Supplementary Information

Heat-Stimulated Lifetime-Controllable Encapsulation for Transient Electronics

Hyukjoon Gwon, and Seungae Lee*

Department of Chemical Engineering, Konkuk University, 120 Neungdong-ro, Gwangjin-gu, Seoul 05029, Republic of Korea

* Corresponding author. Tel.: +82-2-2049-6109; E-mail address: salee@konkuk.ac.kr (S. Lee).

Supplementary Information

1. Comparison of stimuli-responsive encapsulating materials for transient electronics.

Table S1. Summary of the stimuli-responsive encapsulating materials for transient electronics.

Stimuli	Encapsulating material	Degradation mechanism	Reference
Temperature	Cyclic poly(phthalaldehyde) + methanesulfonic acid	Releases encapsulated acid with the application of heat (45 °C), disintegrates the polymeric substrate	1
	Methyl cellulose, PNIPAm	Device dissolves in water below the LCST (45 °C) of methyl cellulose and PNIPAm (32 °C)	2
	Polycaprolactone + Lauric acid	Lauric acid melts with the application of heat (45 °C), allowing rapid water penetration	This work
Light	Light-responsive hydrogel + MgO	Hydrogel layer degrades when exposed to UV light	3
	Cyclic poly(phthalaldehyde) + methanesulfonic acid + photoacid generator	Photoacid generator embedded in the encapsulation layer generates acidic condition, disintegrates the polymeric substrate	4
Electrical current	Si_3N_4 membrane	Electrical current is applied to a reservoir of acidic solution, which generates gas to exert pressure on the Si_3N_4 membrane	5
	CuO/Al nanothermite mixture	Electrical spark ignites the nanothermite mixture, destroying the device through exothermic reactions	6
	Si thin film ribbon	Si thin film is lithinated with the application of electrical current, creating microstructures	7

2. TGA curve of PCL/LA (PCL:LA ratio of 100:1) film.

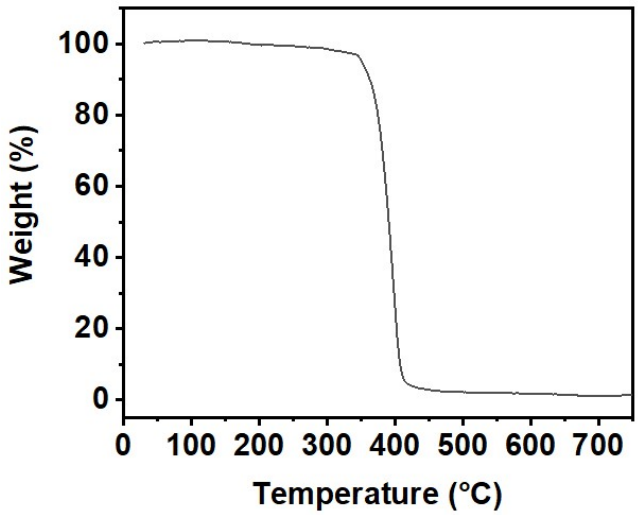

Fig. S1 Thermogravimetric analysis (TGA) curve of PCL/LA (PCL:LA ratio of 100:1) film.

