IEEE International Conference on
"Nanomaterials: Applications & Properties" (NAP-2020)
Sumy, Ukraine, 9-13 Nov. 2020

Nanoribbon Aptamer-Field-Effect Transistors for Biosensing

Chuanzhen Zhao
Dept. of Chemistry & Biochemistry,
California Nanosystems Institute
University of California, Los Angeles
Los Angeles, CA
czzhao@ucla.edu

Qingzhou Liu
Mork Family Department of Chemical Engineering and Materials Science
University of Southern California
Los Angeles, CA
chongwuz@usc.edu

Paul S. Weiss
Dept. of Chemistry & Biochemistry,
California Nanosystems Institute
University of California, Los Angeles
Los Angeles, CA
psw@cnsi.ucla.edu

Chongwu Zhou
Mork Family Department of Chemical Engineering and Materials Science
University of Southern California
Los Angeles, CA
chongwuz@usc.edu

Anne Milasincic Andrews
Depts. of Psychiatry and Chemistry & Biochemistry,
California Nanosystems Institute
University of California, Los Angeles
Los Angeles, CA
aandrews@mednet.ucla.edu

We have developed approaches to fabricate wafer-scale nanoribbon field-effect transistor (FET) biosensors using straightforward top-down processes.[1-4] Nanoribbon FETs are demonstrated as sensing platforms with high sensitivity to a broad range of biological targets. We use shadow mask patterning[3] or chemical lift-off lithography[5] combined with high throughput, low-cost commercial digital versatile disks as masters to pattern micro- or nanoribbons.[2] For all micro- and nanoribbon widths fabricated, highly aligned, quasi-one-dimensional ribbon arrays were produced over centimeter length scales by sputtering to deposit 20-nm thin-film In2O3 or sol-gel low temperature processing to form 4-nm thin-film In2O3 as the semiconductor. The FET biosensors were fabricated on Si, as well as flexible substrates. Nanoribbon FETs with higher surface-to-volume ratios had better detection sensitivities for ions, small molecules, and oligonucleotides.[4] Flexible sensors were fabricated for implantable and wearable bioelectronics toward monitoring chemical signals within and on the body.[3] The FETs on 1.4-μm-thick polyethylene terephthalate (PET) substrates withstood crumpling and bending such that stable transistor performance with high mobility was maintained over >100 bending cycles. Real-time detection of the small-molecule neurotransmitters serotonin and dopamine was achieved by immobilizing recently identified high-affinity nucleic-acid aptamers[6] on individual In2O3 nanoribbon devices. Limits of detection were 10 fM for serotonin and dopamine with detection ranges spanning 6-8 orders of magnitude. Simultaneous sensing of temperature, pH, serotonin, and dopamine on flexible substrates enabled integration of physiological and neurochemical data from individual bioelectronic devices with applicability for *in vivo* brain biosensing.[3] Nanoribbon structures were also used as plasmonic sensors.[1] Sensitivity to local refractive index changes in the nearfield was achieved, as evidenced by real-time tracking of lipid vesicle or protein adsorption. Together, these findings illustrate simple and economical means to pattern large area transistor and plasmonic and nanostructures for applications in biosensing and optoelectronics.

REFERENCES

[1] C. Zhao, X. Xu, A. R. Ferhan, N. Chiang J. A. Jackman, Q. Yang, W. Liu, A. M. Andrews, N. J. Cho, and P. S. Weiss, "Scalable fabrication of quasi-one-dimensional gold nanoribbons for plasmonic sensing." *Nano Lett* 2020, *20* (3), 1747-1754.

[2] C. Zhao, X. Xu, S. H. Bae, Q. Yang, W. Liu, J. N. Belling, K. M. Cheung, Y. S, Rim, Y. Yang, A. M. Andrews, and P. S. Weiss, "Large-area, ultrathin metal-oxide semiconductor nanoribbon arrays fabricated by chemical lift-off lithography." *Nano Lett* 2018, *18* (9), 5590–5595.

[3] Q. Liu, C. Zhao, M. Chen, Y. Liu, Z. Zhao, F. Wu, Z. Li, P. S. Weiss, A. M. Andrews, and C. Zhou, "Flexible multiplexed In_2O_3 nanoribbon aptamer-field-effect transistors for biosensing." *iScience* 2020, *23*, 101469.

[4] C. Zhao, Q. Liu, K. M. Cheung, W. Liu, Q. Yang, X. Xu, P. S. Weiss, C. Zhou, and A. M. Andrews, "Narrower nanoribbon biosensors fabricated by chemical lift-off lithography show higher sensitivity." *ACS Nano* in revision.

[5] W. S. Liao, S. Cheunkar, H. H. Cao, H. R. Bednar, P. S. Weiss, and A. M. Andrews, "Subtractive patterning *via* chemical lift-off lithography." *Science* 2012, *337* (6101), 1517-21.

[6] N. Nakatsuka, K. A. Yang, J. M. Abendroth, K. M. Cheung, X. Xu, H, Yang, C. Zhao, B. Zhu, B. Y. S. Rim, Y. Yang, P. S. Weiss, M. N. Stojanović, and A. M. Andrews, "Aptamer–field-effect transistors overcome Debye length limitations for small-molecule sensing." *Science* 2018, *362*, 319-324.