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Nanowires for High-Performance Integrated Macroelectronics

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Extensive electrical and optical characterization has shown that single-crystal semiconductor nanowires display physical properties that match or exceed those of their bulk counterparts. In addition, our studies have shown that it is possible to manipulate and assemble high-performance devices using low-temperature liquid based processes. These high-performance semiconductor device properties and unconventional processing advantages possible with nanowires can be readily applied in the field of macroelectronics, where integrated devices are patterned over large noncrystalline and/or flexible substrates. The separation of high temperature nanowire synthesis from subsequent ambient temperature assembly allows for electronic devices of varied functionality to be fabricated on virtually any substrate. We have fabricated p-Si nanowire transistors on glass and plastic substrates that display parameters rivaling those of single crystal silicon and exceeding those of state-of-the-art amorphous silicon and organic transistors currently used for flexible electronics on plastic substrates today. With the improved reproducibility obtained through improvements in nanowire growth and the use of multi-nanowire transistors, we have been able to demonstrate integrated logic structures with gain up to megahertz frequencies. On-chip integration of nanowire-based inverters was accomplished in a fully parallel process, and has enabled the fabrication of inverters and ring oscillators with frequencies up to 200 MHz, the highest observed for circuits based on nanoscale materials.