Nanowires for High-Speed Nanoelectronics and Nanophotonics

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Abstract: The application of epitaxial compound semiconductor nanowire heterostructures for low-energy, high-speed nanoelectronics and nanophotonics will be presented.

GaN and related III-nitrides are nowadays the material of choice for the fabrication of high brightness light emitting diodes (LEDs). Recently, a GaN nanowire based GaInN/GaN multi quantum well LED structure has been developed on insulating sapphire by a self-assembled MOVPE approach. Commonly, the c-plane growth is used for both nanowire- and layer-based growth for GaN based LED. The c-plane, however, exhibits a strong internal electrical field due to spontaneous polarization, causing long carrier life-times. Presently, the 3-dB modulation bandwidth of any high performance GaN LED is limited to about 200-300 MHz. This issue may be overcome by the access to the m-plane that is intrinsically free from strong internal electrical field. We present the MOVPE growth, the fabrication, and the electroluminescence performance above 1 GHz of an m-plane core-shell p-i-n InGaN/GaN quantum well nanowire LED grown on conductive n-Silicon (111) substrates providing high-speed LEDs suitable for polymer fiber optical communication.

In addition, novel heterogeneous integration schemes for the implementation of nanowire devices in existing circuits are presented and both an inverter circuit and a sample & hold circuit function is experimentally confirmed. The nanowire is an extremely versatile tool in nanophotonics. The nanowire can uniquely produce and absorb light. For the light it can serve at the mean time both as a waveguide and a resonator, respectively. Hence, compound semiconductor nanowires open up a powerful tool box for the development of future nanophotonic devices and circuits.

Figure 2 shows a simple S/H circuit consisting of a switching FET M1, a hold capacitor C_h, and an output buffer (transistors M2, M3), where the analog input signal is held as a certain amount of charges when M1 is turned off. For high speed S/H performance a very high transconductance transistor is needed which perfectly fits to the performance of InAs NW MISFET [2]. Therefore, the transistor M1 is an InAs NW MISFET. On the other hand a high current driver is required which has been realized by conventional InP heterojunction MISFETs again by heterogeneous integration. Fig. 2c shows the input and output waveforms experimentally obtained from the circuit shown in Fig. 2b which confirms the basic sample-

and-hold circuit operation The observed offsets at the transition from the track mode to the hold mode are due to the clock feed through which can be suppressed by a novel differential scheme S/H circuit enabling 7 bit resolution up to almost 1000 MHz sampling frequency.
The heterogeneous combination of InAs nanowire transistor with InP-based heterojunction MISFET outperforms currently existing nanowire circuits and underline the performance potential of this approach.

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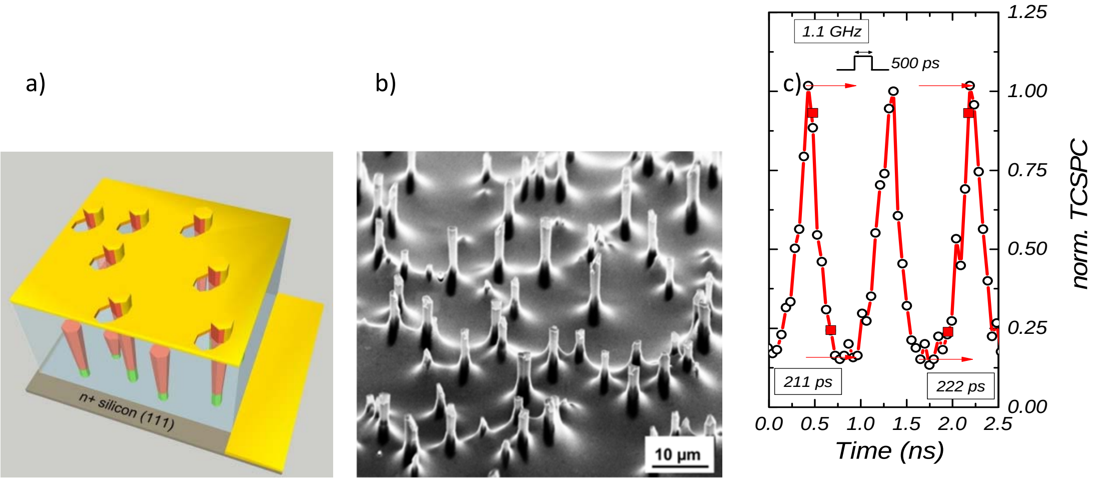

Figure 1: GaN/InGaN nanowires High-Speed Nanowire LED (a) device sketch, (b) SEM micrograph of the processed device, and (c) normalized time correlated single photon counting (TCSPC) signal at 1.1 GHz repetition frequency. The red squares represent the 90%-10% rise- and fall-times of the individual light pulses.

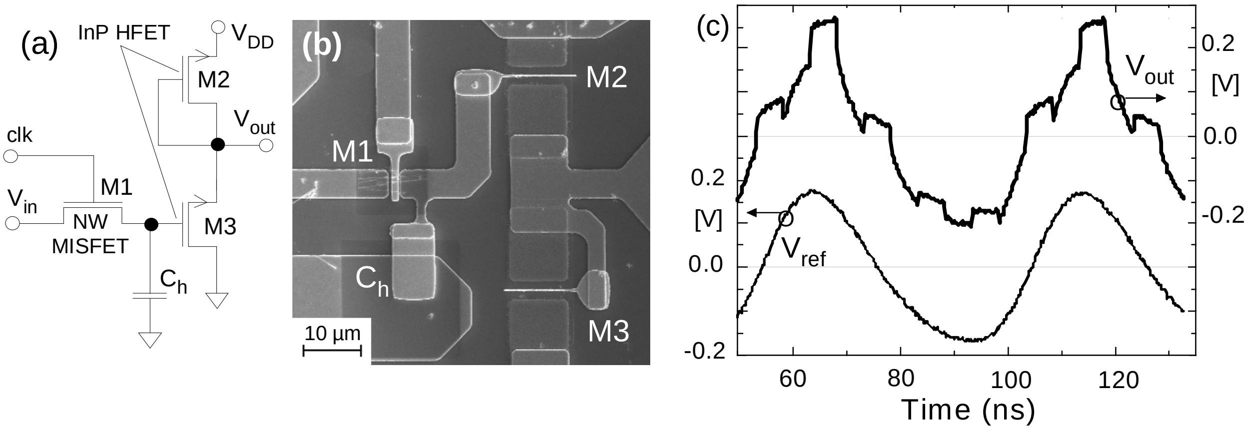

Figure 2. Sample & hold Circuit: (a) schematic, (b) SEM micrograph, and (c) input and output waveforms obtained experimentally at 100 MHz sampling frequency.