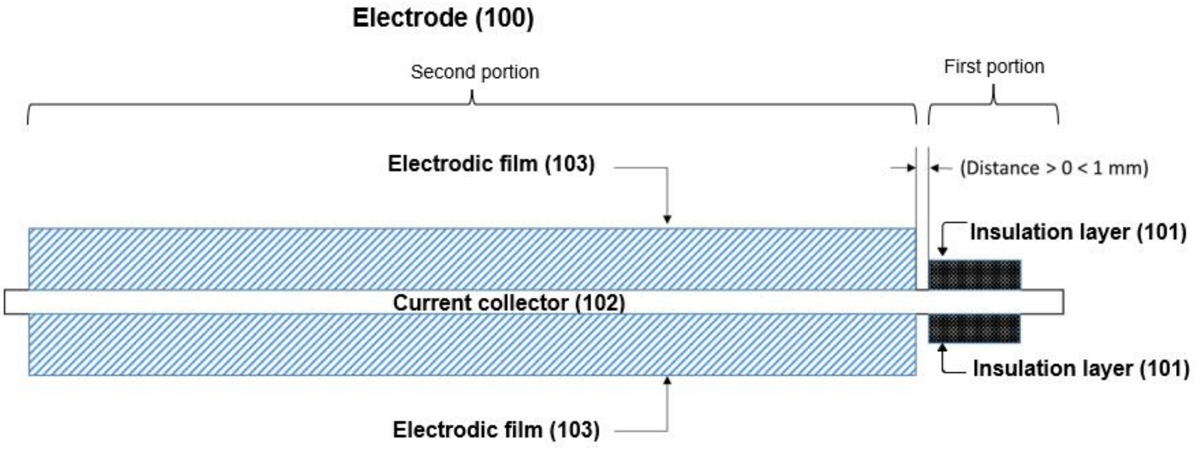

Figure 1

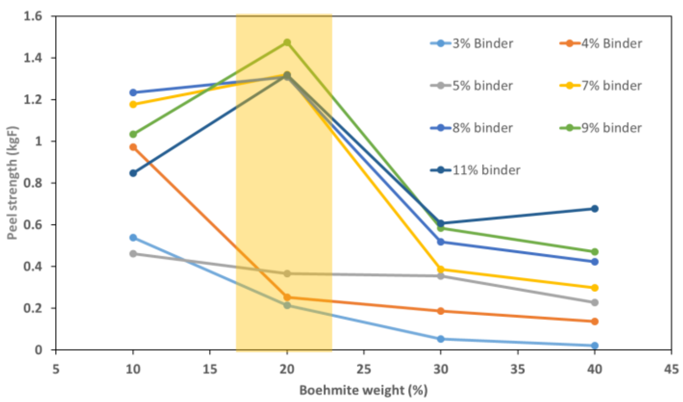

Figure 2

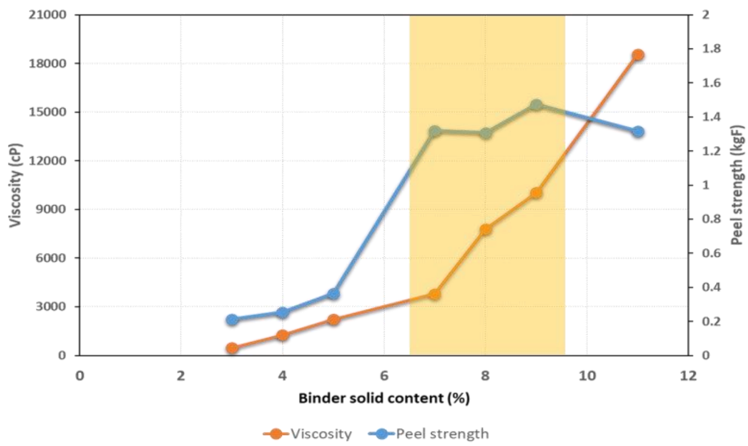

Figure 3

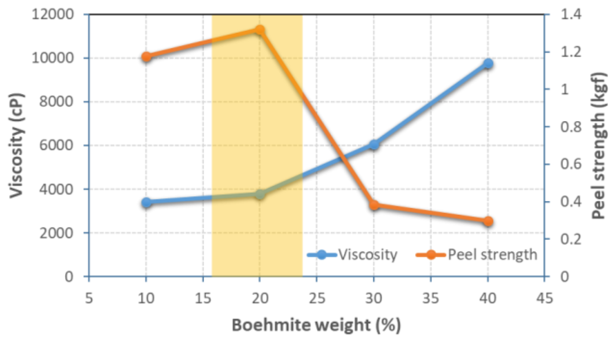

Figure 4

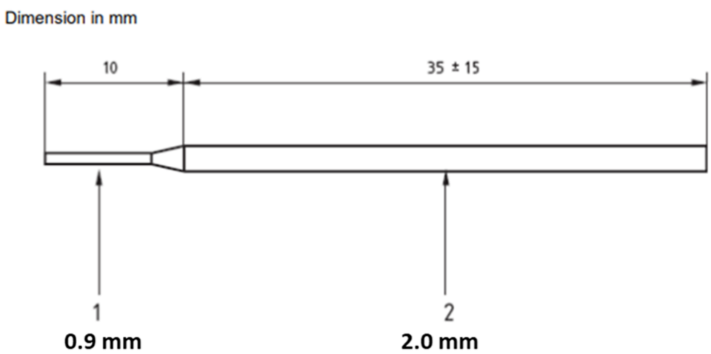

Figure 5

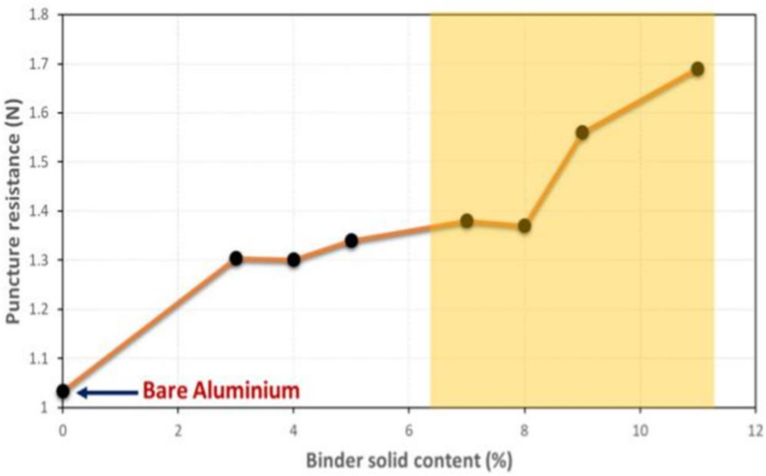

Figure 6

PRASHANT PHILLIPS
IN/PA-1229
Agent for the Applicant

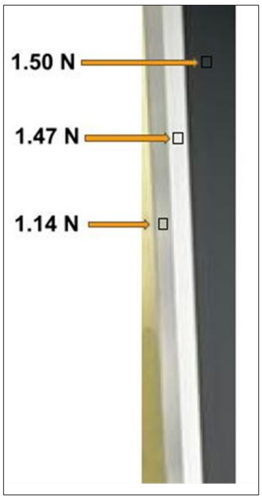

Figure 7

PRASHANT PHILLIPS
IN/PA-1229
Agent for the Applicant

FORM 2

THE PATENTS ACT, 1970
(39 of 1970)
&
THE PATENTS RULES, 2003

COMPLETE SPECIFICATION
(See section 10, rule 13)

***1. Title of the invention*:** AN ELECTRODE COMPRISING INSULATION LAYER WITH HIGH MECHANICAL-STRENGTH AND PREPARATION THEREOF

2. Applicant(s)

NAME	NATIONALITY	ADDRESS
OLA ELECTRIC MOBILITY LIMITED	Indian	Regent Insignia, #414, 3rd Floor, 4th Block, 17th Main, 100 Feet Road, Koramangala, Bangalore, Karnataka 560034, India

3. Preamble to the description

COMPLETE SPECIFICATION

The following specification particularly describes the invention and the manner in which it is to be performed.

FIELD OF INVENTION

[0001] The subject matter of the present disclosure broadly relates to the field of battery. Particularly, the present disclosure relates to electrode.

BACKGROUND OF THE INVENTION

[0002] The rapid increase of lithium-ion batteries in daily life has raised concerns regarding safety and durability issues of lithium-ion batteries. These batteries are formed of positive and negative electrodes. These electrodes are manufactured by applying a mixture layer to both sides of current collector, followed by drying and pressing. Many positive and negative electrodes have an exposed portion-tab region, at the end of the current collector as a current path.

[0003] In cylindrical 4680 cells, tab regions are being crushed as a part of cell design. During the tab crushing at the cathode side the active material coated region also gets crushed along with the tab region (which is generally made of Aluminum) and results in short circuit with the anode. Hence, a technique for preventing or insulating the exposed portion from a short circuit is always required.

[0004] Several research have focussed on the development of various coating composition comprising ceramic material for insulation of tab region. Generally, boehmite coating has been used at the tab region. This can enhance the stability and structural integrity of current collector in the electrode. In general, the boehmite coating was carried out with highly viscous boehmite ink (viscosity around 20kcp - 440 kcp) in nozzle type coater. But coating this highly viscous boehmite ink would be a challenge in the slot die machine. The slot die machine can coat with a viscosity limitation of around 6kcp and coating could not be executed for slurries exceeding this value.

