Docket #: S15-458

Thermoresponsive Material to Prevent Battery Fire

Stanford researchers have developed a high-performance, ultrafast, thermoresponsive polymer that can act as a circuit breaker to prevent fires in next-generation high-energy-density batteries by rapidly and reversibly turning off when overheated. This invention prevents thermal runaway with spiky nickel nanoparticles that are coated with graphene and embedded in a thin film of polyethylene. Under normal temperatures, the nanoparticles are in close proximity and are highly conductive. When the temperature rises beyond a certain threshold, the polymer expands and the nanoparticles are separated to the point that they no longer conduct electricity. This reversible mechanism can shut down a battery in one second, but the battery will quickly resume normal operation and performance after it cools. This material could be incorporated inside batteries as a practical, simple solution for battery safety. It could also be used in temperature sensors or electronics.

Professor Zhenan Bao explains the thermoresponsive material that could prevent the kind of fires that have prompted recalls and bans on a wide range of battery-powered devices.

Stage of Development

The inventors have fabricated the polymer and demonstrated high electrical conductivity of up to 50S cm^{-1} at room temperature with rapid, reversible shut down (decreasing conductivity by 7-8 orders of magnitude in one second) at a temperature range of 50-150^{o}C depending on the selection of materials and their composition.

Related Technologies:

Stanford docket S18-311 - "**Coating Design based on Ion-conductive Organic Networks (IONs) to improve safety and stability of Lithium Metal**

Batteries"

Applications

- **Lithium batteries** - internal safety strategy to prevent fires and explosions due to overheating or shorting; end user applications include:
  - consumer electronics
  - electric vehicles
  - grid energy storage
- **Sensors** - polymer switch to detect temperature changes
- **Electronics**

Advantages

- **High performance** - conductivity up to 50S cm^{-1} at room temperature (about 100x higher than common conductive polymer composites)
- **Reliable, rapid shut down**:
  - at transition temperature, conductivity decreases 7-8 orders of magnitude in one second to prevent fires
  - 10^3 – 10^4 times higher sensitivity to temperature change than previous switching technologies
- **Reversible:**
  - quickly resumes normal, high-performance operation when cooled
  - sustained performance after multiple overheating events
- **Tunable** - the properties of the material can be adjusted to shut down conductivity at different temperatures

Publications

- Z. Chen, P.-C. Hsu, J. Lopez, Y. Li, J. W. F. To, N. Liu, C. Wang, S. C. Andrews, J. Liu, Y. Cui, Z. Bao, "Fast and reversible thermoresponsive polymer switching materials for safer batteries," Nature Energy (2016), doi:10.1038/nenergy.2015.9
- Z. Chen, R. Pfattner, Z. Bao,"Characterization and Understanding of Thermoresponsive Polymer Composites Based on Spiky Nanostructured Fillers,"

Advanced Electronic Materials (2017), doi:10.1002/aelm.201600397
- Mark Schwartz, "New Stanford battery shuts down at high temperatures and restarts when it cools," Stanford Report (Jan. 11, 2016)

Patents

- Published Application: WO2017120594
- Published Application: 20190016871
- Issued: 11,001,695 (USA)

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