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Clad battery connector system

Abstract

A battery cell connector for use with an external device. In an aspect, the battery cell connector comprises a body with at least three layers, configured to simultaneously provide improved weldability and conductivity. In the same aspect, the battery cell connector comprises a terminal connected to the terminal arm of the body of the cell connector and a voltage transmitting component connected to said terminal, wherein the voltage transmitting component is configured to connect to an external device on the opposing end.

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Background/Summary

TECHNICAL FIELD

(1) This disclosure relates to battery connector systems.

BACKGROUND

(2) As battery cells improve, there is a need to have better battery connecting systems, especially for connections between the batteries and a battery management system (BMS). Currently, the use of lithium ion (Li-ion) batteries in such battery cells has increased dramatically. Such battery cells need to be able to be connected in series and parallel arrangements to create battery packs and connect to the BMS, which monitors and protects for overcharge and undercharge of individual

battery cells (as well as other battery pack related functions). Traditional nickel strip and copper alloys have been used to form these connectors (See FIGS. 1 and 2). However, utilizing only copper or nickel strips has drawbacks. For example, copper has higher electrical and thermal conductivity properties, but is hard to weld and solder. Conversely, nickel strips have better weldability and solderability to battery management systems (BMS), but lower electrical and thermal conductivity. Further, many mono metal battery connectors require a lot of material to be used to connect the battery cells to the BMS. Such a design can be more expensive, and less effective.

(3) To overcome these limitations, clad materials have been produced for connectors. While such a system has its advantages, there are some drawbacks. For example, the more metal layers in a clad material, the costlier the clad material. Further, when the clad material is processed (e.g., stamping out parts out of flat stock), the scrap reclaim value is less than that of mono metal, requiring the need for more efficient cell connector geometries when using clad material. In some instances, these connectors are configured to connect directly to the battery cells and BMS, requiring more material. Further, in some instances, the clad material is plated to facilitate solderability to a BMS. Another challenge for cell connectors is that they are designed with large scrap yields. This is okay for systems that are mono metal due to high scrap reclaim. However, clad systems are very sensitive to large scrap yields compared to mono metal systems because the reclaim value (i.e., the ability to reuse the material) is much lower.

(4) Therefore, there is a need for a system that addresses the shortcomings discussed above.

SUMMARY

(5) It is to be understood that this summary is not an extensive overview of the disclosure. This summary is exemplary and not restrictive and it is intended to neither identify key or critical elements of the disclosure nor delineate the scope thereof. The sole purpose of this summary is to explain and exemplify certain concepts of the disclosure as an introduction to the following complete and extensive detailed description.

(6) The present disclosure relates to a system, apparatus, and method for a clad battery cell connector with a connecting wire configured to transmit voltage readings to a battery management system (BMS) by being connected at one end to the body of a battery connector via a terminal that can be welded to the battery connector body and at the other end to a BMS. In an aspect, the clad battery connector can be configured to include three clad layers of metal that do not require plating. In such aspects, the clad battery connector can include a stainless steel/copper/stainless configuration. In some of these aspects, the clad battery connector can include a 304SS/Cu/304SS configuration. In an aspect, the clad battery connector including a 304SS/Cu/304SS configuration provides enhanced weldability and conductivity properties essential for voltage management devices. In an aspect, the battery connector body can be welded to the terminals of the plurality of batteries. In an aspect, the connecting wire connects the clad battery connector to the BMS. In an aspect, the connecting wire can include a tinned copper wire. In an aspect, the wire can be crimped into a terminal at one end to be welded to the clad battery connector. In an aspect, the connecting wire can include a BMS connector end configured to be soldered directly to a BMS for cell voltage management. In an aspect, the use of a three-layered clad battery connector body combined with a voltage transmitting wire attached via crimp terminal reduces manufacturing costs and material waste.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The features and components of the following figures are illustrated to emphasize the general principles of the present disclosure. Corresponding features and components throughout the figures

can be designated by matching reference characters for the sake of consistency and clarity.

(2) FIG. 1 illustrates a typical battery connector system known in the art.

