crystal orientation of the $LiCoO_2$ thin film. The (003) X-ray diffraction peak indicates that the film has lattice planes parallel to the substrate, e.g., layer on which the film was deposited. The (003) peak width, full width at half maximum ("FWHM") decreases and the X-ray peak increases in this series of samples as the energy of the oxygen ions impinging the deposited material increases.

[0203] These examples indicate an increasing crystallite grain size and a larger fraction of ordered grains for sample films "b" and "c" than are found in sample film "a". The (003) orientation of samples "b" and "c" is preferable over an essentially non-ordered, non-crystallized structure of sample "a".

[0204] **FIG. 10** further shows a sample "d" that was deposited using the highest energy secondary source of this example. Sample "d" was deposited using a secondary source energy of 135 eV. X-ray diffraction of sample "d" shows it has the most distinct (101) orientation of all the samples described herein. The desired (101) orientation has lattice planes, which contain lithium ions in a LiCoO electrode material, nearly perpendicular to the substrate. In this orientation, the lattice planes are essentially parallel to the direction of travel of the ions and in the direction nearly perpendicular to the substrate. As this is the direction lithium ions must travel in a lithium battery fabricated according to the embodiments described herein, the preferential (101) orientation leads to superior charging and discharging characteristics. As lithium transport through the $LiCoO_2$ film in the (101) preferential orientation does not rely on diffusion along grain boundaries, which can trap lithium ions and prevent their utilization, the preferential (101) orientation also leads to greater capacity and cycle lifetime. Consequently, this preferred orientation of the $LiCoO_2$ thin film is produced without additional anneal fabrication steps and the internal resistance is lower with lower capacity loss at high discharge rates.

[0205] **FIG. 11** shows a comparison of the (003) x-ray diffraction peak of an ion assisted $LiCoO_2$ film fabricated according to the teachings of the present invention and a conventionally magnetron sputtered $LiCoO_2$ film. Both spectra are for as-deposited films. The ion assisted $LiCoO_2$ film in this spectrum is the same as the "c" sample shown in **FIG. 10**. The sputtered $LiCoO_2$ film was fabricated in an MRC **8667** using 1200 watts RF power, 10% O_2 in Argon, 80 sccm total gas flow (8 sccm O_2 and 72 sccm Ar), 20 mTorr pressure, with the substrate table grounded. Film thickness of the sputtered $LiCoO_2$ film is 5460 Angstroms. The significantly sharper peak for the ion-assisted film indicates the higher degree of long range order in this film. The peak width for this film is approaching that obtained by high temperature annealing of a similar conventionally magnetron sputtered film and exceeds that achieved for 300 degree Celsius annealed films of $LiMn_2O_4$. Accordingly, the $LiCoO_2$ film fabricated according to the teachings of the present invention provides a higher degree of order than conventional $LiCoO_2$ films without resorting to a post deposition anneal step to provide the desired crystal structure in the film. This results in significant manufacturing efficiencies.

[0206] **FIG. 12A** shows a X-ray diffraction spectra of a $LiCoO_2$ layer fabricated according to a conventional method of magnetron sputtering without the subsequent anneal step. The magnetron sputter was performed in MRC **8667** sputter, with 1200 W of RF power, in an environment of argon with 10% oxygen and 80 sccm total gas flow, at a pressure of 20 mTorr. The resulting film thickness is 5460 Angstroms. The x-ray peak full width at half maximum ("half height width") of the peak at 19 degrees of this conventional sample is 2.61 degrees. The half height width is a measure of the crystallite size, which can be calculated from this data as according to known formulas. The crystallite size for this conventionally magnetron sputtered film is 34 Angstroms. This conventional film must be annealed at high temperature to achieve sufficient crystallite size to have adequate electrical properties such that the film is part of a functional and practical battery.

[0207] In other conventional film materials, like $LiMn_2O_4$, nanocrystalline structures have been sputtered into films and prior to their anneal they have a crystallite size of about 40 Angstroms to about 50 Angstroms. Annealing this film at a temperature of about 300 degrees Celsius produces a crystallite size of about 130 Angstroms to about 160 Angstroms. In some embodiments of the present invention, these crystallite sizes are achieved at the time of deposition. Moreover, in some embodiments, superior crystallite sizes are achieved at the time of deposition.

[0208] **FIG. 12B** shows an X-ray diffraction spectrum for a $LiCoO_2$ film fabricated according to the teachings of the present disclosure. Specifically, this film was deposited using a first source and a secondary source of energized ions as discussed above with respect to samples "b" and "c" of **FIG. 11**. The peak for the ion assisted deposition film is significantly higher than the non-assisted spectra of **FIG. 12A**. This indicates a higher degree of long range order in the ion assisted deposition film. The half height width of the peak of the ion-assisted film at 19 degrees is 0.45 degrees. The crystallite size is 242 Angstroms. Accordingly, the present fabrication techniques yield an as deposited film having a crystallite size of greater than seven times that of the conventional deposition methods without post-deposition anneal. Moreover, the present fabrication techniques yield a superior crystallite size even when compared to the conventional film after it has been annealed. The present fabrication technique yields a factor of crystallite size improvement of about a 1.8 to about a 2.6 over the conventional technique. Consequently, the present fabrication method can thus achieve superior crystallite size in the film as they are deposited resulting in faster, more efficient fabrication of thin-film batteries. Such an improved crystallite structure is highly desirable in the cathode film due to the limitations imposed on energy storage in thin-film batteries due to cathode film performance.

[0209] Another aspect of the present fabrication method is the ability to fabricate thin films at essentially room temperature with a crystalline orientation that is essentially perpendicular to a boundary with adjacent films and crystallite size. Ions must travel through these boundaries to charge and discharge the battery. The boundaries include a first boundary that is between the cathode film and the electrolyte film and a second boundary that is between the electrolyte film and the anode film. The crystallite orientation is preferably perpendicular to the boundary planes. That is, the lithium ion lattice planes are parallel to the lithium ion direction of travel during charging and discharging the thin-film battery. This orientation lowers the internal battery