3. NMR spectra of PCL, LA, and PCL/LA films.

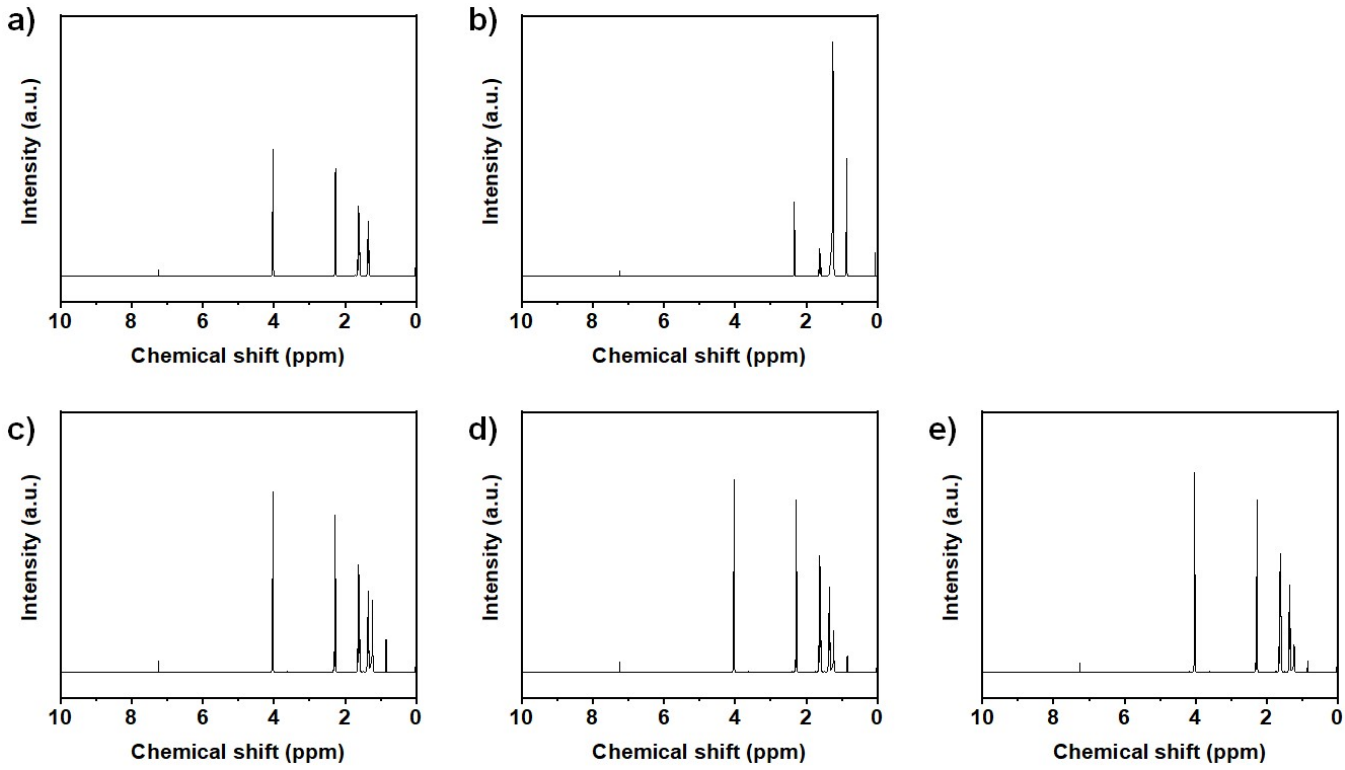

Fig. S2 ^{1}H NMR spectra of a) PCL, b) LA, and PCL/LA films with PCL:LA ratios of c) 5:1, d) 10:1, and e) 15:1.

