Binder-free graphene film via solvent exchange process as anode in Li-ion battery

Duc Anh Dinh[a], Haiyan Sun[a], Antonio Esau Del Rio Castillo[a], Simone Monaco[b], Andrea Capasso[a], Alberto Ansaldo[a], Mirko Prato[b], Vittorio Pellegrini[a], Bruno Scrosati[a], Liberato Manna[b] and Francesco Bonaccorso[a]

[a]Istituto Italiano di Tecnologia, Graphene Labs, Via Morego 30, Genoa, 16163, Italy
[b]Istituto Italiano di Tecnologia, Chemistry Department, Via Morego 30, Genoa, 16163, Italy
haiyan.sun@iit.it

Abstract

Graphene showcases several key properties that can address emerging technological needs, in particular for the storage of energy in the ever-growing market of portable and wearable electronic devices.[1] The challenge is now to develop high quality graphene flakes in large volumes to ultimately suit the needs of an industrial-scale production.[2] Liquid-phase exfoliation (LPE) of graphite [3] is emerging as a promising tool for mass production of graphene flakes, which can be prepared in the form of inks.[4,5] In particular, graphene produced by LPE is being considered a promising material for anode in Li-ion battery.[6,7]

Here we report the fabrication of graphene-based anodes by LPE of graphite in N-Methyl2pyrrolidone (NMP). This method allows us to obtain graphene flakes with controlled morphological properties of single layer (SLG) and few layers (FLG) graphene flakes with lateral size of ~100nm (Fig a). A solvent exchange process is used to remove the NMP and re-disperse the flakes, at a higher concentration (5g/l), in ethanol. We then formed a graphene film by drop-casting the graphene flakes at ambient conditions on a copper foil, without any binder or conductive agents, typically used in conventional LIBs.

The electrochemical tests of SLG- and FLG-based anodes in a half-cell configuration demonstrate a reversible specific capacity of ~ 500 mAh g^{-1} after 100 cycles at a current density of 100 mA g^{-1}, with coulombic efficiency >99.5% (Fig b). More importantly, the as-produced SLG- and FLG-based anode is assembled in a full-cell configuration with commercial $LiNi_{0.5}Mn_{1.5}O_4$ (LNMO) as cathode. The full cell shows promising electrochemical results, such as very high flat-plateau voltage profile at 4.7 V and a reversible specific capacity of ~100 mAh g_{LNMO}^{-1}. Hence, our work successfully achieved an advanced method for graphene based electrodes fabrication, with advantages of fast deposition, low cost and scalable production method. Our process opens the way to enhance the specific capacity, energy densities, lifetime and safety of LIBs, as well as minimize their cost and environmental impacts.

References

[1] F. Bonaccorso et al. Science 347 1246501, 2015
[2] F. Bonaccorso et al., Mater. Today 15, 564, 2012
[3] Y. Hernandez et al. Nat.Nano 9 563, 2008
[4] F. Torrisi et al. ACS Nano 4 2992, 2012
[5] A. Capasso et al. Solid State Comm. 224, 53, 2015
[6] J. Hassoun et al. Nano Lett. 14 4901, 2014
[7] H. Sun et al. J. Mater. Chem. A DOI:10.1039/c5ta08553e 2016

Figures

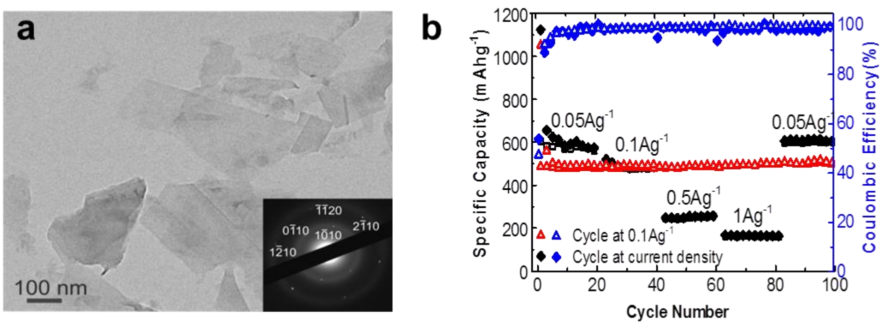

Figure: a) Bright-field TEM image of graphene flakes in NMP at high magnification. Inset: electron diffraction pattern. b) Specific capacity and coulombic efficiency over charge/discharge galvanostatic cycles at different current densities (ranging from 0.05 to 1 Ag^{-1}) of graphene-based anodes.