[0005] Hence, there is a need to develop a compatible, high mechanically strengthened electrode with an effective coating composition, which can overcome the effect of tab crushing on the electrode and the challenge regarding working conditions of slot die machine.

SUMMARY OF THE INVENTION

[0006] In an aspect of the present disclosure, there is provided an electrode (100) comprising: a. an insulation layer (101); b. a current collector (102); and c. an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector.

[0007] In another aspect of the present disclosure, there is provided a process for preparing the electrode composition as described herein, the process comprising: a. mixing a first binder, a ceramic material, and a solvent to obtain a slurry of insulation layer; b. blending an active material, a conductive additive and a second binder to obtain a mixture of electrodic film; and c. coating the slurry of insulation layer on a first portion of the current collector and coating the mixture of electrodic film second portion of the current collector, to obtain an electrode.

[0008] In yet another aspect of the present disclosure, there is provided an electrochemical cell comprising: a cathode comprising the electrode as disclosed herein; an anode; and an electrolyte.

[0009] These and other features, aspects, and advantages of the present subject matter will be better understood with reference to the following description. This summary is provided to introduce a selection of concepts in a simplified form. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The following drawings form a part of the present specification and are included to further illustrate aspects of the present disclosure. The disclosure may be better understood by reference to the drawings in combination with the detailed description of the specific embodiments presented herein.

[0011] Figure 1 depicts the diagrammatic representation of electrode, in accordance with an embodiment of the present disclosure.

[0012] Figure 2 depicts the variation of peel strength with boehmite content (%), in accordance with an embodiment of the present disclosure.

[0013] Figure 3 depicts the variation in viscosity and peel strength with binder solid content (%), in accordance with an embodiment of the present disclosure.

[0014] Figure 4 depicts the variation in viscosity and peel strength with Boehmite concentration (%), in accordance with an embodiment of the present disclosure.

[0015] Figure 5 depicts the probe used for measurement of puncture resistance, in accordance with an embodiment of the present disclosure.

[0016] Figure 6 depicts effect of binder solid content on puncture resistance, in accordance with an embodiment of the present disclosure.

[0017] Figure 7 depicts puncture resistance for the bare aluminium foil, boehmite coating and cathode surface, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Those skilled in the art will be aware that the present disclosure is subject to variations and modifications other than those specifically described. It is to be understood that the present disclosure includes all such variations and modifications. The disclosure also includes all such steps, features, compositions, and compounds referred to or indicated in this specification, individually or collectively, and any and all combinations of any or more of such steps or features.

Definitions

[0019] For convenience, before further description of the present disclosure, certain terms employed in the specification, and examples are delineated here. These definitions should be read in the light of the remainder of the disclosure and understood as by a person of skill in the art. The terms used herein have the meanings recognized and known to those of skill in the art, however, for convenience and completeness, particular terms and their meanings are set forth below.

[0020] The articles “a”, “an” and “the” are used to refer to one or to more than one (i.e., to at least one) of the grammatical object of the article.

[0021] The terms “comprise” and “comprising” are used in the inclusive, open sense, meaning that additional elements may be included. It is not intended to be construed as “consists of only”.

[0022] Throughout this specification, unless the context requires otherwise the word “comprise”, and variations such as “comprises” and “comprising”, will be understood to imply the inclusion of a stated element or step or group of elements or steps but not the exclusion of any other element or step or group of element or steps.

[0023] The term “including” is used to mean “including but not limited to”. “Including” and “including but not limited to” are used interchangeably.

[0024] The term “w/w” means the percentage by weight, relative to the weight of the total composition, unless otherwise specified.

[0025] The term "at least one" is used to mean one or more and thus includes individual components as well as mixtures/combinations.

[0026] The term “electrodic film” refers to the film or layer of an electrode which comprises an active material, binder and conductive additives that take part in the electrochemical reaction. The electrodic film may be cathodic film comprising a cathode active material or anodic film comprising an anode active material. In an aspect of the present disclosure, there is provided an electrode comprising an electrodic film, an insulation layer and a current collector, wherein the electrodic film is a cathodic film comprising a cathode active material, a second binder and a conductive additive.

[0027] The term “active material” refers to the active constituent of an electrode, which comprises the particles that undergo oxidation or reduction, resulting in reversible ion storage. Examples of active material in the present disclosure includes but not limited to layered oxides, nickel manganese cobalt (NMC), nickel cobalt aluminium (NCA), lithium iron phosphate (LFP), lithium manganese iron phosphate (LMFP), or combinations thereof.

[0028] The term “conductive additive” refers to electrode components added to the system that facilitates access to energy by aiding the electron pathways in materials that are relatively poor at accepting charge. Examples of conductive additives could be electrically conductive carbon materials such as carbon black, graphene, mesoporous carbon, activated carbon, super P, carbon nanofiber, vapour grown carbon nanofiber, carbon nanotube, acetylene black, C60, carbon nanotube, graphene, few layered graphene, single layered graphene, or combinations thereof.