(3) FIG. 2 illustrates the battery connector system of FIG. 1.

(4) FIG. 3 illustrates a comparison of a part designed for good material yield and a part designed for poor material yield.

(5) FIG. 4 illustrates a high scrap yield design for connectors known in the art.

(6) FIG. 5 illustrates the stamping schematics for the high scrap yield design illustrated in FIG. 4 as well as the required dimensions (e.g. stock width and advance).

(7) FIG. 6 illustrates a battery connector system according to an aspect of the current invention.

(8) FIG. 7 illustrates the stamping schematics for the current invention illustrated in FIG. 6 as well as the required dimensions (e.g. stock width and advance).

(9) FIGS. 8 and 8A-C illustrate the integration of the battery connector system of FIG. 6 in connection with a Battery Management System (BMS).

(10) FIGS. 9 and 9A-C illustrate a battery connector system integrated with a BMS and batteries according to an aspect of the present invention.

DETAILED DESCRIPTION

I. Definitions

(11) As used herein, range values may vary $\pm 10\%$ depending on properties such as finishing thickness or manufacturing conditions.

(12) As used herein, “American Wire Gauge (AWG)” describes the diameter of wires used in the current invention. This metric involves a logarithmic stepped standardized wire gauge.

(13) As used herein, “International Annealed Copper Standard (IACS)” represents the percentage at which a material can conduct electrical current relative to that of copper, a known conductor with an IACS value of 100%.

(14) As used herein, “crimped” refers to an item that has undergone a compression resulting in a fold. In the context of the current invention, a wire may be crimped into a terminal such that the terminal and wire are sufficiently connected.

(15) As used herein, “weldable” refers to how easily welded a material is. In order to be considered easily welded, a material must be compatible with a variety of welding techniques (e.g. TIG, MIG, Stick, etc.) and not require undue surface preparation to ensure a quality weld. Other aspects contributing to a material being weldable include low thermal and electrical conductivity, which allow heat to not be easily conducted away from the welding joint.

(16) As used herein, “tinned” refers to a material that has been coated in a layer of tin such that the material can easily be soldered to another surface. The material which has been tinned typically is not easily soldered, which presents the need for this process.

II. Battery Cell Connector System

(17) The present disclosure can be understood more readily by reference to the following detailed description, examples, drawings, and claims, and their previous and following description.

However, before the present devices, systems, and/or methods are disclosed and described, it is to be understood that this disclosure is not limited to the specific devices, systems, and/or methods disclosed unless otherwise specified, as such can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting.

(18) The current invention is directed towards a battery cell connector system **10** that includes a battery connector **100** with a voltage transmitting component **200** to connect to a battery management system (BMS) **30**, as shown in FIGS. 6-9. In an aspect, the battery connector **100** is configured to engage/touch/connect a plurality of battery cells **20**, and the voltage transmitting component **200** is configured to connect the cladded battery connector to an external device, such as a BMS **30**.

(19) In an aspect, the battery connector **100** includes a body **110** made from a clad material. In a

portion of these aspects, the clad material comprises at least a three-layer clad material, though more layers could be used if necessary based on application. However, it is preferable that clad material that forms the body **110** includes at least one inner layer **112** and two outer layers **114** (e.g., see FIGS. **8A** and **9A**). In an aspect, the layers of the body are configured such that the outer layers **114** are highly weldable while an inner **112** layer is highly conductive. In an aspect, current from the batteries **20** in contact with the battery connector body **110** will follow a path of least electrical resistance through the outer, weldable layers **114** into the inner, conductive layer **112**. In an aspect, using three layers may reduce production costs associated with more layers (e.g. five-layered clad materials). The clad material is configured to be non-plated. Eliminating plating can reduce production cost. However, such an elimination can produce potential soldering issues, which the voltage transmitting component **200** addresses, as shown below.

