Amorphous silicon thin-anodes for lithium-ion batteries deposited by low pressure chemical vapor deposition

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Recently, much research has been performed on the thin film rechargeable microbatteries [1-4]. Lithium metal is the most favorable negative electrode material in the aspects of electrode potential and specific energies. But, lithium metal is very reactive and should be handled in moisture-free environments. And, dendritic Li growth as the metal was replated during each subsequent discharge-recharge cycle has evoked research for substitutive anode materials [5-6]. Thus, various alternative materials such as lithium alloys [7-8] and metal oxides [9-10] have been extensively studied. Carbons are also used for negative electrodes because lithium can reversibly inserted into them [11]. However, carbon anodes have irreversible capacity loss (ICL) in the first cycle and require high temperature annealing [12-13]

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In this work, we report that amorphous silicon (a-Si) thin-films fabricated by low pressure chemical vapor deposition (LPCVD) using Si_2H_6 as source gas have excellent characteristics as anodes for lithium-ion microbatteris. The high reversible capacity and cycle performance are presented. Galvanostatic charge-discharge test of half cells were performed. Thin-film amorphous silicon anodes exhibited the highest reversible capacity (4000mAh/g), which is about 95% of the theoretical capacity in case of $Li_{22}Si_5$ (Fig.1). The cyclability was enhanced by controlling the lower voltage limit or by reducing the amount of cycled charge quantity (Fig. 2). With specific capacity of 500mAh/g, we could cycle the cell up to 1500 cycles. Hence, amorphous silicon anodes are very promising candidates as anodes for lithium-ion rechargeable batteries.

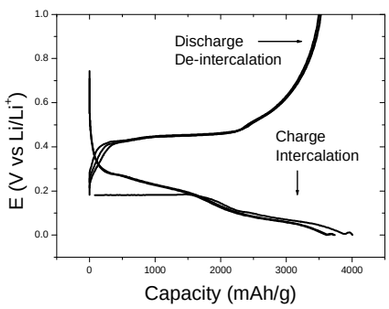

Fig. 1. Cycling of electrochemical Li insertion (charge) and release (discharge) on a-Si thin film at a constant current of 100 A per 1cm^2, conducted at room temperature between the voltage limits of 0V (insertion) and 1V (release) versus a Li counter electrode. Data were extracted for the first three cycles.

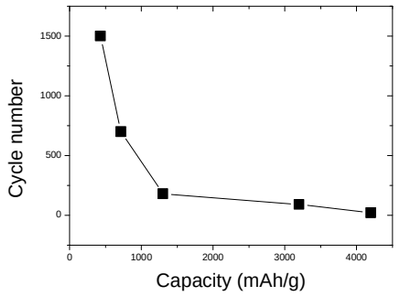

Fig. 2. Cycle life of a-Si thin film according to various cycled fixed charge quantity.

References

[1] K. Kanehori, K. Matsumoto, K. Miyauchi and T. Kudo, Solid State Ionics **9/10** 1445 (1983)
[2] A. Levasseur, M. Kbala, P. Hagenmuller, G. Coururier and Y. Danto, Solid State Ionics **9/10** 1439 (1983)
[3] R. Creus, J. Sarradin, R. Astier, A. Pradel and M. Ribes, Mater. Sci. Eng. B3 **109** (1989)
[4] J.B. Bates, N.J. Dudney, B. Neudecker, A. Ueda, C.D. Evans, Solid State Ionics **135** 33 (2000)
[5] R.A. Huggins, J. Power Sources **81-82** 13 (1999)
[6] J.M. Tarascon, M. Armand, Nature **414** 359 (2001)
[7] J.O. Besenhard, J. Yang, M. Winter, Solid State Ionics **90** 281 (1996)
[8] H Kim, B Park, H.J. Sohn, T. Kang, J. Power Sources **90** 59 (2000)
[9] Y. Idota, T. Kubota, A. Matsufuji, Y. Maekawa, T. Miyasaka, Science **276** 1395 (1997)
[10] F. Ding Z. Fu, M. Zhou, Q. Qin, J. Electrochem. Soc. **146** 3554 (1999)
[11] R. Yazami, P. Touzain, J. Power Sources **9** 365 (1983)
[12] K. Kinoshita, K. Zaghib, J. Power Sources **4818** 1 (2002)
[13] W. Xing, J.S. Xue, T. Zheng, A. Gibaud, J.R. Dahn, J. Electrochem. Soc. **143** 3482 (1996)