[0029] The term “insulation layer” refers to a layer which insulate the internal material from the surrounding which may be coated on the protruding direction of an electrode tab, depicted as (101) in Figure 1. The insulation layer is coated at a distance in a range of 0.1 to 1mm, from the active material coated region in order to avoid the masking of active material by the insulating layer. For the purpose of the present disclosure, the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide, or combinations thereof.

[0030] The term “current collector” refers to the electric bridging component which collects electrical current generated at the electrodes of electrochemical devices and connect with external circuits. For the purpose of the present disclosure, the current collector includes but not limited to aluminium foil, shiny aluminium foils, polymer sandwiched aluminium foil, or combinations thereof.

[0031] The term “binder” refers to the polymeric substance that provides adhesion and mechanical integrity, to the active material when loaded on a current collector to obtain an electrode. The binder of the present disclosure includes but not limited to polyvinylidene fluoride (PVDF), vinylidene fluoride (VDF), poly(vinylidene-co-hexafluoropropylene) (PVDF-HFP), polyacrylonitrile (PAN), polyamides, polytetrafluoroethylene, polyvinylidene fluoride, polyethylene oxide, fluoroethylene vinyl ether (FEVE), fluoroethylene polymer (FEP), or combinations thereof. In an aspect of the present disclosure, the term “first binder” refers to the binder substance employed in an insulation layer as disclosed herein along with a ceramic material. In another aspect of the preset disclosure, the first binder is selected from polyvinylidene fluoride (PVDF), vinylidene fluoride (VDF), poly(vinylidene-co-hexafluoropropylene) (PVDF-HFP), polyacrylonitrile (PAN), polyamides or combinations thereof. In yet another aspect of the present disclosure, the term “second binder” refers to the binder substance employed in an electrodic film along with an active material and optionally conductive additives. In still another aspect of the present disclosure, the second binder is selected from polytetrafluoroethylene, polyvinylidene fluoride, polyethylene oxide, fluoroethylene vinyl ether (FEVE), fluoroethylene polymer (FEP), or combinations thereof.

[0032] Ratios, concentrations, amounts, and other numerical data may be presented herein in a range format. It is to be understood that such range format is used merely for convenience and brevity and should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited.

[0033] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the disclosure, the preferred methods, and materials are now described. All publications mentioned herein are incorporated herein by reference.

[0034] The present disclosure is not to be limited in scope by the specific embodiments described herein, which are intended for the purposes of exemplification only. Functionally equivalent products, compositions, formulations, and methods are clearly within the scope of the disclosure, as described herein.

[0035] As discussed, there is a need for an electrode with a highly efficient mechanically strong, effective coating. In the cell design process tab crushing leads to crushing of cathode side, active material coated region which results in short circuit with the anode. Generally, ceramic coatings are carried out with highly viscous liquids using nozzle type injectors. To overcome all these issues there is a requirement of fabrication of an electrode with highly effective mechanically strengthening ceramic composition. This composition can be achieved by varying the binder solution solid content and maintaining the same ceramic material content. Further, this layer is coated at a distance from the active material coated region in order to avoid the masking of active material by the insulating layer. This ceramic coating will have a high mechanical integrity and insulating behaviour. During the tab crushing the insulation layer will not allow the external force to be transferred to the active material coated region and prevents it from getting crushed.

[0036] Accordingly, the present disclosure provides an electrode (100) comprising an insulation layer (101), a current collector (102), and an electrodic film (103), enable the uniform coating of the mix on the collector, thereby resulting in an electrode with high mechanical strength. The present disclosure also provides a process for preparing the electrode composition, an electrode, and an electrochemical cell comprising the composition.

[0037] The present disclosure is not to be limited in scope by the specific embodiments described herein, which are intended for the purposes of exemplification only. Functionally equivalent products, compositions, and methods are clearly within the scope of the disclosure, as described herein.

[0038] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector.

[0039] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated continuously with the insulation layer (101) on upper side and lower side of a first portion of the current collector and with the electrodic film (103) on upper side and lower side of a second portion of the current collector.

[0040] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated continuously with the insulation layer (101) on upper side of a first portion of the current collector and with the electrodic film (103) on upper side of a second portion of the current collector.

[0041] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector, wherein the ceramic material is in a weight range of 60 to 90 %, with respect to the total weight of the insulation layer. In another embodiment of the present disclosure, the ceramic material is in a weight range of 70 to 80 %, with respect to the total weight of the insulation layer. In yet another embodiment of the present disclosure, the ceramic material is in a weight range of 74 to 76 %, with respect to the total weight of the insulation layer.

[0042] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103)., wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder selected from polyvinylidene fluoride (PVDF), vinylidene fluoride (VDF), poly(vinylidene-co-hexafluoropropylene) (PVDF-HFP), polyacrylonitrile (PAN), polyamides or combinations thereof; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector.