(20) In aspects of the battery connector system **10** that include a three-layered clad material body **110**, the outer layers **114** can be steel, stainless steel, or an alloy thereof with an inner layer **112** of copper or copper alloys, with the stainless steel of the outer layers **114** surrounding the copper of the inner layer **112**. In such aspects, steel, stainless steel, or alloys thereof are selected for the outer layers **114** due to high weldability. In these aspects, a variety of stainless steel grades (e.g., 304 SS, 316SS, 430 SS, etc.) can be utilized. In other aspects, other weldable metals, including, but not limited to, nickel, aluminum, brass, and alloys thereof, can be utilized for the other layers **114**.

(21) In an aspect, copper and copper alloys are selected for the inner layer **112** due to high electrical conductivity. In other aspects, highly conductive metals, including, but not limited to, silver, gold, aluminum, zinc, nickel, brass, bronze, and alloys thereof, can be utilized for the inner layer **112**. In other aspects, various other materials can be utilized.

(22) In an exemplary aspect, the three-layer clad material has a 304 SS/Cu/304 SS configuration though other grades of stainless steel could be used. In another aspect, a five-layer clad material can be utilized as well. For example, five layer clad materials having configurations of Ni/304 SS/Cu/304 SS/Ni or Ni/430 SS/Cu/430 SS/Ni can be utilized.

(23) In an aspect, the IACS of the three-layer clad material can range between 40% to 80% while the IACS of the five-layer clad material can range between 26% to 60%. In an aspect, the thermal conductivity of both the three-layer clad and the five-layer clad material can range between 178 W/m-K to 317 W/m-K. Electrical conductivity can be converted to an estimate of Thermal Conductivity through the Wiedemann-Franz law.

(24) In an aspect, the tensile strength of the three-layer clad material can range between 282 MPa to 475 MPa while the tensile strength of the five-layer clad material can range between 360 MPa to 550 MPa. In an aspect, the yield strength of the three-layer clad material can range between 93 MPa to 205 MPa while the yield strength of the five-layer clad material can range between 110 MPa to 265 MPa. In an aspect, the density of the three-layer clad material and the five-layer clad material can range between 8,415 kg/m³ to 8,666 kg/m³. In an aspect, the elongation percentage of the three-layer clad material and the five-layer clad material can range between 43% to 48%. In an aspect, the Erichsen cup height of the three-layer clad material and the five-layer clad material can range between 11.2 mm to 11.9 mm. In an aspect, the elastic modulus of the three-layer clad material and the five-layer clad material can range between 131 GPa to 165 GPa. In an aspect, the constant of thermal expansion of the three-layer clad material and the five-layer clad material can range between 16.6 $\mu\text{m/m}^\circ\text{C}$. to 17.1 $\mu\text{m/m}^\circ\text{C}$.

(25) In an aspect, the specific heat of the three-layer clad material and the five-layer clad material can range between 413 J/kg- $^\circ\text{C}$. to 447 J/kg- $^\circ\text{C}$. In an aspect, the resistivity of the three-layer clad material and the five-layer clad material can range between 2.155×10^{-8} ohm-m to 4.310×10^{-8} ohm-m. The clad material can include additional properties, minus those ones attributable to the plating layer (e.g., nickel), similar to those of the clad materials

disclosed in U.S. patent application Ser. No. 14/730,921 (now granted U.S. Pat. No. 10,707,472), which is hereby incorporated by reference in its entirety. Additional exemplary properties (e.g. density, elastic modulus, etc.) of exemplary clad materials used in the invention are displayed in Table 1 below.

(26) TABLE-US-00001 TABLE 1 Composition Austenitic Stainless Steel/Copper/Austenitic Stainless Steel Ratio 40% Copper 60% Copper 80% Copper Physical Properties Li- Li- Li- 201 Nickel Ni Plated @ 20° C. (typical ionClad™ ionClad™ ionClad™ (Annealed) Steel (AISI properties) 40 Annealed 60 Annealed 80 Annealed 1020) Density (kg/m.sup.3) 8,415 8,580 8,666 8,900 7,870 Yield Strength 205 138 93 103 350 (MPa) Tensile Strength 475 368 282 414 420 (MPa) Elongation % 45 48 43 45 15 Erichsen Cup 11.2 11.9 N/A 12.1 N/A Height (mm) Elastic Modulus 165 148 131 207 186 (GPa) CTE: (μm/m° C.) 16.6 16.7 17.1 13.3 11.7 Thermal 178 253 317 79 52 Conductivity.sup.(2) (W/m-K) Specific Heat (J/Kg- 447 423 413 456 486 ° C.) Conductivity (% 40% 60% 80% 20% 11% IACS).sup.(1) Resistivity (ohm-m) 4.310E-08 2.874E-08 2.155E-08 8.621E-08 1.567E-07 .sup.(1)Properties can vary depending on finish thickness .sup.(2)Parallel to strip direction .sup.(3)Li-ionC1ad™80 mechanical properties based on limited data

