Three Elemental Regenerated Cellulose Piezoelectric Energy Harvester

Jongbeom Im[1], Seung-Ki Min[1], Hyun Chan Kim[1], Jaehwan Kim[1], Jedol Dayou[2#]

1 Creative Research Center for Nanocellulose Future Composites, Department of Mechanical Engineering, Inha University, 100 Inha-Ro, Nam-Ku, Incheon 22212, South Korea.

2 Energy, Vibration and Sound Research Group (e-VIBS), Faculty of Science and Natural Resources, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, MALAYSIA

Corresponding author. E-Mail: jed@ums.edu.my; Tel: +60-88-320-000; Fax: +6-088-435324

ABSTRACT

Harvesting ambient vibration energy using piezoelectric cantilever beam or piezobeam was found to increase substantially by splitting a given piezobeam into several pieces with equal width, and then combined them in parallel connection. This increase was reported as mainly contributed from the reduction of the piezobeam damping when the width was reduced and therefore increasing the displacement amplitude to produce higher harvesting power compared to single beam with the same total width. The finding is further investigated in this paper by considering load resistance and impedance matching in conjunction with using up to three elements of regenerated cellulose piezobeam. Two connection modes were examined, parallel and series, in terms of their harvesting capability at resonance frequency. It was found that series connection generates even higher power output than parallel connection in both two and three piezobeam elements. It is further revealed that series connection has more allowance in impedance matching than parallel connection, which offers additional flexibility when fabricating piezoelectric-based energy harvester.

KEYWORDS: Cellulose EAPap; Piezoelectric energy harvester; Structural damping; Energy conversion; Width-splitting method

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INTRODUCTION

Rapid progress in microelectronics devices such as for remote and wireless sensing applications has highlighted the importance of harvesting energy from ambient environment. Storing harvested energy to a rechargeable battery that attached to the device which can be used when needed was considered as common solution. However, size, weight and life span of the energy harvester system including the battery as well as their physical structure constantly create problems (Kim *et al*., 2011). On the other hand, the demand for self-powered feature in the electronics device has increased in the last few years.

Amongst the energy sources from ambient surrounding, vibration can be the best option as it can be acquired relatively easy (Park *et al*., 2016) This wasted energy can be converted into electricity by using appropriate vibration energy harvester. Currently, there are three common types of electromechanical converters for harvesting purpose: electrostatic (Suzuki, 2011), electromagnetic (Park & Kim, 2016; Zorlu, 2011), and piezoelectric transducers (Deng *et al*., 2015). Amongst them, piezoelectric transducers have gained substantial attention due to the benefits of these transducers overcoming the mentioned problems (Ottman *et al*., 2002; Rupp *et al*., 2009; Benasciutti *et al*., 2010; Chow *et al*., 2013).

Lead zirconate titanate (PZT) has been widely used as vibration energy harvester because it has relatively high electromechanical coupling and energy conversion rate (Dayou *et al*., 2009). Other materials such as polyvinylidene fluoride (PVDF) (Jeon *et al*., 2009), electro-active polymer (EAP) (Song *et al*., 2011) and cellulosed electro active paper (better known as EAPap) (Abas *et al*., 2014) have also been investigated. Cellulose was initially reported with very weak piezoelectric property in the 1950s and therefore was insignificant in research investigation (Fukada, 1955). However, with technology advancement and with proper material preparation, cellulose was later discovered to have large displacement responses when electricity is applied and therefore its potential applications as piezoelectric material have been extended (Kim *et al.*, 2011). Cellulose which is abundant in nature is biodegradable, lightweight, fracture tolerant and inexpensive, thus it is promising to future applications including piezoelectric energy harvesting.

Recent investigations shows that array of piezoelectric elements in parallel connection produced higher electrical power output compared to a single piezoelectric of same total dimensions (Chow *et al.*, 2013; Dayou *et al.*, 2012; Dayou *et al.*, 2015). However, electrical load resistance and its impedance matching were not considered in maximizing the harvested electrical power output. This paper is a detail investigation for maximizing the harvested electrical power output of the previous works using cellulose-based piezoelectric material or EAPap under load resistance consideration. Up to three elements of EAPap piezoelectric cantilever beam (EAPap piezobeam) were used in this investigation, and both in series and parallel connections were made under the load resistance change. The effect of load resistance and impedance matching for maximizing the power output is discussed.

EXPERIMENTAL METHOD

Preparation of cellulose EAPap

Fabrication of cellulose EAPap piezoelectric was well explained in the previous work (Kim *et al.*, 2008).

Preparation of EAPap piezobeam

Aluminium cantilever beam was used in this investigation as the host structure for capturing the ambient vibration energy by bending of the structure.

Experimental procedure

Schematic diagram of the experimental setup is illustrated in Figure 3.

RESULTS AND DISCUSSIONS

Resonance responses of individual EAPap piezobeam energy harvester

The vibration amplitude of a cantilever beam energy harvester is at maximum when the beam vibrates at its fundamental natural frequency and therefore the harvested energy shows its highest value.

CONCLUSIONS

The effect of splitting a given piezoelectric cantilever beam as energy harvester was further investigated in this paper up to two splits or three elements, connected in series and parallel. Regenerated cellulose EAPap film were fabricated and used as the piezoelectric energy harvesting materials with aluminum as host cantilever beam. Under in phase vibration of all the participating split beams, and under the source and load impedances matching condition, the power output from the array of two and three elements of piezoelectric energy harvester increased with of the number of split compared to single beam with similar total dimensions, regardless of series or parallel connection between the elements. Detail investigation shows that series connection generates higher power output compared to its counterpart of parallel connection. In addition, this paper reveals new insights where impedance matching of series connection has more allowance than parallel connection of split piezoelectric energy harvesters. This detail finding might be important when fabricating array of piezoelectric energy harvester.

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