Preparation of Carbon/Silicon Hybrid Nanostructured Anodes for Lithium ion Batteries by CVD and Liquid Phase Deposition

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Introduction

C/Si hybrid systems for Li-ion batteries have been studied for many years.[1] C properties (softness, conductivity, intercalation of Li^+) are ideal to prevent the volumetric expansion of Si lattice due to alloying with lithium. The contemporary use of C and Si allows to combine the high capacitance of $SiLi_x$ alloys (up to 4200mAh/g for x=4.4) with the traditional graphitic anodes safety standards.[2] However, to offer the expected durability integrity and capacitance over time, Si must be well dispersed inside the C matrix, with the highest possible Si/C ratio, while C materials must be porous, with large surface area and optimized pore dimension to shorten Li^+ pathways.[3-4]

Here we present a method to obtain a highly stable composite material made of a nanostructured silicon enclosed into an interconnected carbon nanostructure.

Materials and Methods

As shown in figure 1 we fabricated a hybrid structure made by growing carbon nanowalls (CNW) with a peculiar hydrogen-free CVD process [5], thus gaining an exceptional control over the final product in terms of morphology and structure. Si is added by dip coating using a stable suspension of Si nanoparticles (NPs) in ethanol. The used substrate, a high conductive carbon paper sheet, guarantees to obtain a monolithic anode.

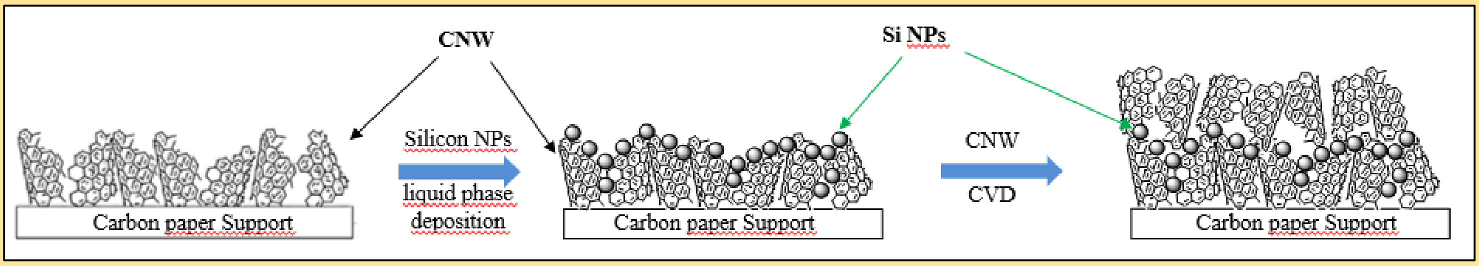

Figure 2 electrodes preparation process

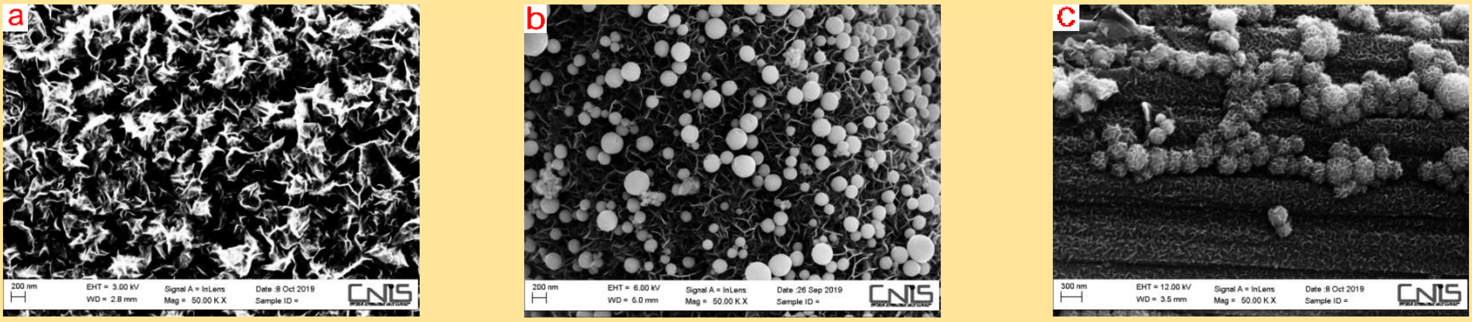

Figure 1 SEM images of a) CNW on carbon paper support, b) Si NPs deposed over CNW, c) CNW-covered Si NPs over CNW

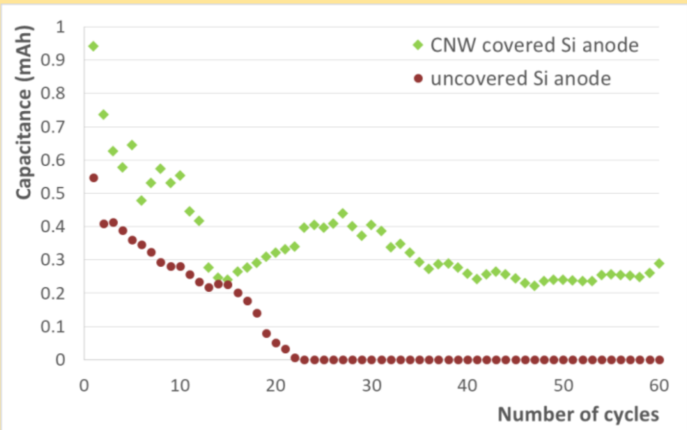

Figure 3 comparison between the capacitance offered by an uncovered silicon anode made of Si NPs (red dot) and an electrode made of Si NPs covered by a CNW layer (green squares)

Results

By following the steps represented in Figure 1 we constructed a customized compact porous material, where the active component is well embedded inside a light support whose pores offer large gaps to accommodate silicon dimensional variations without losing electrical contact. SEM images are reported in Figure 2.

We tested our electrode within a T cell lithium ion devices in the range 0.04-1.2V vs Li/Li^+ with metallic Lithium as counter electrode. A comparison of the obtained device with an electrode made without the external layer of CNW demonstrates that the presented material could offer a far superior capacitance retention, maintaining stability over several cycles, while an uncovered Si electrode capacitance fades and the device stops working after few cycles (figure 3).

Conclusions

The facile route developed, offering high control of the synthetic conditions, paves the way to the design and fabrication of a library of customized nanomaterials with optimized morphology for a variety of applications in the field of energy production and storage devices.

Bibliography

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