(27) The clad material that forms the body **110** of the battery connector **100** can be bonded together via various methods, including rolling, cold-bond rolling, and other known bonding methods. By utilizing a clad material for the battery connector **100**, a combination of properties of two different materials can be utilized. By utilizing copper or a copper alloy thereof and steel, stainless steel or an alloy thereof, the battery connector **100** has a combination of higher electrical and thermal conductivity due to the inner layer **112** of copper or a copper alloy thereof and a high weldability from the outer layer **114**, the layer that will be welded, of steel, stainless steel, or an alloy thereof. In an aspect, the outer steel layer **114** is highly weldable due to its ability to be used in a variety of welding applications with low surface preparation. In a preferred aspect, the outer steel layer **114** can be welded via resistance welding. In other aspects, the outer steel layer can be welded via TIG welding, Micro TIG welding, laser welding, ultrasonic welding, and other known welding techniques.

(28) The clad material can be formed into the body **110** of the battery connector **100** in numerous ways. In an aspect, the body **110** of the battery connector **100** is stamped out of flat stock of the clad material (see FIG. 7). However, other methods known in the art can be used to make the connector **100**. In an aspect, the battery connector **100** can be made into numerous forms that are dependent on the number and needed configuration of the battery cells **20**.

(29) In general, the battery connector **100** will have a number of arms **120** (e.g., FIGS. 6 and 8-9), some of which may include battery engagement tabs **122**, depending on the form of welding used to contact the body **110** to the battery cells **20**, extending from a central member **124**. For example, the clad battery connector **100** is configured to have five arms **120**, four of which are configured to engage four LI-ion battery cells **20** in parallel. The fifth arm **120** can be configured to be a terminal arm **126**. However, in other aspects, various other types of battery cells **20**, in series, parallel, or both, as well as other numbers of cells **20**, can be utilized. Likewise, the lengths, widths, and orientation (flat, angled, shortened, etc.) of the arms **120** can vary dependent on the ultimate layout of the battery cells **20**, and their relation to the BMS **30**.

(30) In an aspect, a terminal **150** can be connected to the outer surface/outer layer **114** of the battery connector **100**, as shown in FIGS. 8, 8B, 9, and -9B. In some aspects, the terminal **150** can be connected to the terminal arm **126** of the connector **100**. The terminal **150** can be selected from a material such that it is easily welded to the outer layer **114** of the battery connector body **110**. Easily welded materials can be selected from stainless steel, steel, nickel, aluminum, brass, alloys thereof, and other easily welded materials known in the art. In an aspect, the terminal **150** can be a crimped terminal **150** welded to the battery connector **110** (e.g. at the terminal arm **126**) on one side **152** while receiving the voltage transmitting component **200** via crimping on the other side **154**. In

other aspects, other known varieties of terminals **150** could be used to connect the voltage transmitting component **200** and battery connector **100**, such as welding a male terminal feature on the battery cell connector body **110**, crimping a female terminal onto the voltage transmitting component **200**, and inserting the two terminals into each other.

