A Hybrid Broadband Vibration Micro Energy Harvester Based on Piezo and Triboelectric Effect

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This paper reports a novel hybrid broadband micro vibration energy harvester (EH), which consists of an AlN MEMS piezoelectric vibration EH unit and a PTFE based single-electrode mode triboelectric EH unit. AlN piezoelectric vibration EH was a hot research topic of MEMS EH owing to its high energy density, high stability, and CMOS compatibility. In recent years, the study of the high-performance AlN piezoelectric film (*Barth et al.* 2016[1], *Minh et al.* 2015[2]), the novel structure design (*Guido et al.* 2016[3], *Sharma et al.* 2015[4], *Wang et al.* 2014[5]), and the piezo vibration bandwidth expanding (*Jackson et al.* 2014[6]) were the focal points on the enhancement of the device power output. The EH device discussed in this paper features its broad work bandwidth by placing an stopper underneath the vibrating proof mass for amplitude limiting, at the mean time, another part of energy was efficiently collected through mutual collision between the proof mass and stopper utilizing triboelectric mechanism. As a result, a higher power output density is realized by this hybrid mechanism method.

A schematic diagram of the hybrid broadband vibration micro EH device is illustrated in Fig. 1 and the device optical image is shown in Fig.2. Figure 3 shows the SEM of the cross-section image of AlN-Si piezoelectric cantilever beam, the AlN piezo film with crystal orientation (002) deposited by pulsed-DC magnetron sputtering. The output performance of hybrid broadband vibration micro EH device is shown in Table 1, which shows that the open-circuit voltage (V_{oc}) and short-circuit current (I_{sc}) of AlN piezo vibration EH unit can reach 1.52 V and 11.5 μA before amplitude limiting and 0.7 V and 8.2 μA after amplitude limiting. The V_{oc} and I_{sc} of the amplitude limiting unit of single- electrode mode triboelectric EH unit can reach 10 V and 0.7 μA, respectively. The work bandwidth of AlN piezo vibration EH expands from ~ 1 Hz to ~9 Hz (Fig.4), which makes it more adaptable to the surrounding environmental frequency change. Experimental results show that the prototype can achieve the output power of 5.066 μW and 1.32 μW of AlN piezo EH unit and PTFE tribo EH unit, the work bandwidth of ~9 Hz, respectively, at the acceleration of 1g and the frequency of 204.3 Hz (Fig.5). This hybrid broadband vibration micro EH paves a way for new generation of high power density EH development and it potentially accelerate the deployment of the wireless sensor network.

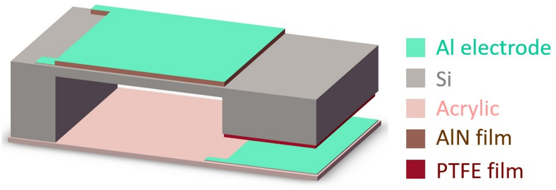

Fig. 1 Schematic diagram of the hybrid broadband vibration micro EH device.

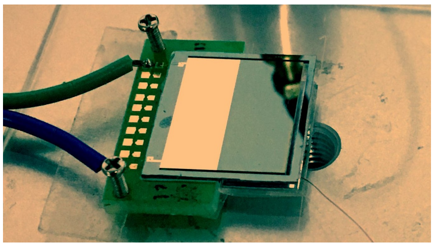

Fig. 2 Optical image of the hybrid broadband vibration micro EH device.

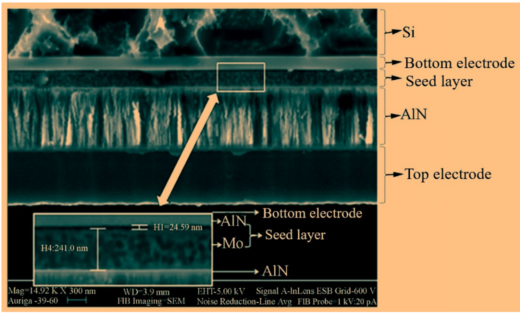

Fig. 3 SEM of the cross section of AlN-Si piezo cantilever beam.

Table 1 Output performance of hybrid broadband vibration micro EH device.

	AlN piezo EH unit		***PTFE tribo EH unit***	
	V_{oc} (V)	*I_{sc}(μA)*	*V_{oc} (V)*	*I_{sc} (μA)*
Before amplitude limiting	*1.52*	*11.5*	—	—
After amplitude limiting	*0.7*	*8.2*	*10*	*0.7*

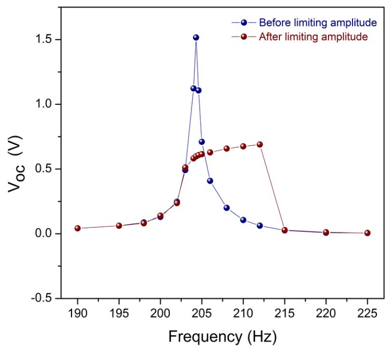

Fig. 4 The output voltage vs frequency of AlN piezo vibration unit before and after amplitude limiting by collision.

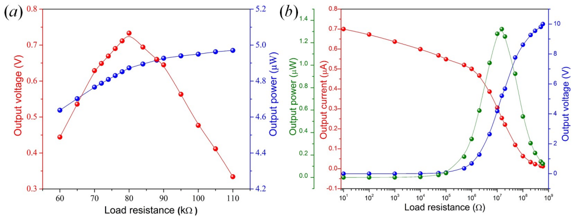

Fig. 5 The load characteristic and output power of hybrid broadband vibration micro EH device.

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