[0043] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector, wherein the first binder has a solid content in a range of 5.5 to 10 %, with respect to the total weight of the insulation layer. In another embodiment of the present disclosure, the binder has a solid content is in range of 6 to 9%. In yet another embodiment of the present disclosure the binder has a solid content is in range of 6 to 8%. In still another embodiment of the present disclosure the binder has a solid content of 7%.

[0044] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material selected from layered oxides, nickel manganese cobalt (NMC), nickel cobalt aluminium (NCA), lithium iron phosphate (LFP), lithium manganese iron phosphate (LMFP), or combinations thereof, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer

(101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector.

[0045] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector, wherein the active material is in a weight range of 95 to 98%, with respect to the total weight of the electrodic film.

[0046] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive selected from carbon black, graphene, mesoporous carbon, acetylene black, activated carbon, super P, carbon nanofiber, vapour grown carbon nanofiber, carbon nanotube, or combinations thereof, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector.

[0047] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector, wherein the conductive additive is in a weight range of 1 to 4%, with respect to the total weight of the electrodic film.

[0048] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector, wherein the second binder is selected from polytetrafluoroethylene, polyvinylidene fluoride, polyethylene oxide, fluoroethylene vinyl ether (FEVE), fluoroethylene polymer (FEP), or combinations thereof.

[0049] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector, wherein the second binder is in a weight range of 0.1 to 3%, with respect to the total weight of the electrodic film.

[0050] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises 60 to 90 % by weight of a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder with a solid content in a range of 5.5 to 10 %, selected from polyvinylidene fluoride (PVDF), vinylidene fluoride (VDF), poly(vinylidene-co-hexafluoropropylene) (PVDF-HFP), polyacrylonitrile (PAN), polyamides or combinations thereof; wherein the electrodic film comprises

95 to 98% by weight of an active material selected from layered oxides, nickel manganese cobalt (NMC), nickel cobalt aluminium (NCA), lithium iron phosphate (LFP), lithium manganese iron phosphate (LMFP), or combinations thereof, 1 to 4% by weight of a conductive additive selected from carbon black, graphene, mesoporous carbon, acetylene black, activated carbon, super P, carbon nanofiber, vapour grown carbon nanofiber, carbon nanotube, or combinations thereof, and 0.1 to 3% by weight of a second binder selected from polytetrafluoroethylene, polyvinylidene fluoride, polyethylene oxide, fluoroethylene vinyl ether (FEVE), fluoroethylene polymer (FEP), or combinations thereof; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector.

[0051] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises 70 to 80 % by weight of a ceramic material of boehmite, and a first binder with a solid content in a range of 6 to 9 %, selected as polyvinylidene fluoride (PVDF), wherein the electrodic film comprises 95 to 98% by weight of an active material selected from nickel manganese cobalt (NMC), 1 to 4% by weight of a conductive additive selected from, super P, and 0.1 to 3% by weight of a second binder selected from polytetrafluoroethylene, and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector.

[0052] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector, wherein the first portion and the second portion are separated by a distance in a range of 0.01 to 1 mm.

[0053] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector, wherein the electrode has a peel strength in a range of 1 to 1.5 kgf; a puncture resistance in a range of 1.35 to 1.60 N. In another embodiment of the present disclosure, the electrode has a peel strength in a range of 0.2135 to 1.4745 kgf; a puncture resistance in a range of 1.30 to 1.69 N. In yet another embodiment of the present disclosure, the puncture resistivity measurement follows puncture resistance protocol of European standards (EN 14477:2004).

[0054] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector, wherein the insulation layer has an electrical resistivity in a range of 20000 to 25000 Ohm/cm.

[0055] In an embodiment of the present disclosure, there is provided an electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector, wherein the electrode is a cathode.

[0056] In an embodiment of the present disclosure, there is provided a cathode (100) composition comprising an insulation layer (101); a current collector (102); and a cathodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the cathodic film comprises a cathode active material selected from layered oxides, nickel manganese cobalt (NMC), nickel cobalt aluminium (NCA), lithium iron phosphate (LFP), lithium manganese iron phosphate (LMFP), or combinations thereof, a conductive additive selected from carbon black, graphene, mesoporous carbon, acetylene black, activated carbon, super P, carbon nanofiber, vapour grown carbon nanofiber, carbon nanotube, or combinations thereof, and a second binder selected from polytetrafluoroethylene, polyvinylidene fluoride, polyethylene oxide, fluoroethylene vinyl ether (FEVE), fluoroethylene polymer (FEP), or combinations thereof; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector. In an embodiment of the present disclosure, there is provided a process of an electrode as disclosed herein, process comprises, a. mixing a first binder, a ceramic material, and a solvent to obtain a slurry of insulation layer; b. blending an active material, a conductive additive and a second binder to obtain a mixture of electrodic film; and c. coating the slurry of insulation layer on a first portion of the current collector and coating the mixture of electrodic film second portion of the current collector, to obtain an electrode.

