Energy Harvesting and Storage System for Aero Vehicles

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ABSTRACT:

We have been working energy-harvesting and storage systems (EHSS) for aero vehicles over the last five years. EHSS includes, (i) dye-sensitized solar cells(DSSC), (ii) li-ion battery and (iii) thermal electric materials and modules, as well as integration of these into load-bearing airborne structures. Design parameters of EHSS components are specific energy-conversion coefficient, load-bearing, limited durability in support of Unmanned aero vehicles(UAV) and micro-aero vehicles(MAV). If all these are optimized, the EHSS would increase the flight time of the UAV. UW team has developed home-made EHSS tailored for UAV/MAV and integratable into airborne structures. Three prototype designs will be discussed in my talk: Design 1 for DSSC integrated in a structure, , (ii) Design 2: li-ion battery and (iii) Design 3: thermoelectric(TE) modules integrated in UAV combustion chamber. For Design 1, we have synthesized two types, (i) DSSC based on thin glass, and (ii) DSSC based on flexible PET film.

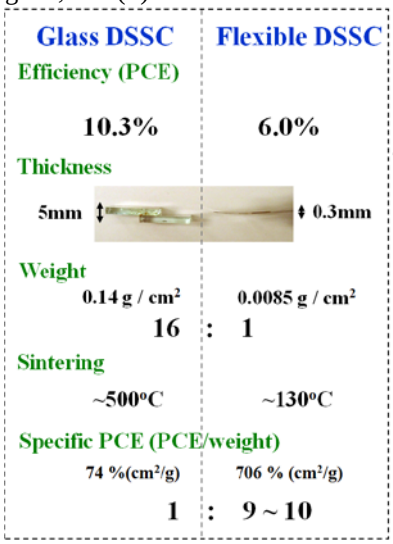

Fig. 1 shows comparison of these two DSSC performance and their other characteristics. It is noted from this comparison that use of glass substrate gives rise to higher power conversion efficiency(PCE) than flexible substrate based design. This is attributed to the fact that the bonding of TiO2 layer on glass substrate is stronger due to its sintering temperature being higher where the glass substrate can survive in such high temperature while the sintering of TiO2 to PET flexible substrate needs to be made under modest temperature, resulting in weaker bonding of TiO2 on PET film. However, the integration of DSSC on the surface of wing structures, requires flexible substrate in order to make the integrated DSSC more durable under dynamic mechanical loading. In the above DSSC designs, we used gel electrolyte for for wider temperature capability, assuming that the integrated DSSC would be used in airborne environment which may go into lower temperature as the altitude is increased. The ionic conductivity of the gel electrolyte is proportional to temperature, so that for use in airborne environment with higher altitudes, our gel electrolyte needs to be operative without loss of the ionic conductivity.

As to Design 2, Li-ion battery for use as airborne energy storage system, we designed the Li-ion battery based on cathodic element being nanofiber composite made of $LiCoO_2$ and Carbon nanotubes(CNT), which are co-spun by electrospinning machine. Fig. 2 shows the nanostructure of as-spun and annealed nanofiber composite. The introduction of CNT will not only improve the mechincal strength of LiCoO2 nanofiber, but also increase the conducvitity of cathode.

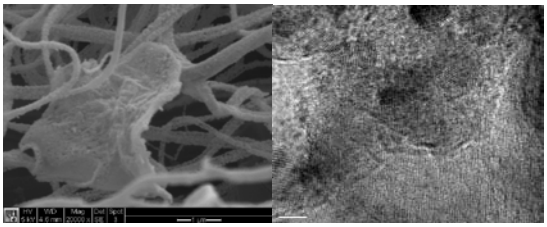

Fig.2 SEM(left) and TEM(right) photos of $LiCoO_2$-CNT composite nanofibers

As to Design 3, TE module integrated in of the as-

assembled TE module integrated, to find that use of linear TE module design is better suited to achieve higher energy conversion efficiency of the TE modules over 13%. However, the processing several key components and their integrations into the surrounding housing are still technically high hurdles. TE module is composed of set of two TE plates, n1, n2 and p1 and p2 where n1 and n2 are the n-type TE plates and p1 and p2 are the p-type TE plates, and subscripts 1 and 2 denote the higher temperature and lower temperature TE plates, respectively. We are currently working in the processing of these components, then finally integrate them into the combustion chamber walls. For lower temperature TE plates, we use Bi2Te3 while the higher temperature TE plates are made of Mg2Si-Bi (n-type) and MnSi (p-type). It is noted that all these materials relatively , light weight, and their costs are modest.

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Keywords: Energy-harvesting (EH), Energy-storage (ES), integration of EH and ES, dye-sensitized solar cells(DSSC), li-ion battery, thermoelectric(TE) modules, unmanned air vehicles (UAV), Combustion chamber, load-bearing structure