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Supporting Information

Efficient Energy Harvesting of GaN p-n Junction Piezoelectric Generator through Suppressed Internal Field Screening

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Figure S1. Schematic diagram of the custom-designed piezoelectric testing unit, consisting of a nut, bolt, and torque driver to apply stress to the sample at a pressure of 4 MPa. A rectangular pressure pulse generated by quickly rotating the torque driver by hand was used for the piezoelectric output measurement. The inset shows a magnified photograph of this unit with a GaN PG.

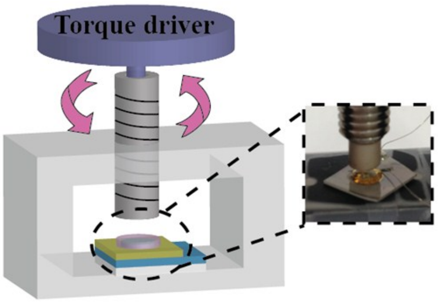


Figure S2. a) Schematic structure of the designed Schottky junction-based PG (SPG). The Schottky contact is formed between n-GaN and Ni without annealing, and its area is about 0.8 mm^2. b) The output voltage and c) typical *I–V* characteristics measured from SPG and HH (pn-PG).

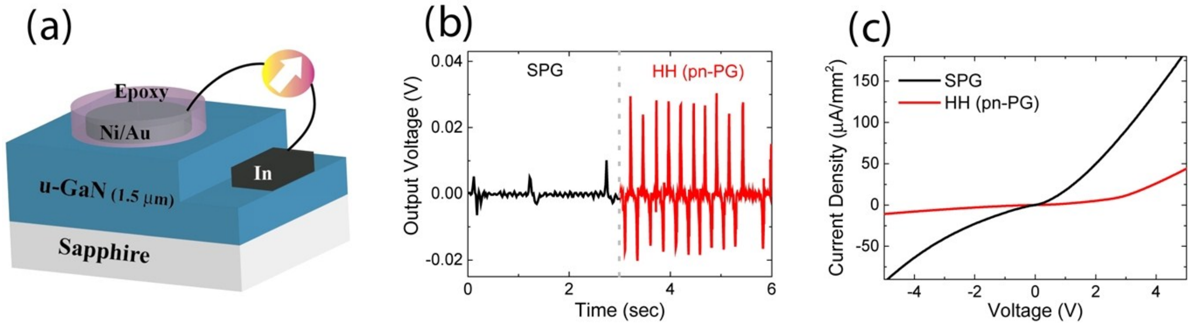


Figure S3. a) Output voltage decay measured from a) LH, b) MH, and c) HH pn-PGs under a single stress cycle. The decay constants were estimated using a factor of 1/e.

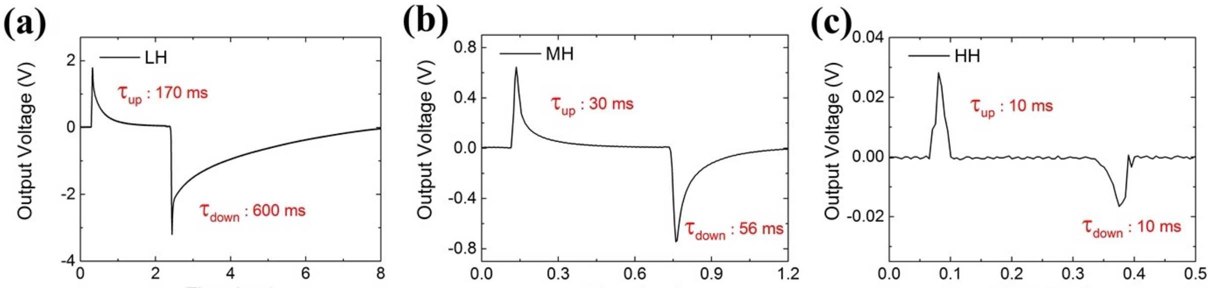
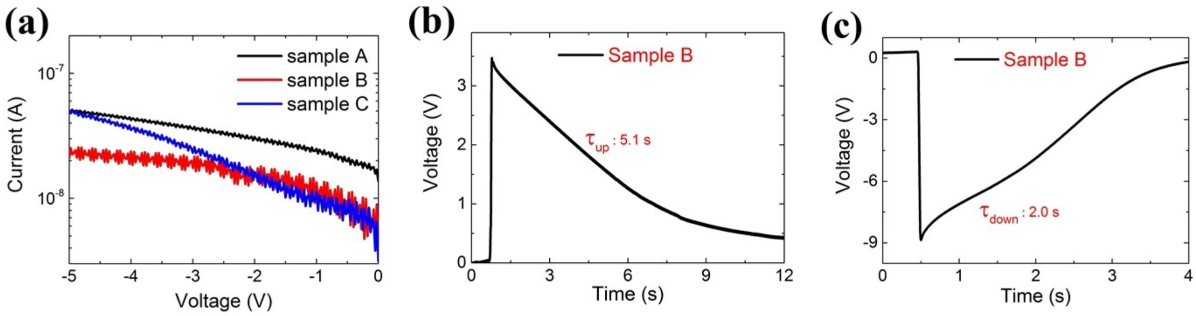


Figure S4. (a) I-V curves of sample A, B, and C. (b), (c) Output voltage decay measured from sample B under a single stress.



Piezoelectric charge generation model

When a piezoelectric material is under compressive stress, piezoelectric charges are generated due to the non-centrosymmetry of the crystal structure. The charge generation speed depends on the speed of compressive stress. We assume, for simplicity, that compressive stress is applied exponentially to a sample and its corresponding output voltage $V(t)$ can be expressed using a simple formula:

$$V(t)=V_{max}\,(1-\exp(-t/\tau_1)) \tag{1}$$

where V_{max} is the maximum output voltage, t is time, and τ_1 is the decay constant describing piezoelectric charge generation. If the speed of compressive stress is fast, then τ_1 decreases and the output voltage quickly reaches a maximum value V_{max}. 20 ms of τ_1 is used for this simulation and this value leads to the simulation result matched with experimental one. Because the applied stress is fixed, V_{max} is mostly dependent on the free-carrier concentration, which limits the capacity of carrier screening. After piezoelectric charge generation, carrier screening occurs immediately and this process is not measurable. With increasing carrier concentration, more piezoelectric charges are screened and finally a low V_{max} appears. In our simulation, constant V_{max} was used to focus on the junction current screening effect.

Junction current screening model

Figure 2b, c, and d show the decay behavior of output voltages measured from low hole (LH), medium hole (MH), and high hole (HH) concentration pn-PGs, respectively. These graphs show that the output voltage decays roughly exponentially after reaching a maximum. The junction current is one possible screening term that can be used to explain this decay behavior, as represented in the following simple formula:

$$V(t)=V_{max}\,(1-\exp(-t/\tau_1))\,\exp(-t/\tau_2) \qquad (2)$$

where τ_2 is the decay constant for junction current screening. This decay constant is roughly estimated from the decay graphs in Figure 2b, c, and d using a factor of 1/e. From our calculations, the decay constant decreases with increasing hole concentration. It is important to note that slow junction current screening leads to low $V(t)$ and an output voltage that persists for a longer period of time.