[0057] In an embodiment of the present disclosure, there is provided a process of an electrode as disclosed herein, process comprises, a. mixing a first binder, a ceramic material, and a solvent to obtain a slurry of insulation layer; b. blending an active material, a conductive additive and a second binder to obtain a mixture of electrodic film; and c. coating the slurry of insulation layer on a first portion of the current collector and coating the mixture of electrodic film second portion of the current collector, to obtain an electrode, wherein coating is carried out by slot die coating, gravure coating, roller coating, doctor blade coating, or the like.

[0058] In an embodiment of the present disclosure, there is provided a process of preparing an electrode as disclosed herein, wherein the slurry of insulation layer has a viscosity in a range of 2000 to 12000 cP at 50 s^{-1}. In another embodiment of the present disclosure, the insulation layer has a viscosity in a range of 2000 to 7000 cP at 50 s^{-1}. In yet another embodiment of the present disclosure, the insulation layer has a viscosity in a range of 3000 to 4000 cP at 50 s^{-1}. In still another embodiment of the present disclosure, the insulation layer has a viscosity in a range of 3500 to 4000 cP at 50 s^{-1}.

[0059] In an embodiment of the present disclosure, there is provided a process of an electrode as disclosed herein, wherein the solvent is selected from N-methyl pyrrolidone (NMP), dimethylformamide (DMF), dimethylacetamide (DMAc), dimethyl sulfoxide (DMSO), propylene carbonate (PC), or combinations thereof; and the solvent is in a weight range of 60 to 90% with respect to the weight of the slurry of insulation layer.

[0060] In an embodiment of the present disclosure, there is provided a process of an electrode as disclosed herein, wherein the slurry of insulation layer comprises the first binder has a solid content in a weight range of 5 to 25%, with respect to the total weight of the slurry of insulation layer.

[0061] In an embodiment of the present disclosure, there is provided a process of an electrode as disclosed herein, wherein the ceramic material has average particle size is in a range of 0.5 to 2 micron.

[0062] In an embodiment of the present disclosure, there is provided a process of an electrode as disclosed herein, wherein the ceramic material and first binder is in a weight ratio range of 6:1 to 10:1, with respect to the total weight of the slurry of insulation layer. In another embodiment of the present disclosure, the ceramic material and first binder is in a weight ratio range of 6.5:1 to 9.5:1, with respect to the total weight of the slurry of insulation layer. In yet another embodiment of the present disclosure, the ceramic material and first binder is in a weight ratio range of 8:1 to 9:1, with respect to the total weight of the slurry of insulation layer.

[0063] In an embodiment of the present disclosure, an electrochemical cell comprising: a cathode comprising the electrode (100) composition comprising an insulation layer (101); a current collector (102); and an electrodic film (103), wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector; an anode; and an electrolyte.

[0064] In an embodiment of the present disclosure, there is provided a battery comprising the electrochemical cell comprising: an anode comprising the electrode as disclosed herein; a cathode; and an electrolyte, wherein the electrochemical cell is in a form of cylindrical jelly roll cell, or the like.

[0065] Although the subject matter has been described in considerable detail with reference to certain examples and implementations thereof, other implementations are possible.

EXAMPLES

The disclosure will now be illustrated with working examples, which is intended to illustrate the working of disclosure and not intended to take restrictively to imply any limitations on the scope of the present disclosure. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this disclosure belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice of the disclosed methods and compositions, the exemplary methods, devices and materials are described herein. It is to be understood that this disclosure is not limited to particular methods, and experimental conditions described, as such methods and conditions may apply.

EXAMPLE 1

Preparation of the electrode

[0066] The objective of this example is to elaborate the method of preparing the disclosed electrode composition.

[0067] The electrode of the present disclosure comprises an insulation layer (101), a current collector (102) and an electrodic film (103). 3 to 11% by weight of Polyvinylidene fluoride (PVDF) (first binder) having were mixed in 89 to 97% by weight of N-methyl pyrrolidone (NMP) solvent to obtain different binder solutions having a solid content in a range of 3 to 11%. To these binder solutions, various concentrations of boehmite in a range of 10 to 40% were added to obtain various slurries of insulation layer.

