NANOPOROUS Ag-Cnts FOAMED ELECTRODE FOR LITHIUM INTERCALATION

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ABCTRACT

Intercalation of lithium into Ag-CNTs sample is reported here. We have used a nano- porous silver foam as a frame for deposition of the CNTs inside the pores by electrophoresis deposition (EPD) technique. By using chronopotentiometry method, we have noticed that the Li storage capacity of the prepared Ag-CNTs electrode was improved noticeably in comparison with literature. In addition, a very good functional stability for the prepared electrode has been tested during subsequent cycles of charge / discharge (C&D) procedures. By scanning the cycle's regulated current from 0.2 up to 1.0 mA , it was shown that in the range of 0.4 - 0.6 mA the Li storage capacity and reversibility of the C&D cycles became optimum, as well.

Keywords: Carbon nanotubes; Li intercalation; Foamed Ag; Electrophoresis deposition

INTRODUCTION

Li-Ion batteries have been widely used in portable electronic devices due to their high energy density, high operating voltage and excellent charge and discharge (C&D) cyclic stability [1–3]. For these applications, it is critical that Li-Ion batteries should have high capacity and good rate performance [3]. Carbon materials [3–5], such as CNTs have been widely used as conductive additives in fabrication of the battery's working electrode because of their high electrical conductivity. To effectively utilize the active materials in the electrode, the contents of these CNT additives should be often reach up to 10~20 wt.%. On the other hand, some unexpected new symptoms such as electrochemicalagglomeration, unstable SEI film formation [6] and so on, lead to significant capacity fading due to deteriorated electric contact between particles. Therefore, it would be the most promising approach to make improvement in dispersing carbonaceous particles well on some substrate materials in order to attain better cycling stability [7].

METHODS OF SAMPLE MANUFACTURING AND ANALYSIS

Our aim was to fabricate higher performance working electrodes in electrochemical applications from mechanical and electrical point of view. The

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effective strategy was that to pin the CNTs into the nano- scaled pores of the silver foam substrate (see *Fig.1*) by using electrophoresis deposition (EPD) technique [8]. The defused CNTs inside pores of the silver foam made better inter-junctions with it, therefore; the charge exchange process on the surface of the electrode has been facilitated in electrochemical usages. In spite of higher weight percentage of the CNTs content, such a structure of the porous silver electrode is beneficial to buffer the volume variation of the CNTs during lithium adsorption (charging) and desorption (discharging) periods [9].

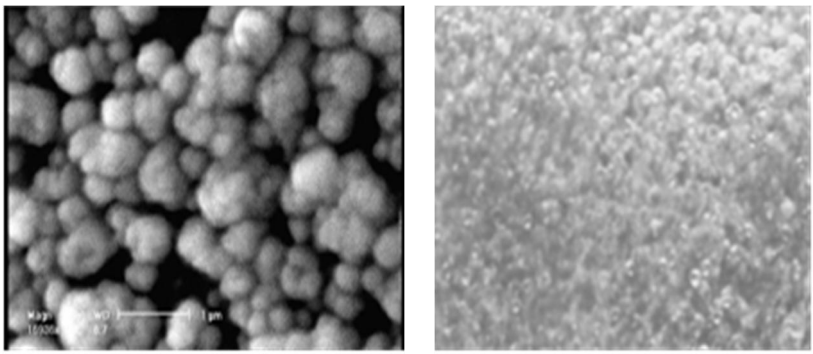

Fig. 1– left- TEMimage of the Ag foam surface with nano-scale porosity, Right- magnified image of the foam surfice

Finally, we have tried to optimize the lithium storage capacity in the working electrode by scanning the applied cyclic current in the chronopotentiometry measurements and the optimum Li storage capacity was achieved in the range of 0.4 - 0.6 mA of the current.

RESULTS ANDDISCUSSION

Fig.2 shows the typical voltage profiles of first, sixth and eleventh charge and discharge cycles for the Ag-CNTs electrode according to the regulated currents as : I = 0.2, 0.4, 0.6, 0.8 and 1 mA. In the case of I = 0.2 mA upon the first discharge process the cell voltage initially drops rapidly until it reaches about 0.8V where there is a plateau for a considerable amount of time. The plateau has been reported for the influence of amorphous forms of carbon previously [10, 11] and this removes gradually during subsequent cycles, probably because the interconnections between the silver frame and the CNTs have been stabilized after several times of lithiating and delithiating.

In battery's terminology, "reversible capacity ratio" (RCR) defines as the ratio of capacity displayed in the charging half to total discharge capacity and here, during the first cycle it was about 0.40 and for subsequent cycles reached to about 0.50. This increasing of the RCR can be attributed to re-arrangement

procedure of the CNTs inside the pores of the Ag foam during the next C&D cycles.

By scanning the regulated current, with steps of 0.2 mA, up to 1 mA and running 11 cycles in each step, it can be seen that the discharge profiles behave in the aforementioned general trend. However, a noticeable point occurs in the range of; I = 0.4- 0.6 mA, because the cycle profiles were converged and coincidental and also the reversible discharge capacity became optimized at I = 0.4 mA.

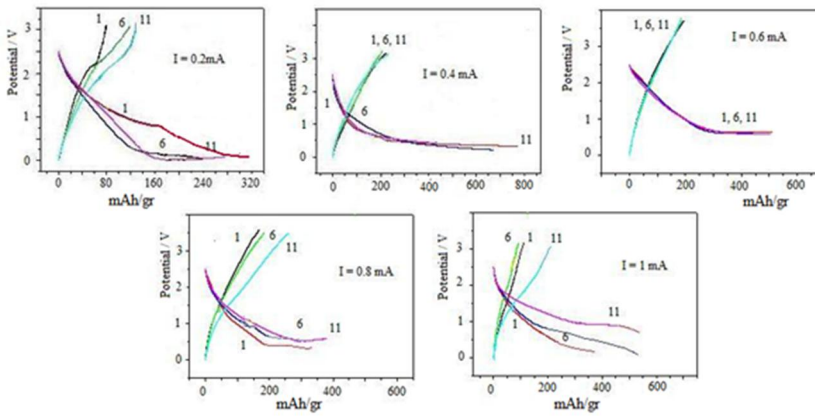

Fig. 2– Regulated current C&D voltage profile scans for: I = 0.2, 0.4, 0.6, 0.8 and 1.0 mA. Numbers on the graphs show the corresponding cycle numbers

CONCLUSION

Improvement of functional performance of CNTs contain electrodes for electrochemical lithium storage applications e.g. Li-Ion batteries, has been considered.

In this ground, foamed Ag substrate has been used for EPD process to deposit CNTs inside its pores. By this method, it is expected a higher amount loading of the CNTs and also better interconnections between them and the silver frame.

On the other hand, Chronopotentiometry measurements show that i: Li storage capacity of the foamed silver is several times more than the plane Ag electrode, ii: the prepared Ag-CNTs working electrodes have very notable functional stability during successive C&D cyclic applications without any disintegration of the CNTs from the foamed silver frame. Because the porous structure of the electrodes have ability to buffer the volume variation of the electrodes during lithium charging (expansion) and discharging (contraction) periods.

In addition by scanning the regulated current from 0.2 up to 1mA, there was a convergence between C&D cyclic voltage profiles in the range of 0.4-0.6 mA and also, an optimization on reversible Li storage capacity has been observed in this range for the electrodes. This optimized behavior of the prepared electrodes could be interpreted as a result of dependency of the SEI film formation (near surface of the Ag-CNTs electrode) to the regulated current values during the C&D cycles.

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