(31) As discussed previously, battery connectors used today traditionally include an integrated BMS connector with the connector body, as shown in FIG. 1. The battery connector system **10** of the current invention does not have an integrated BMS connector attached to the top of the body of the battery connector **100**; instead, the battery connector system **100** utilizes a voltage transmitting component **200** to replace the integrated BMS connector as displayed in FIG. 6. Using the voltage transmitting component **200** eliminates the need of an integrated BMS connector, made from the same clad material or a mono metal in the case of the prior art. Thus, the manufacture of the battery connector system **10**, and more specifically the battery connector **100**, is easier with lower material requirements and costs. Lower material requirements facilitate a lighter device in the case of the current invention when compared to the prior art. A comparison of prior art material requirements and costs to those of the current invention is shown in Table 2 below. Further, by utilizing a voltage transmitting component **200**, a smaller scrap yield is designed, as shown in FIGS. 5 and 7. That is, less material has to be cut from the clad material to make the battery connector body **110** and arms **120**, **126**. While it is okay to design connectors of mono metals with large scrap yields due to the high scrap reclaim, the same cannot be said of clad metal connectors. Scrap cannot be as easily reclaimed with clad materials as there are multiple materials that are in the scrap.

(32) TABLE-US-00002 TABLE 2 Material Integrated 22 Total Battery Part Weight Cost (\$ per AWG 40 mm Connector Design Style (Kg/lbs) Kg/\$ per lb) Wire Cost (\$) System Cost (\$) Prior Art 0.0068/ 16/7.27 0 0.109 with 0.015 Integrated BMS Connector (No Wire) Li-ion Clad 0.0023/ 21/9.55 0.0409 0.087 Connector 0.0049 with Integrated Wire-Lead (Current Invention)

(33) In an aspect, a voltage transmitting component **200** can be used to connect the battery connector **100** to the BMS **30**. As the main purpose of the voltage transmitting component **200** is to pass along enough current for voltage readings (which tends to be low current compared to that transmitted through the body **110**) for the BMS **30** to monitor the status of the battery cells **20**, via the battery connector **100**, the voltage transmitting component **200** will typically have a high conductivity value. The length, gage, and other characteristics (e.g. stranded or solid) of the voltage transmitting component **200** can be selected from a variety of combinations depending on application requirements.

(34) In an aspect, the voltage transmitting component **200** has a battery connector end **210** and a BMS connecting end **220**. In an aspect, the voltage transmitting component **200** can be a wire **200**. In such aspects, the wire **200** includes a tinned copper wire. In other aspects, the voltage transmitting component **200** can be any suitable conductive material such as copper, silver, gold, aluminum, zinc, nickel, brass, bronze, alloys thereof, and other materials known in the art. In extreme environments, the voltage transmitting component **200** can be coated with Teflon. In aspects, when the conductive material used for the voltage transmitting component **200** is not solderable (e.g., copper), the voltage transmitting component **200** at least at the BMS connecting end **220** is treated so that it can be soldered to the BMS **30** as shown in FIGS. 8-9. In such aspects, the BMS connecting end **30** can be tinned. In aspects of the voltage transmitting component **200** being solderable (e.g., nickel), tinning is not necessary.

(35) In an aspect, the voltage transmitting component **200** at the battery connector end **210** may be crimped (e.g., putting a terminal on the end) to allow resistance welding to the battery connector **100**, as shown in FIGS. 9 and 9B. The BMS connector end **220** of the voltage transmitting component **200** is configured to be soldered directly to a BMS **30** (FIGS. 8C and 9C). The length and the cross-section of the voltage transmitting component **200** can vary based upon the function, size, and location, relative to the battery connector **100**, of the BMS **30**. For example, if the voltage transmitting component **200** to the battery connector **100** is strictly for measuring cell voltage, the

cross-section can be small. In other aspects, when the voltage transmitting component **200** is used for connecting directly to the load, a voltage transmitting component **200** with a larger cross-section can be used. In an exemplary aspect, the voltage transmitting component **200** may be 22 AWG 7/30 stranded tinned copper wire with a length of 40 mm, though other voltage transmitting components may be used. In such an aspect, PVC wire insulation may be used. In additional aspects, AWG sizes of the voltage transmitting component may range from AWG 18 to AWG 26, but other sizes can also be employed. In additional aspects, stranding configurations of the voltage transmitting component may include, but are not limited to, 19/23, 19/29, and other available stranding configurations. In additional aspects, lengths of the voltage transmitting component may range from 15 mm to 600 mm, but other lengths can also be employed. In additional aspects, the voltage transmitting component may comprise solid wire configurations. The variety of configurations for the voltage transmitting component, **200**, described above afford a customizability in using the battery cell connector system, **10**, with a variety of configurations of pluralities of battery cells, **20**. The combined effect of the voltage transmitting component, **200**, with a previously described terminal, **150**, allows the decoupling of the battery connector body, **110**, from the voltage transmitting component, **200**, for total design customizability.