[0068] 3% of PVDF was mixed in 97% by weight of NMP solvent to obtain a binder solution. 80% by weight of the binder solution about 20 % by weight of boehmite with respect to the total weight of the binder solution (ceramic material) having average particle size of about 0.5 to 2 micron was added to obtain slurries of insulation layer. About 97.5% by weight of nickel manganese cobalt (NMC)(active material), 1.5% by weight of super P (conductive additive), and 1% by weight of polytetrafluoroethylene (PTFE; second binder) were blended to obtain a mixture of an electrodic film. The mixture of the electrodic film was uniformly coated by slot die coating on upper side and lower side of a second portion of an aluminium current collector (102) and the slurry of insulation layer was coated on upper side and lower side of a first portion of the current collector by slot die coating, with first and second portion within $> 0 < 1$ mm apart, followed by drying to obtain an electrode. The electrode was roll pressed in the form of a film on top of the current collector in a two or multiple roller system, at a required pressure. The rollers were heated to have better compaction and solvent removal. Further, surface modifications or coatings were made optionally on the current collector to improve adhesion, thereby obtaining a stable electrode. Figure 1 shows the coating of insulation layer (101) on a first portion of current collector, and coating of electrodic film (103) on the second portion of the electrode.

EXAMPLE 2

Analysis of mechanical properties of electrode

The mechanical properties of electrode were analysed by using the electrode with various concentration of boehmite coating. The average particle size of boehmite coating was 1-2 micron.

A. Peel strength

The peel strength of the obtained electrodes was studied and analysed.

[0069] It was observed that peel strength of the insulation layer highly depended on the parameters of first binder solid content and weight percentage of ceramic material. The peel strength for various first binder solid content (3% to 11%) and various boehmite weight percentages (10% - 40% with respect to total weight of the binder and the solvent) were measured and plotted in Figure 2. It was observed that high peel strength was observed for the electrode having insulation layer with binder solid content from 7% to 9%. The peel strength was higher for boehmite weight of 20% with respect to total weight of the binder and the solvent. At higher binder solid content and boehmite content, the peel strength was found to be decreased. The optimal range for better peel strength was around 6 % to 9% as shown in Figure 3. Hence the best working binder solid content was found to be 7%.

[0070] The peel strength for various boehmite concentrations (10% - 40%) with 7% binder solid content were measured and plotted against viscosity as shown in Figure 4. The highest peel strength was observed that for 20% boehmite concentration (with respect to total weight of the binder and the solvent), and viscosity was also found within the limit of the range 3500 - 4000 cP. Hence, the best working value of boehmite concentration was observed to be 20%.

B. Puncture resistance

[0071] The mechanical integrity of electrode was analysed by measurement of puncture resistivity of the electrode. The puncture resistance measurement was carried out by the European standards (EN 14477:2004). It was done by using a probe with 0.9 mm diameter tip (Figure 5). The puncture resistivity was measured for 20% concentration of boehmite with respect to total weight of the binder and the solvent containing insulation layer coating with different binder solid content. It was observed that as soon as binder solid content increased, puncture resistivity also increased (Figure 6). The puncture resistance for insulation layer comprising 20% boehmite concentration and 7% first binder solid content coated current collector was comparatively higher in comparison to bare aluminium foil (Figure 7). Hence suggested that the boehmite coating remarkably improved the mechanical integrity of the foil. This insulation layer coating offered high resistance towards imparted force during tab crushing.

[0072] The data related to mechanical resistance studies for 20% boehmite concentration are tabulated in Table-1.

Table-1

Boehmite content (%)	Binder solid content (%)	Peel strength (kgF)	Viscosity (cP)	Puncture resistance (N)
20	3	0.2135	481	1.3037
	4	0.253	1263	1.3011
	5	0.366	2226	1.34
	7	1.319	3799	1.38
	8	1.3075	7790	1.37
	9	1.4745	10047	1.56
	11	1.318	18567	1.69

The table 1 data indicated the higher peel strength, higher puncture resistivity and required viscosity was achieved for 7% binder content and 20% boehmite concentration with respect to total weight of the binder and the solvent.

ADVANTAGES OF THE PRESENT INVENTION

[0073] The present disclosure provides an electrode (100) composition comprising an insulation layer (101), a current collector (102), and an electrodic film (103), enable the uniform coating of the mix on the collector, thereby resulting in an electrode with high mechanical strength. The present disclosure also provides a process for preparing the electrode composition, an electrode, and an electrochemical cell comprising the composition. In the electrode the high mechanical strength ceramic layer is coated on the positive current collector with a finite gap between the active material coated region and tab. This kind of ceramic layer coating provides better mechanical stability during tab crushing and avoids the damage of the active material coated region. The viscosity of the slurry is low falling within the range of 3000 to 4000cP for uniform coating which results in better mechanical stability. The viscosity of the slurry is achieved by optimizing the solid content of binder solution from 5.5% to 10%, and particularly, the binder solid content around 6 to 7% has a viscosity range within the slot die coater limit. This slurry coated electrodes shows better mechanical stability during the tab crushing. Hence, the challenge regarding working conditions of protoline machine can be overcome very easily.

