

PROVISIONAL PATENT APPLICATION

SYSTEMS AND METHODS FOR CREATING STRUCTURAL BATTERIES

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BRIEF DESCRIPTION OF APPENDICES AND DRAWINGS

[0001] The accompanying appendices illustrate a number of exemplary embodiments and are a part of the specification. Together with the following description, these appendices and drawings demonstrate and explain various principles of the present disclosure.

[0002] Appendix A details various environments in which the present disclosure may operate.

[0003] FIG. 1 illustrates a cross-section of a device that includes structural batteries.

[0004] FIG. 2 is an illustration of a portion of a device that includes structural batteries.

[0005] FIG. 3 is a cutaway illustration of a device that includes structural batteries.

[0006] Throughout the appendices and drawings, identical reference characters and descriptions indicate similar, but not necessarily identical, elements. While the exemplary embodiments described herein are susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the appendices and drawings and will be described in detail herein. However, the exemplary embodiments described herein are not intended to be limited to the particular forms disclosed. Rather, the present disclosure covers all modifications, equivalents, and alternatives falling within this disclosure.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0007] State of the art lithium-ion batteries for wearable consumer electronic devices consist of a graphite anode, a lithium cobalt oxide cathode, a separator, and a liquid electrolyte,

all housed within a steel can package. Today's wearable products face hard tradeoffs and constraints when trying to improve weight, industrial design (ID), and comfort. Today's batteries must be rigid. Cyclic flexure will reduce the cycle life of conventional Li-ion batteries, so the sections where they are incorporated into must remain rigid. This sets constraints on the overall device flexibility, limiting manufacturers' ability to meet comfort-driven targets. Since batteries today cannot provide significant stiffness to the devices they are assembled into, this requires thick-walled device packaging to maintain the required rigidity, increasing weight and volume. In addition, today's batteries are predominantly cuboidal. Integrating cuboidal cells into these devices set hard constraints on ID or cell size.

[0008] Conventional device assembly often requires substantial dead volume to account for manufacturing tolerances, increasing overall device volume. Conventional battery pouch packaging is often bulky due to packaging inefficiencies (e.g., edge folds). Decreasing packaging volume today requires moving to steel can outer layers for batteries, which adds significant weight.

[0009] Besides weight, volume, and initial capacity, batteries must maintain capacity over an extended cycle life. To date, technologies which promise to significantly increase energy density (e.g., silicon anode, electrodeposited LCO cathode, lithium metal, thin-film solid state) are unable to meet cycle life requirements. The keys to reducing battery weight and improving ID and comfort within wearable device form factor are to: 1) Eliminate the heavy steel can packaging of SOA Li-ion cells, 2) Enable integration of batteries into parts of wearable devices that are typically underutilized, reducing dead volume and improving ID, and 3) Enable more flexible, lower stiffness wearables for better fit and comfort. With the approaches described

below, it is possible to enable reduced weight and volume at the device level, along with ID and SKU fit and comfort improvements.

[0010] The systems described herein may include a structural, flexible battery core. In some embodiments, a battery may be injected with polymer electrolytes that provide tunable stiffness to the battery without sacrificing performance. This may enable the battery to serve as a structural component of a device. For example, a battery that is part of a pair of smart glasses may provide the required temple-arm-level stiffness and thereby lower requirements on packaging rigidity. Additionally, in some embodiments the systems described herein may include performant flexible batteries with a tunable stiffness that are robust to cyclic deformation (e.g., during don/doff of wearable devices), thereby further decreasing required packaging rigidity while also enabling improved fit and comfort.

[0011] In one embodiment, the systems described herein may apply a thin, lightweight, flexible hermetic coating to batteries. Due to the moisture sensitivity of Li-ion cells, packaging hermeticity is critical to battery performance. In some examples this coating may include chemical vapor disposition and/or atomic layer disposition oxide/polymer multi-layer coatings and/or deposited Ta-C (polycrystalline diamond) deposition. Additionally or alternatively, the coating may include nano-laminated metal oxides/polyamide stretchable moisture- and gas-barrier films by integrated atomic/molecular layer deposition.