4. Thickness profile of PCL and PCL/LA films.

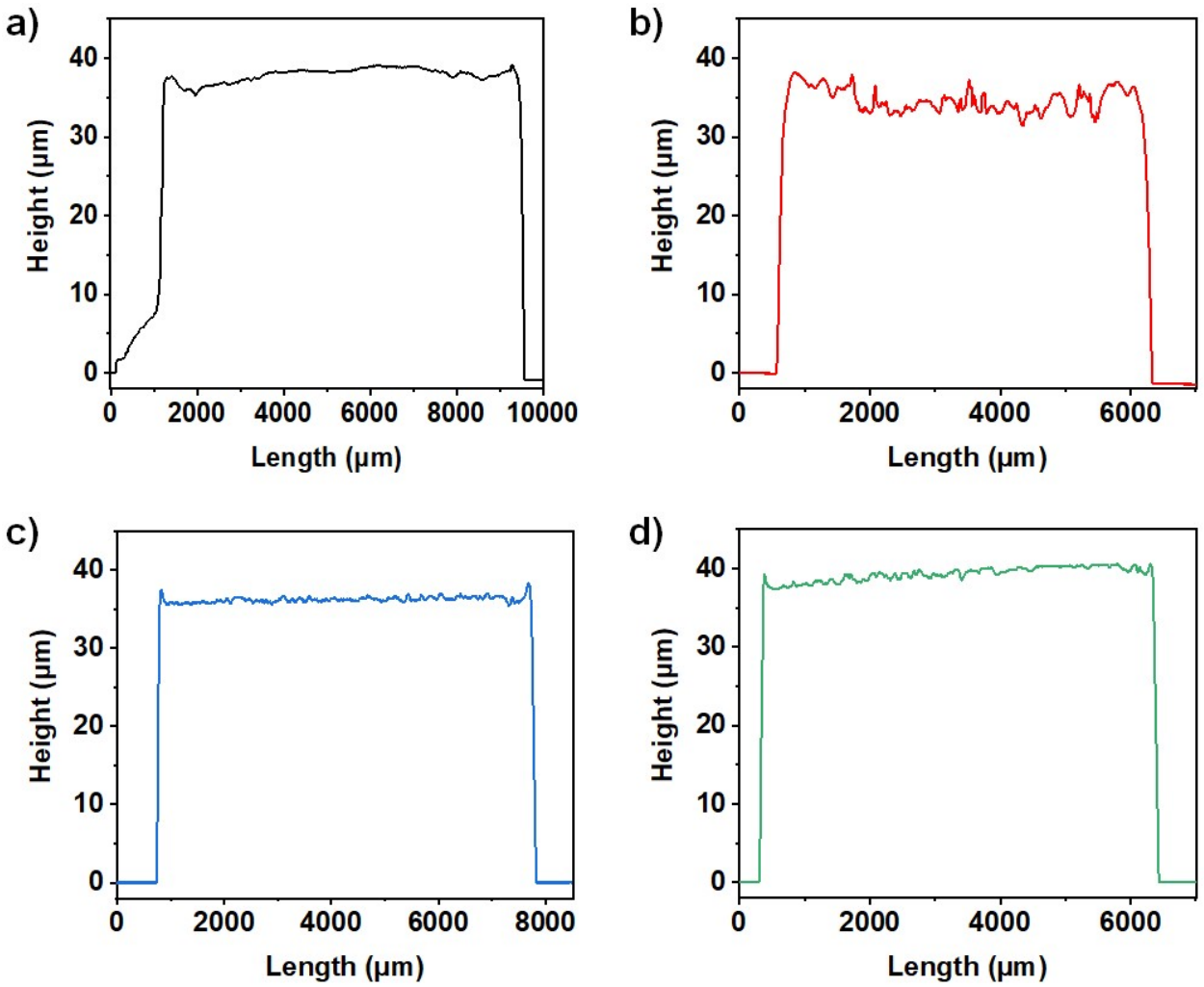

Fig. S3 Thickness profile of the as-prepared a) PCL and PCL/LA film with PCL:LA ratios of b) 5:1, c) 10:1, and d) 15:1.

