient the battery. And this is precisely where it starts to get challenging for Empa’s thin-film specialists. The ultra-thin solid Bücheler and his team are looking to invent should be mechanically stable and withstand high voltages. At the same time, it should let lithium ions pass through as easily as possible.

Bücheler is experimenting with alloys made of lithium, lanthanum and zirconium oxide, mixed with small percentages of other metals. To produce his ultra-thin films, he uses what is referred to as a sputtering system: in a high vacuum, material is removed from several targets, and then condenses on a small sample plate. The suitability of such fabricated alloys is then studied using a series of physical analysis methods – such as X-ray diffraction, Raman spectroscopy, X-ray photoelectron spectroscopy and mass spectrometry.

The tricky thing about the thin-film technique: the connection between the individual films needs to be very tight as well as even across the entire surface of the battery. “If the ion flow is higher in some places than in others, the battery will soon malfunction,” says Bücheler. However, the search for the perfect material might ultimately pay off. A lithium ion battery with solid thin-film electrolytes no longer needs a graphite anode like today’s “wet” lithium ion batteries. The anode can be made of metallic lithium, which would significantly increase the battery’s charge density. With the same weight and volume, one of these batteries would be considerably more efficient – and also charge much faster.