[0012] In one embodiment, a structural battery may include thin, directly-overmolded cosmetic packaging. This cosmetic packaging may be the external layer of the product that directly comes into contact with the consumer. Assembling batteries into pre-formed device packaging often allocates significant volume to account for manufacturing tolerances. This

volume can be recovered by using manufacturing approaches that enable directly overmolding batteries. Structural batteries plus direct overmolding may enable significant decrease in required packaging wall thickness which, when paired with advancement in molding technology, further decreases weight and volume.

[0013] Additionally or alternatively, a structural battery may include shaped cell design. In some embodiments, 3D shaped cells may be arranged via a combination of built-in stack curvature and terraced stack design. Combined, these may allow batteries to be extended into underutilized sections (e.g. the curved temple tips of glasses temple arms for smart glasses, etc.). The shape can be defined by stacking the cell layers in a shaped mold and/or by stacking the layers in a flat mold which is subsequently shaped.

[0014] For example, as illustrated in FIG. 1, a structural battery may be shaped to match the curvature of the temple arm of a pair of smart glasses, using space that would have been wasted if the battery were cuboidal in shape. As illustrated in FIG. 2, a structural battery that is capable of withstanding torque may be used in various curved elements of a device that sustain torque during usage of the device, such as the end of a temple arm of a pair of smart glasses that sustains torque when donned or doffed. As illustrated in FIG. 3, in some embodiments, structural batteries may be distributed throughout multiple parts of a device, such as different locations in the temple arm of a pair of smart glasses. Although illustrated as a component of smart glasses, a structural battery may be used in various types of wearable and non-wearable devices.

[0015] In some aspects, the techniques described herein relate to a method including coating a battery with a multi-layer hermetic coating; and overmolding the coated battery such that the coating remains intact through the overmolding process.

[0016] In some aspects, the techniques described herein relate to a method, wherein overmolding the coated battery includes overmolding the coated battery into a curved shape.

[0017] In some aspects, the techniques described herein relate to a method, wherein the battery includes a plurality of layers such that at least two layers within the plurality include at least two distinct form factors.

[0018] In some aspects, the techniques described herein relate to a method, further including coating the coated battery with a cosmetic packaging layer.

[0019] In some aspects, the techniques described herein relate to a method, further including constructing a wearable device using the coated battery as a structural element of the wearable device.

[0020] In some aspects, the techniques described herein relate to a method, wherein the wearable device includes a pair of smart glasses and the structural element includes a temple arm of the smart glasses.

[0021] In some aspects, the techniques described herein relate to a method, further including injecting an electrolyte solution into the battery.

[0022] The process parameters and sequence of the steps described and/or illustrated herein are given by way of example only and can be varied as desired. For example, while the steps illustrated and/or described herein may be shown or discussed in a particular order, these steps do not necessarily need to be performed in the order illustrated or discussed.

The various exemplary methods described and/or illustrated herein may also omit one or more of the steps described or illustrated herein or include additional steps in addition to those disclosed.

[0023] The preceding description has been provided to enable others skilled in the art to best utilize various aspects of the exemplary embodiments disclosed herein. This exemplary description is not intended to be exhaustive or to be limited to any precise form disclosed. Many modifications and variations are possible without departing from the spirit and scope of the present disclosure. The embodiments disclosed herein should be considered in all respects illustrative and not restrictive. Reference should be made to any claims appended hereto and their equivalents in determining the scope of the present disclosure.

[0024] Unless otherwise noted, the terms “connected to” and “coupled to” (and their derivatives), as used in the specification and/or claims, are to be construed as permitting both direct and indirect (i.e., via other elements or components) connection. In addition, the terms “a” or “an,” as used in the specification and/or claims, are to be construed as meaning “at least one of.” Finally, for ease of use, the terms “including” and “having” (and their derivatives), as used in the specification and/or claims, are interchangeable with and have the same meaning as the word “comprising.”