5. SEM images of the PCL and PCL/LA films under degradation in PBS at 45 °C.

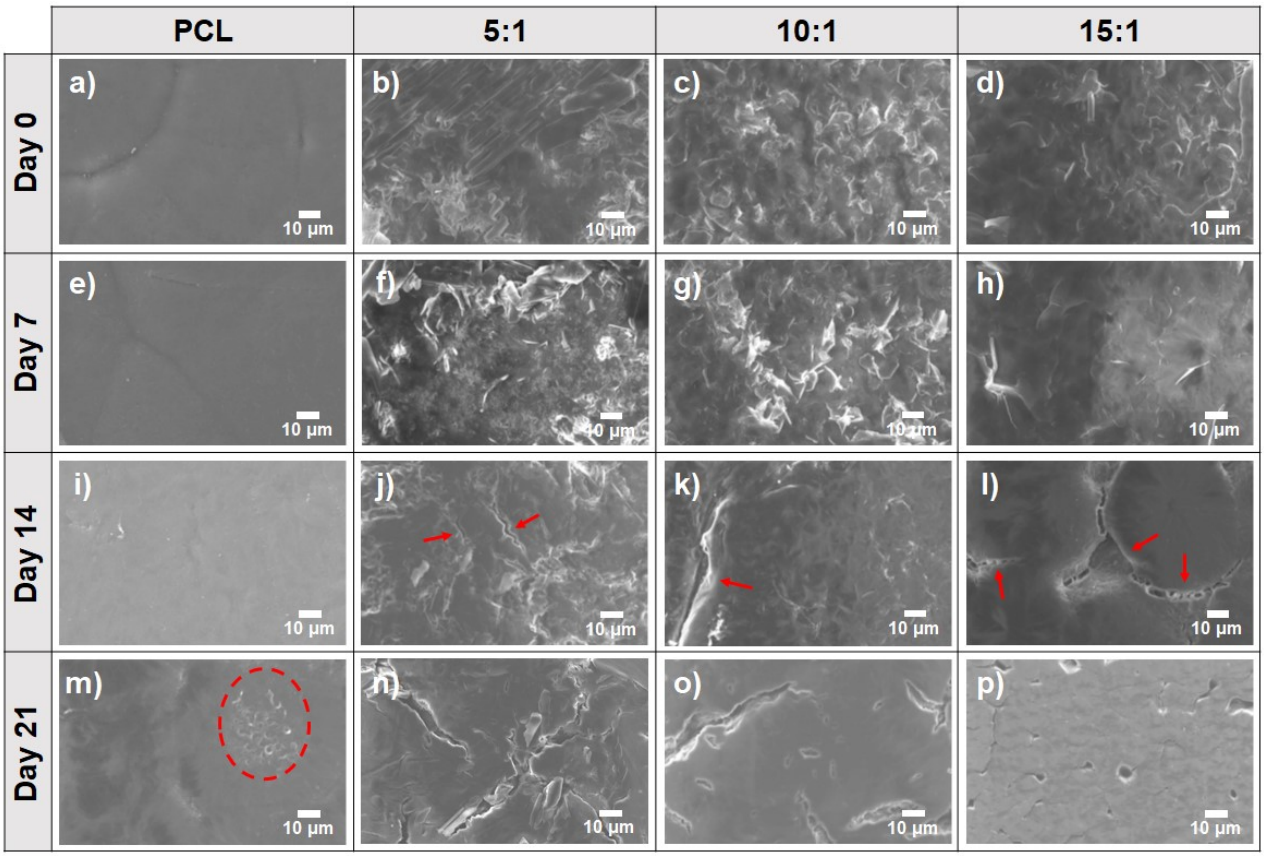

Fig. S4 SEM images of PCL and PCL/LA films with various compositions (PCL:LA ratios of 5:1, 10:1, and 15:1, respectively) during degradation in PBS (pH 7.2) at 45 ˚C over three weeks. The arrows show the formation of cracks and pores, whereas the dashed-line circle shows the surface erosion of the films.

