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Transparent, Flexible, All-Solid-State Supercapacitor Using Silver Nanowire and Manganese Dioxide

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Extended Abstract

Transparent electronics, especially energy storage device is a rapidly growing technology due to its potential application as a power source of many next-generation transparent electronic systems including displays, windows, and automobiles.[1,2] Among the transparent energy storage device, transparent supercapacitor attracts huge attention owing to its high power and long lifetime compared to battery.[3,4] Supercapacitors, also called as electrochemical capacitors store charges by accumulation of ions on the surfaces. To accumulate a large number of ions, the electrode should have high specific area. Carbonaceous materials often used as the electrode material for supercapacitor due to its high specific area and electrical conductivity. [5,6]

On the other hand, pseudocapacitors that utilizing metal oxides or conductive polymers store charges by faradaic reaction at the surface, can have higher specific capacitance than carbonaceous materials which store charges by forming and electrical double-layer on the surface.[7] Especially, manganese oxide (MnO_2) is the most widely used pseudocapacitve material due to its high theoretical specific capacitance (1370 Fg^{-1}), low material cost, and environmentally friendly nature.[8] However, due to its low electrical conductivity, actual specific capacitance of the MnO_2 is much lower than the theoretical specific capacitance. Furthermore, as MnO_2 has low specific area, it needs an underneath material that has high electrical conductivity and specific area for high performance supercapacitor.

In this research, to increase actual specific capacitance of the MnO_2 and fabricate transparent supercapacitor, we utilized a silver nanowire electrode as the underneath material of the MnO_2. Silver nanowire is known to have comparable sheet resistance and transparency in the visible range to those of the most widely used transparent electrode, Indium tin oxide (ITO).[9] In addition, silver nanowire can be solution-processed on the flexible substrate and has high specific area that comes from its extremely thin diameter.

A commercially available silver nanowire solution (Nanopyxis Co.) was used for this research. The solution was spin casted on the polyethylene terephthalate (PET) substrate at coating speed of 1000rpm for 30s. Various concentration and spin coating condition was tried to find optimum condition for the transparent supercapacitor. Manganese dioxide was deposited by an electrochemical plating method. Briefly, the silver nanowire electrode was immersed into a 0.05M $Mn(Ac)_2/Na_2SO_4$ electrolyte at room temperature. The electroplating was performed in a two-electrode system with an Ag/AgCl as the reference electrode, and the silver nanowire electrode as the working electrode. The thickness of MnO_2 is crucial point for the performance of the supercapacitor. Various deposition voltages, time were tried to find optimum condition. 0.7V of applied voltage and the duration time of 10minute were selected as an optimum condition. A supercapacitor must have a separator, which prevent from the short circuit of the device. Transparent supercapacitor must have transparent separator, for that, we employed a transparent solid electrolyte which composed of polyvinyl alcohol and lithium perchlorate. The solid electrolyte also acts as separator. Liquid electrolyte needs safety encapsulation and has leakage problem, compared to that, solid electrolyte is safer and more suitable for realizing flexible device.

Four kinds of silver nanowire solutions which have a concentration of 0.4wt%, 0.8wt%, 1.5wt%, 2wt% were used for this research. Transmittance of supercapacitor devices were measured after assembly of two electrode and electrolyte. Measurement result were 82% (0.4wt%), 68% (0.8wt%), 44% (1.5wt%), 23% (2wt%). Cyclovoltammetry measurements were also conducted to evaluate performance of the devices. The devices showed stable cyclovoltammetry shape and the specific capacitance of the devices were 28mF/cm^2 (0.4wt%), 38mF/cm^2 (0.8wt%), 93mF/cm^2 (1.5wt%), 124mF/cm^2 (2wt%) at scan rate of a 200mV/s.

In conclusion, we have reported a transparent, flexible, all-solid-state supercapacitor that composed of silver nanowire and MnO_2. Silver nanowire was the excellent electrode material for the transparent, flexible supercapacitor since it has excellent electrical conductivity, transparency, specific area. Because fabrication of the supercapacitor doesn't involve any vacuum process and done by productive solution process, our research has potential to impact future transparent, flexible electronics industry.

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