Opportunity Title: Flexible Solid-State Batteries Fellowship
Opportunity Reference Code: ICPD-2024-39

Organization Office of the Director of National Intelligence (ODNI)

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Complete your application – Enter the rest of the information required for the IC Postdoc Program Research Opportunity. The application itself contains detailed instructions for each one of these components: availability, citizenship, transcripts, dissertation abstract, publication and presentation plan, and information about your Research Advisor co-applicant.

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If you have questions, send an email to ICPostdoc@orau.org. Please include the reference code for this opportunity in your email.

Application Deadline 2/28/2024 6:00:00 PM Eastern Time Zone

Description **Research Topic Description, including Problem Statement:**

Solid state batteries are at a maturity where they are commercially available. This is typically limited to use in devices that require low power levels, such as wireless sensors (marketsandmarkets.com), this is due to higher resistance that is typically exhibited compared to Li-ion cells utilizing liquid electrolytes. There is significant research in reducing internal resistance, and if achieved could unlock a much greater market share in the EV market for example, as solid-state batteries are typically significantly safer to use than liquid electrolyte-based batteries and more energy can be packed into the same space.

Related to this topic, is the growth of wearable technologies and specifically flexible batteries that can enable wearable electronics (Deng and He, Energies 2023). This is still an emerging market and although there has been research in the area of flexible batteries, uptake in the commercial market has been limited (marketandmarkets.com).

By combining developments of solid-state batteries, and flexible batteries, it is believed a viable battery could be developed for the wearables market that can store significant amount of energy and have increased safety for the user. There have been developments in flexible electrodes by utilizing non-metallic current collectors, printed materials and increasing binder content, but there is a lack of research on developing the solid electrolyte/separator material that can also offer a degree of flexibility.

Therefore, this research topic should focus on developing and proving that a solid-state electrolyte can be manufactured which can also be bent and flexed and is appropriate for use in a wearable scenario.

Example Approaches:

Early approaches to solid-state batteries have been demonstrated using solid polymer electrolytes (SPEs) or inorganic solid electrolytes (ISEs) based on sulfides or oxides. They often suffered from low rate due to poor ionic conductivity or poor electrochemical stability compared to liquid electrolytes. The rigid structures also required high levels of compression to ensure good electrical contact to suppress lithium dendrite growth during extended cycling. These requirements are incompatible with wearable or flexible structures and so a new approach is required.

Recently, hybrid systems have been created that benefit from the increased ionic mobility of a solvent trapped in a polymer, such as hydrogel electrolytes (Xin Li, Chem. Eng. J., 2022). However, these formulations can be semi-solids / quasi-solid-state and so require thick layers or separators. The structures can provide higher performance and flexibility but rarely are evaluated using wearables and accept lower operating voltages to overcome limited environmental protection.

Other approaches avoiding liquids have included blending the polymer and ceramic together through either a polymer in ceramic or ceramic in polymer structure (Kun Zhang, Adv. En. Mat., 2022). They often will have extremely strong structures but suffer from lower ionic conductivity. These demonstrated a secondary benefit of the electrolyte providing an environmental protection layer in addition to active electrolyte.

Flexibility has also been achieved by imparting the ISE into a fabric-based substrate (Yunhui Gong, Materials Today, 2018). The addition of carbon conductive additives and more flexible anode/cathode elements has further refined this approach (Changmin Shi, Energy Storage Materials, 2023). Hierarchical designs can enable the sharing of physical properties and enable the use of rigid ceramics into a woven structure that is perfectly adaptable to wearables.

The flexibility can also be gained from utilizing thin structures, such as drawn fibers. A team at MIT demonstrated that multi-layered structures of battery elements could be drawn simultaneously to achieve a fiber battery (Tural Khudiyev, materials today, 2022). This extremely thin structure wouldn’t necessarily require the flexibility of a classical sheet electrode due to the narrow structure. The design will struggle with stress and strain if using inflexible elements but shows a novel approach.

Relevance to the Intelligence Community:

There is significant research in reducing internal resistance, and if achieved could unlock a much greater market share in the EV market for example, as solid-state batteries are typically significantly safer to use than liquid electrolyte-based batteries and more energy can be packed into the same space.

Key Words: Energy storage, batteries, Li-ion, solid state, flexible, wearables

Qualifications **Postdoc Eligibility**

- U.S. citizens only
- Ph.D. in a relevant field must be completed before beginning the appointment and within five years of the appointment start date
- Proposal must be associated with an accredited U.S. university, college, or U.S. government laboratory
- Eligible candidates may only receive one award from the IC Postdoctoral Research Fellowship Program

Research Advisor Eligibility

- Must be an employee of an accredited U.S. university, college or U.S. government laboratory
- Are not required to be U.S. citizens

Eligibility Requirements

- **Citizenship:** U.S. Citizen Only
- **Degree:** Doctoral Degree.
- **Discipline(s):**
  - **Chemistry and Materials Sciences** (12)
  - **Communications and Graphics Design** (3)
  - **Computer, Information, and Data Sciences** (16)
  - **Earth and Geosciences** (21)
  - **Engineering** (27)
  - **Environmental and Marine Sciences** (14)
  - **Life Health and Medical Sciences** (45)
  - **Mathematics and Statistics** (11)
  - **Other Non-Science & Engineering** (2)
  - **Physics** (16)
  - **Science & Engineering-related** (1)
  - **Social and Behavioral Sciences** (30)