6. Photographs of PCL and PCL/LA films after accelerated degradation testing.

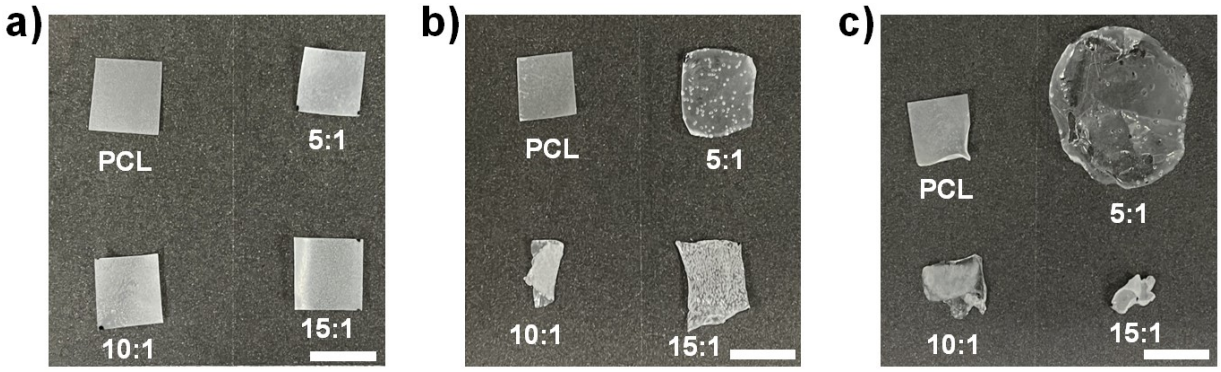

Fig. S5 Photographs of PCL film (upper left) and PCL/LA films with PCL:LA composition of 5:1 (upper right), 10:1 (bottom left), and 15:1 (bottom right) after being immersed in pH 9 buffer solution for 1 h at temperatures of a) 37 °C, b) 45 °C, and c) 55 °C (scale bar = 1 cm).

