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Electrically conductive ultrananocrystalline diamond films for biocompatible all-carbon heaters and corrosion resistant long-life lithium ion battery

Yon-hua Tzeng[a,d,*], Shou-pu Yeh[a], Wei-Cheng Fang[a], Yueh-Chieh Chu[a], Yin-Wei Cheng[b], Chi-Kai Lin[c], Yueh-Chieh Chu[d], Ali Abouimrane[c], Zonghai Chen[c], Yang Renae, Chuan-Pu Liu[b], Orlando Auciello[f]

[a] Institute of Microelectronics, National Cheng Kung University, Tainan, Taiwan
[b] Department of Materials Science and Engineering, National Cheng Kung University, Tainan, Taiwan
[c] Chemical Sciences and Engineering Division, Argonne National Laboratory, Argonne, IL, USA
[d] Institute of Microelectronics, National Cheng Kung University, Tainan, Taiwan
[e] X-Ray Science Division, Argonne National Laboratory, Argonne, IL, USA
[f] Materials Science & Eng Department and Bioengineering Department, University of Texas-Dallas, Richardson, TX, USA

tzengyo@mail.ncku.edu.tw

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Grain boundary engineering of chemically vapor deposited nitrogen-incorporated ultrananocrystalline diamond (NUNCD) provides both excellent properties of a diamond coating and optimized electrical resistivity by design for novel applications. Nitrogen induced graphitic carbon formed in grain boundaries of a matrix of UNCD grains of 2-10 nm in sizes promotes the electrical conductivity and lithium permeability through the hard diamond coating which retains its mechanical robustness and chemical inertness for applications in biomedical environments such as a surgical tool or corrosive electrochemical environments such as an electrode in a lithium ion battery.

Under proper conditions, graphitic carbon becomes graphene and hybrids of graphene and diamond structures are synthesized. By fine tuning the diamond phase and graphitic phase in such a graphene-diamond hybrid, insulating diamond films can be synthesized to encapsulate a carbon resistive heater made of patterned conductive diamond-graphene hybrids. This all-carbon heater is corrosion resistant and biocompatible [1].

Under the support by NSC's "Dragon Gate" grant, PI, Professor Yonhua Tzeng and co-PI, Professor Chuan-Pu Liu led doctoral students, Yin-Wei Cheng, Yueh-Chieh Chu, and Chia-hao Tu from Electrical Engineering Department and Materials Science and Engineering Department to carry out collaborative research in Argonne National Laboratory in Chicago, Illinois, USA. The host at Argonne National Laboratory was Argonne Fellow, Dr. Orlando Auciello. One of the research focuses is to investigate the characteristics of electrically conductive NUNCD as a coating on natural graphite anode of a lithium ion battery for achieving extended charging-discharging cycling lifetime. Figure 1 shows a schematic diagram of a lithium ion battery with its anode coated with a nitrogen-incorporated ultrananocrystalline diamond film. The outcome was so good that a US patent was filed and a paper was published in Advanced Materials [2].

We found that NUNCD is not only electrically conductive but also permeable to lithium ions. When it is coated on a nature graphite anode, it provides mechanical robustness to the anode and prevent the anode graphite particles from breaking apart and losing electrical contacts. It also serves as a current spreader to distribute lithium ion current uniformly across the anode surface. This prevents high current density spots where, graphite particles break apart more easily and whiskers may grow to short circuit a battery. As a result, the same lithium ion battery with NUNCD coated natural graphite anode survives more charging and discharging cycles than those without NUNCD coatings by more than ten times. More details about lithium ion battery can be found in the introductory article in MRS Bulletin [3].

Mr. Yin-Wei Cheng extended the technology and accomplishments he got from working abroad in Argonne National Lab under support by NSC "Dragon Gate" grant to apply for the NARL's Innovation and Startups competition aiming at producing and marketing high performance lithium ion battery. So far Mr. Cheng's team ranks among top twenty teams. The competition continues with the final winners expected to be generated and announced on July 20, 2014[4].

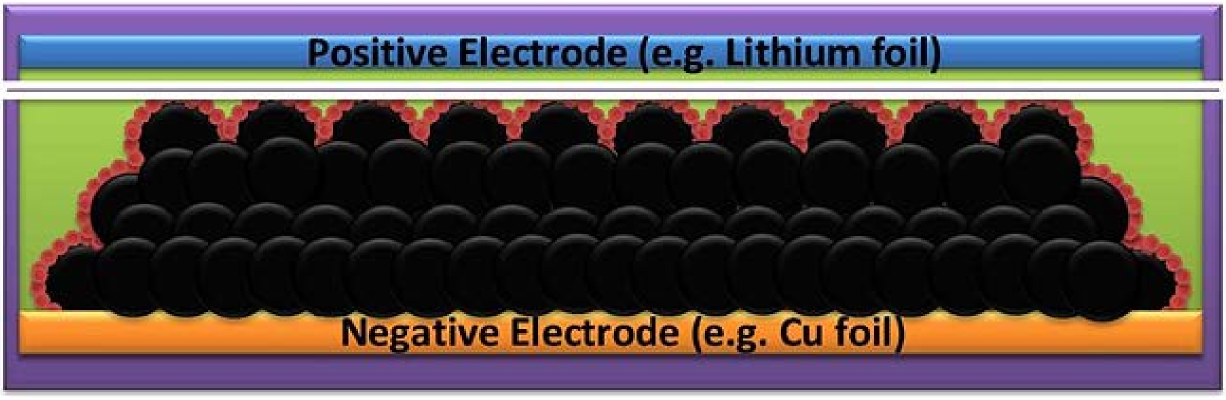

Figure 1. Schematic for a lithium ion battery with the anode coated with an electrically conductive nitrogen-incorporated ultrananocrystalline diamond film.

References:

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