I/We Claim:

1. An electrode (100) comprising:
    a. an insulation layer (101);
    b. a current collector (102); and
    c. an electrodic film (103);

    wherein the insulation layer comprises a ceramic material selected from boehmite, silica, alumina, zirconium oxide or combinations thereof, and a first binder;

    wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and

    wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector.
2. The electrode as claimed in claim 1, wherein the ceramic material is in a weight range of 60 to 90 %, with respect to the total weight of the insulation layer.
3. The electrode as claimed in claim 1, wherein the first binder is selected from polyvinylidene fluoride (PVDF), vinylidene fluoride (VDF), poly(vinylidene-co-hexafluoropropylene) (PVDF-HFP), polyacrylonitrile (PAN), polyamides or combinations thereof.
4. The electrode as claimed in claim 1, wherein the first binder has a solid content in a range of 4 to 10 %, with respect to the total weight of the insulation layer.
5. The electrode as claimed in claim 1, wherein the active material is selected from layered oxides, nickel manganese cobalt (NMC), nickel cobalt aluminium (NCA), lithium iron phosphate (LFP), lithium manganese iron phosphate (LMFP), or combinations thereof.
6. The electrode as claimed in claim 1, wherein the active material is in a weight range of 95 to 98%, with respect to the total weight of the electrodic film.

7. The electrode as claimed in claim 1, wherein the conductive additive is selected from carbon black, graphene, mesoporous carbon, acetylene black, activated carbon, super P, carbon nanofiber, vapour grown carbon nanofiber, carbon nanotube, or combinations thereof.
8. The electrode as claimed in claim 1, wherein the conductive additive is in a weight range of 1 to 4%, with respect to the total weight of the electrodic film.
9. The electrode as claimed in claim 1, wherein the second binder is selected from polytetrafluoroethylene, polyvinylidene fluoride, polyethylene oxide, fluoroethylene vinyl ether (FEVE), fluoroethylene polymer (FEP), or combinations thereof.
10. The electrode as claimed in claim 1, wherein the second binder is in a weight range of 0.1 to 3%, with respect to the total weight of the electrodic film.
11. The electrode as claimed in claim 1, wherein the first portion and the second portion are separated by a distance in a range of 0 to 1 mm.
12. The electrode as claimed in claim 1, wherein the electrode has a peel strength in a range of 0.2 to 1.5 kgf; a puncture resistance in a range of 1.3 to 1.60 N.
13. The electrode as claimed in claim 1, wherein the insulation layer has an electrical resistivity in a range of 20000 to 30000 Ohm/cm.
14. The electrode as claimed in claim 1 wherein the electrode is a cathode.
15. A process for preparation of electrode as claimed in claim 1, the process comprising:
    a. mixing a first binder, a ceramic material, and a solvent to obtain a slurry of insulation layer;
    b. blending an active material, a conductive additive and a second binder to obtain a mixture of electrodic film; and
    c. coating the slurry of insulation layer on a first portion of the current collector and coating the mixture of electrodic film second portion of the current collector, to obtain an electrode.

16. The process as claimed in claim 15, wherein the slurry of insulation layer has a viscosity in a range of 2000 to 12,000 cP at 50 s^{-1}.

17. The process as claimed in claim 15, wherein the solvent is selected from N-methyl pyrrolidone (NMP), dimethylformamide (DMF), dimethylacetamide (DMAc), dimethyl sulfoxide (DMSO), propylene carbonate (PC), or combinations thereof; and the solvent is in a weight range of 89 to 97% with respect to the weight of the slurry of insulation layer.

18. The process as claimed in claim 15, wherein the slurry of insulation layer comprises the ceramic material in a weight range of 10 to 40%, with respect to the total weight of the binder and the solvent.

19. The process as claimed in claim 15, wherein the ceramic material has average particle size in a range of 0.5 to 2 micron.

20. The process as claimed in claim 15, wherein the ceramic material and first binder is in a weight ratio range of 6:1 to 10:1, with respect to the total weight of the slurry of insulation layer.

21. An electrochemical cell comprising:
    a. an anode;
    b. a cathode comprising the electrode as claimed in claim 1; and
    c. an electrolyte.

22. A battery comprising the electrochemical cell as claimed in claim 21.

Date **09 February 2024**

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To,
The Controller of Patents
The Patent Office at **Chennai**

ABSTRACT

AN ELECTRODE COMPRISING INSULATION LAYER WITH HIGH MECHANICAL-STRENGTH AND PREPARATION THEREOF

The present disclosure provides an electrode (100) comprising an insulation layer (101), a current collector (102), and an electrodic film (103), wherein the insulation layer comprises a ceramic material and a first binder; wherein the electrodic film comprises an active material, a conductive additive, and a second binder; and wherein the current collector (102) is coated with the insulation layer (101) on a first portion of the current collector and with the electrodic film (103) on a second portion of the current collector. The present disclosure further provides a battery and electrochemical cell comprising the electrode.

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