7. Stress-strain curves of PCL and PCL/LA films after immersion in PBS at 45 °C.

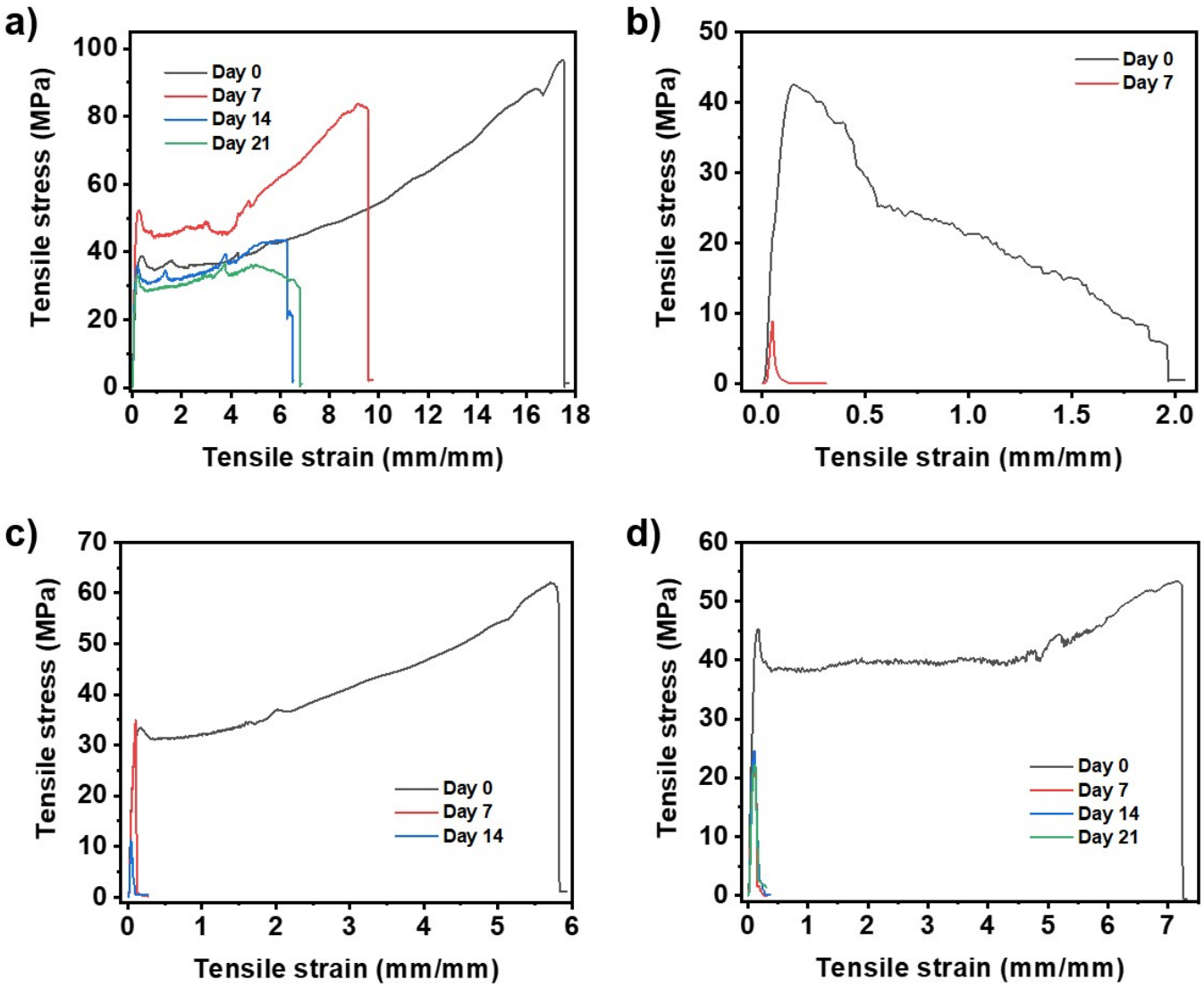

Fig. S6 Stress–strain curves of the a) PCL film and PCL/LA film with PCL:LA ratios of b) 5:1, c) 10:1, and d) 15:1 after immersion in PBS (pH 7.2) at 45 °C for three weeks.

8. Stress-strain curves of PCL and PCL/LA films after multiple bending cycles.

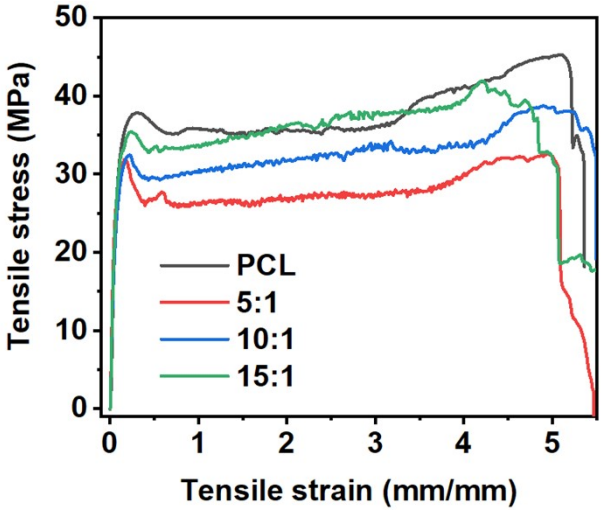

Fig. S7 Stress–strain curves of the PCL film and PCL/LA films with PCL:LA ratios of 5:1, 10:1, and 15:1 after 1,000 bending cycles.

