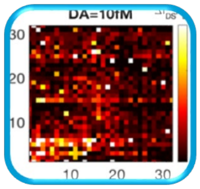

➢ Bottom-Up Nanowire Technologies for Printed Electronics and Biosensing

Ultrathin semiconductor nanowires and nanoscopic metal- semiconductor junctions with diameters down to ~ 3 nm are interesting as transducer materials for gas-, chemical- and bio-sensor applications, given their high surface to volume ratio. To enable the sensing of species with ultra-low concentrations without the need of expensive amplification equipment the Walter Weber Group has set-up an ion sensitive nanowire based sensor device technology platform in close cooperation with biologists, material scientists, and electronic packaging groups. **Specificity** is provided by immobilized receptors at the nanowire surface that selectively bind the molecular targets. Ultra-low measurement **resolution is empowered by the choice of nanowires** that different to bulk and -2D ISFET channels allow a full channel depletion upon binding of a few and even single molecular targets. To ensure a large **detection range** and to obtain large **current output** for a realistic portable application a multi-nanowire channel transducer with ~ 1.000 parallel aligned nanowires is applied. The devices are able to provide relatively high output currents up to 0.3 mA at 1 V as given by the sum of the individual nanoscopic-channels (Fig. 1) [1-2].

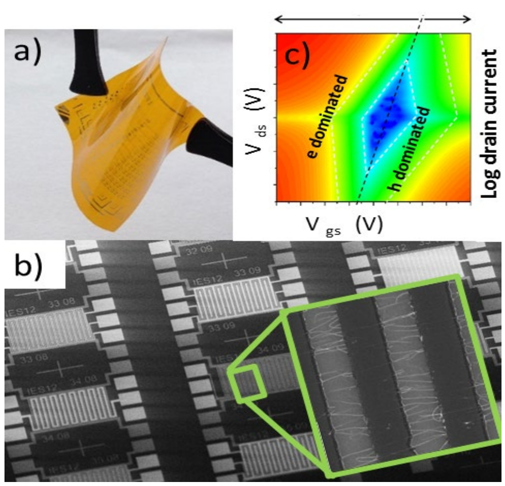

Fig. 1 Printed parallel nanowire sensor platform. a) Photo of a mechanically flexible avian-influenza H1N1 nanowire sensor. b) SEM image of devices with close up view of the parallel printed nanowire pH and bio-sensor with current output of 0.3 mA at 1V bias. c) Measured IV characteristic map.

In cooperation with IFW (D. Makarov and O. Schmidt) and MBZ (L. Baraban and G. Cuniberti) both in Dresden, Germany we were able to build mechanically flexible H1N1 **avian influenza virus** sensors [3], human **α-thrombin** sensors as a basis for point-of-care blood protein analysis [4], as well as **glucose detection** through a glucose oxidase (GOx) enzymatic test. We recently studied the **signal to noise behavior** of these nanowire ISFET transducers in dependence of channel geometry in dry and wet conditions [5].

In another sensor system approach we developed a functional **nanowire sensor layer on top of a completely processed CMOS chip** (Fig. 3.7, [6]). In this hybrid bottom-up to top-down integration scheme the high sensitivity and specificity of bio-coated nanowires and nano-junctions are combined with a dedicated low-noise CMOS on-chip amplification circuitry. In cooperation with the Bioengineering Laboratory of ETH-Zürich and RIKEN in Kobe-Japan my group has successfully carried out the hybrid integration of bottom-up synthesized Si nanowires on a fully processed CMOS amplification and steering chip as a 32x32 array platform for chemical- and bio-sensing with spatiotemporal resolution and parallel readout. Thereto a back end compatible integration process was developed, the Si nanowires were transferred and assembled selectively at the desired electrodes by dielectrophoresis.

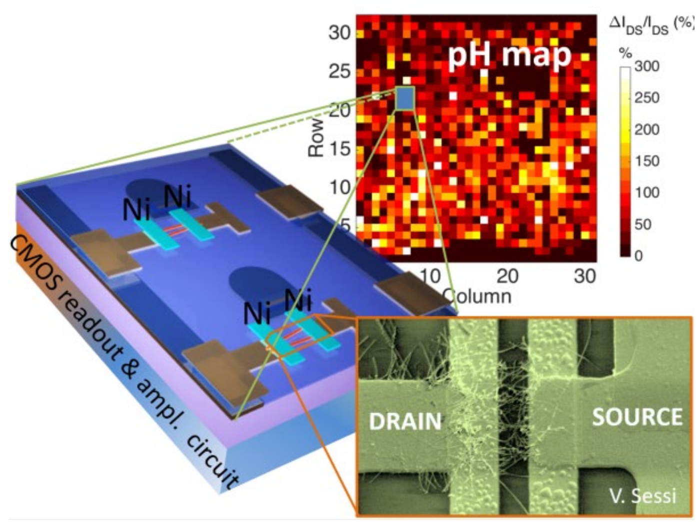

Fig. 3.7. Hybrid bottom-up nanowire - CMOS integrated chip delivering a functional sensor platform for spatiotemporal pH and biosensing. The chip consists of a 32 x 32 matrix of individually addressable sensor sites with on-site amplification.

Literature:

[1] D.-Y. Jeon *et al.*, "Scaling and Graphical Transport-Map Analysis of Ambipolar Schottky-Barrier Thin-Film Transistors Based on a Parallel Array of Si Nanowires," *Nano Lett.*, vol. 15, no. 7, pp. 4578–4584, Jul. 2015.

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[6] V. Sessi *et al.*, "A CMOS-based Silicon Nanowire Array for Biosensing Applications," *Nano-Bio-Sens. Conf. Proc*, 2017.