(36) In an aspect, the voltage transmitting component **200** is connected to a BMS **30** as to measure voltage outputs from a plurality of battery cells **20**. Measuring voltage outputs of batteries **20** in series or parallel allows maintenance of battery safety and reliability. In an aspect, a charge voltage of 4.8V and a discharge voltage of 2.5V, managed by the BMS **30** are desired. In other aspects, the voltage transmitting component **200** is connected to an external device selected from a BMS **30**, a voltmeter, and other devices known in the art that monitor properties of battery cells **20**. In an aspect, the voltage transmitting component **200** can assist in providing measured properties of the battery cells **20** that include capability estimation, state of charge, state of health, thermal management, load, current, and other properties known in the art to be important in the functioning of batteries and other electrical devices.

(37) Although several aspects have been disclosed in the foregoing specification, it is understood by those skilled in the art that many modifications and other aspects will come to mind to which this disclosure pertains, having the benefit of the teaching presented in the foregoing description and associated drawings. It is thus understood that the disclosure is not limited to the specific aspects disclosed hereinabove, and that many modifications and other aspects are intended to be included within the scope of any claims that can recite the disclosed subject matter.

(38) It should be emphasized that the above-described aspects are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the present disclosure. Any process descriptions or blocks in flow diagrams should be understood as representing modules, segments, or portions of code which comprise one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included in which functions may not be included or executed at all, can be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present disclosure. Many variations and modifications can be made to the above-described aspect(s) without departing substantially from the spirit and principles of the present disclosure. Further, the scope of the present disclosure is intended to cover any and all combinations and sub-combinations of all elements, features, and aspects discussed above. All such modifications and variations are intended to be included herein within the scope of the present disclosure, and all possible claims to individual aspects or combinations of elements or steps are intended to be supported by the present disclosure.

Claims

1. A battery cell connector for use with a battery management system (BMS), the battery cell connector comprising: a. a non-plated battery connector body configured to connect a plurality of batteries, wherein the body consists of three layers comprised of two outer layers and one inner layer, wherein the body is: i. highly electrically conductive having a range of 26% IACS to 80% IACS; ii. highly weldable having a range of 178 W/mK to 317 W/mK; and iii. wherein the body comprises stainless steel and copper; b. a terminal in communication with the battery connector via a welded connection; and c. a wire voltage transmitting component having a terminal end and a BMS end, wherein the terminal end is crimped to be connected to the terminal and wherein the BMS end is tinned in order to be soldered to the BMS.
 2. The battery cell connector of claim 1, wherein the outer layers of the body are selected from metals that are highly weldable having a range between 178 to 317 W/mK.
 3. The battery cell connector of claim 1, wherein an inner layer is comprised of a conductive metal.
 4. The battery cell connector of claim 1, wherein the body is connected to a plurality of batteries by welding the body directly to battery terminals of the plurality of battery terminals.
 5. The battery cell connector of claim 1, wherein the wire of the voltage transmitting component is copper tinned.
 6. The battery cell connector of claim 1, wherein the voltage transmitting component is configured to pass along to the BMS a property of the plurality of batteries.
 7. The battery cell connector of claim 6, wherein the property being measured is selected from capability estimation, state of charge, state of health, thermal management, or voltage.
 8. The battery cell connector of claim 7, wherein the voltage measured is charge and discharge voltages.
 9. The battery cell connector of claim 1, wherein the layers of the body further comprises nickel.
 10. The battery cell connector of claim 1, wherein the body has a tensile strength ranging between approximately 282 MPa to 550 MPa.
 11. The battery cell connector of claim 1, wherein the non-plated battery connector is absent nickel.
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