9. Dual-stimuli responsiveness test with an additional layer of polyacrylic acid (PAA) film.

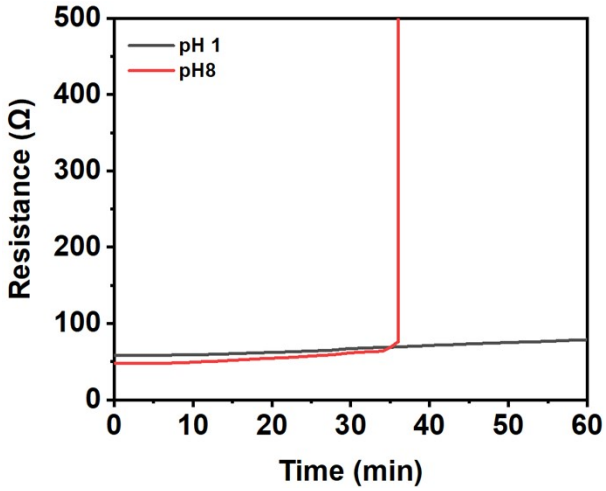

Fig. S8 Stimuli responsiveness test of the PAA and PCL/LA (PCL:LA ratio of 10:1) bilayer film. Two Mg resistor patterns encapsulated with PAA and PCL/LA films were exposed to two different solutions while being heated at 45 °C; one was exposed to pH 1 buffer solution, and the other was exposed to pH 8 buffer solution.

10. Effect of encapsulating material on the performance of piezoresistive pressure sensor.

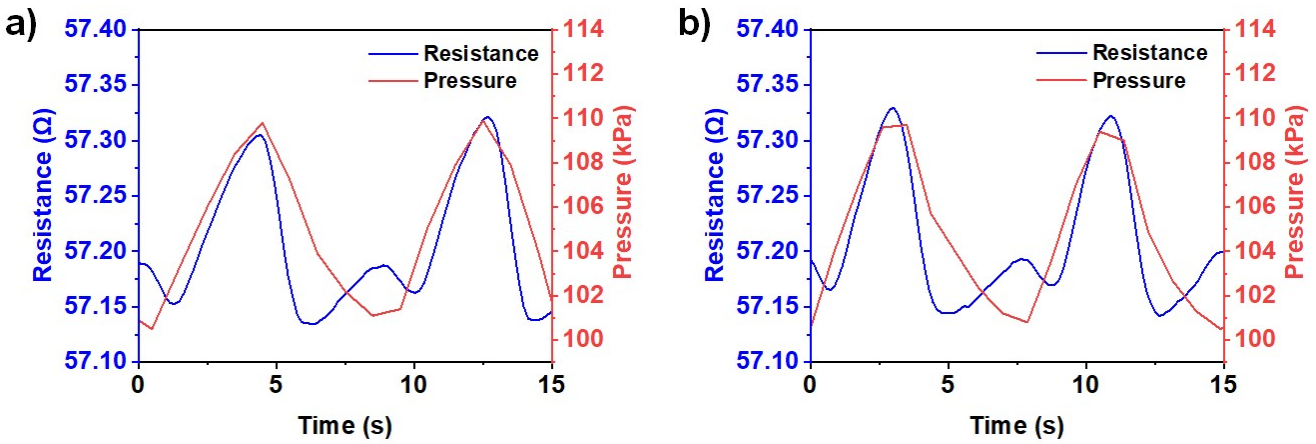

Fig. S9 Pressure response of the piezoresistive pressure sensor a) without an encapsulation, and b) encapsulated with the PCL/LA film (PCL:LA ratio of 10:1).

Piezoresistive pressure sensor was fabricated by e-beam evaporating Cr (10 nm)/Au (100 nm) resistor pattens on PLGA film (thickness ≈ 40 μm). The PLGA film was then applied over a trench prepared by molding PCL pellets, and the depth of the trench was *ca.* 1 mm. Copper wires were attached to the resistor patterns for the monitoring of resistance change of the patterns. The pressure response of the piezoresistive pressure sensors was measured with and without PLC/LA film encapsulation. The electrical resistance of the pressure sensors was measured with a digital multimeter (USB-4065, National Instruments), and pressure was applied to the sensor by placing the device in a syringe while monitoring the pressure change using a commercial pressure sensor (NeuLog). The real-time monitoring of resistance and pressure change showed that the piezoresistive pressure sensor showed changes in resistance depending on the application and removal of external pressure. The sensitivity of the pressure sensor without an encapsulant is 2.57 Ω $mmHg^{-1}$, while the sensitivity of the pressure sensor after applying the PCL/LA film is 2.51 Ω $mmHg^{-1}$, showing that encapsulation has a minimal effect on the performance of the encapsulated electronic device.

11. References

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