

source. In another embodiment, the first source is a chemical vapor deposition source. A second source provides energized particles to the location. The energized particles impinge on the electrolyte material and assist in forming a desired structure of the electrolyte film 61C. In some embodiments, the second source provides energized particles simultaneously with the first source supplying the electrolyte material. The use of the energized particles conforms the electrolyte film 61C to electrode first film 59 such that the electrolyte film provides the necessary insulative property, namely preventing electrons from travelling directly between the electrode first film 59 and the electrode second film 63, i.e., shorting the electrodes. In some embodiments, the second source is an ion source as described herein, e.g., sources 313, 413, or 713. The second source provides energized ions that supply energy to the electrolyte material from the first source. The energy that is supplied by the ions assists in conforming the formed electrolyte film 61C to the electrode first layer 59. It is believed that the use of the energized particles in the energy range referenced herein provides the growing electrolyte material an extended period of mobility upon the previous film surface, and this extended period of mobility allows the electrolyte material to grow in a more defect-free manner.

[0139] In some embodiments, it is desired to form the electrolyte film 61C as thin as possible to lower its contribution to the internal resistance of the energy-storage device. It is also desired to maintain the electrolyte's property of blocking the flow of electrons (which would result in a short of the cathode to the anode) while permitting the flow of the ions that provide the battery function across the electrolyte. Using the methods and systems described herein, the electrolyte film 61C is formed to a thickness 61C' of less than about 5000 Angstroms. In some embodiments, the electrolyte film 61C has a thickness 61C' of less than about 2500 Angstroms. In some embodiments, the electrolyte film 61C has a thickness 61C' of less than about 1000 Angstroms. In some embodiments, the electrolyte film 61C has a thickness 61C' of less than about 500 Angstroms. In some embodiments, the electrolyte film 61C has a thickness 61C' of less than about 250 Angstroms. In some embodiments, the electrolyte film 61C has a thickness 61C' of less than about 100 Angstroms. In some embodiments, the electrolyte film 61C has a thickness 61C' in a range of about 10 Angstroms to about 200 Angstroms. In some embodiments, the electrolyte film 61C has a thickness 61C' in a range of about 10 Angstroms to about 100 Angstroms.

[0140] In one embodiment, the electrolyte film 61C includes LiPON and is formed using the first source 311 with the second source 313 or 413. As used herein, LiPON refers generally to lithium phosphorus oxynitride materials. One example is  $\text{Li}_3\text{PO}_4\text{N}_x$ . Other examples incorporate higher ratios of nitrogen in order to increase lithium ion mobility across the electrolyte. In some embodiments, the first source 311 provides  $\text{Li}_3\text{PO}_4$  in a nitrogen atmosphere. In other embodiments, the first source 311 provides  $\text{Li}_3\text{PO}_4$  in a vacuum environment wherein the background pressure is less than  $1\text{E}-3$  Torr. The second source 313 or 413 provides energized particles from a source gas. In some embodiments, the secondary source is an ion source supplying energetic ions from a source gas comprising oxygen (e.g.,  $\text{O}_2$ ) or nitrogen (e.g.,  $\text{N}_2$ ). The source gas, in other embodiments, comprises a noble gas, e.g., argon, xenon, helium, neon, and krypton. The energized particles and/or ions

increase the energy of the material forming the electrolyte film 61C, thus enhancing layer-by-layer growth. Accordingly, the electrolyte film is of a higher quality than conventional electrolyte layers.

[0141] An embodiment for forming a LiPON electrolyte film 61C includes the first source providing  $\text{Li}_3\text{PO}_4$  at or to the location where the LiPON electrolyte film is to be formed and second source providing energized nitrogen particles to or near the same location. The energized nitrogen particles react with  $\text{Li}_3\text{PO}_4$  provided at the location for forming the electrolyte film. This increases the amount of nitrogen in the LiPON electrolyte film. Increasing the nitrogen content is desirable to increase lithium ion mobility across the electrolyte.

[0142] In a further embodiment, the chamber in which the substrate 55 is positioned has a nitrogen enhanced atmosphere. A LiPON electrolyte film 61C is formed by the  $\text{Li}_3\text{PO}_4$  supplied by the first source reacting with the nitrogen in the chamber. The second source provides energized particles assisting in the formation of the electrolyte film. In another embodiment, the second source also provides nitrogen to the  $\text{Li}_3\text{PO}_4$  at the location. Thus, the  $\text{Li}_3\text{PO}_4$  reacts with both the nitrogen in the chamber and with energized, nitrogen containing particles supplied by the second source. This increases the nitrogen content of the electrolyte film 61C. In some embodiments, increasing the nitrogen content in the electrolyte film 61C is desirable since published data from the Department of Energy lab at Oak Ridge, Tennessee indicates an increase in nitrogen content increases the ion conductivity or mobility in the electrolyte film.

[0143] As will be understood by reading the present invention, the systems shown herein for depositing films are adaptable to form the electrolyte film 61C according to the present invention. Examples of some such systems are shown in FIGS. 3-7. FIG. 1D shows another embodiment of an energy storage device according to the teachings of the present invention. A supercapacitor 70 is formed on the energy-storage device 50C having the ultra-thin electrolyte film 61. The energy-storage device 50C being formed on the substrate prior to forming the supercapacitor 70 represents an embodiment of layer/devices being formed on the substrate prior to applying the techniques described herein to form energy-storage and/or energy conversion devices. The supercapacitor 70 includes an intermediate film 73 formed in physical contact with electrode films 71 and 75. In some embodiments, the intermediate film 73 is an electrolyte for storing and discharging electrical charge by a faradaic process. In some embodiments, the intermediate film 73 includes a dielectric material. The contact film 65 is in physical and electrical contact with electrode 71. Thus, in this embodiment contact film 65 is a shared contact film for both the energy storage device 50C and supercapacitor 70. In other embodiments, energy storage device SOC and supercapacitor 70 have separate contact films. In some embodiments, the intermediate film 73 includes LiPON. In some embodiments, the electrolyte film 73 includes TaO. In some embodiments, the electrode films are  $\text{RuO}_2$ . A contact film 77 is formed on the electrode film 75. A lead 76 extends from the contact film 77 to contact one plate of the supercapacitor to an external circuit.

[0144] A method for fabricating the solid-state energy-storage device 50 will now be described with reference to