Carbon nanotube transistor on 3-D printed polyvinyl alcohol (PVA) substrate for transient electronics

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Transient electronics, documented in numerous reports, are an emerging class of technology, which employs materials that can vanish in a controlled, triggerable manner when exposed to various stimuli [1]. Therefore, transient electronics have potential applications in various fields, such as biomedical implants, environmental sensors, and secure memory devices [2, 3]. It has been reported that the timescale of transience can be controlled by the dissolution rate of water-soluble polymer substrates, such as polyvinyl alcohol (PVA) and silk, in which various types of electronics can be integrated [1-3]. However, despite the significant progress on water-soluble polymer substrates, applications of these substrates are limited because the life cycles of the electronics are solely controlled by the dissolution rate of the substrate materials selected at initial fabrication.

In the present work, we demonstrate a carbon nanotube (CNT) based transient electronics for accurately controlling the transience time, to operate for prescribed times and disappear at controlled rates. We utilized highly purified, preseparated 99% semiconducting CNTs because they offer a combination of superior electrical and mechanical properties; hence, they were used to fabricate various transient CNT electronics. The fabricated CNT electronics were transferred onto a water-soluble PVA substrate which provides solution-triggerable degradation. Most importantly, for precise control of the transient time a 3-D printer was employed to form the facile PVA substrate; the transience time can be accurately controlled in this substrate by modifying the PVA density adjusted by a 3-D printer. We expect that our proposed transient system can serve as a toolbox for producing solution-based transient electronics and components with tailorable disintegration.

References

1. S.-W. Hwang, H. Tao, D.-H. Kim, H. Cheng, J.-K. Song, E. Rill, M. A. Brenckle, B. Panilaitis, S. M. Won, Y.-S. Kim, Y. M. Song, K. J. Yu, A. Ameen, R. Li, Y. Su, M. Yang, D. L. Kaplan, M. R. Zakin, M. J. Slepian, Y. Huang, F. G. Omenetto, and J. A. Rogers, *Science* 337, 6102 **(2012)**.
2. D.-H. Kim, J. Viventi, J. J. Amsden, J. Xiao, L. Vigeland, Y.-S. Kim, J. A. Blanco, B. Panilaitis, E. S. Frechette, D. Contreras, D. L. Kaplan, F. G. Omenetto, Y. Huang, K.-C. Hwang, M. R. Zakin, B. Litt, and J. A. Rogers, *Nat. Mater.* 9, 6 **(2010)**.
3. K. K. Fu, Z. Wang, J. Dai, M. Carter, and L. Hu, *Chem. Mater.* 28, 11 **(2016)**.

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