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A Reprogrammable Universal Logic Gate Based on a Nano Cantilever Resonator

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Extended Abstract

With nanofabrication capabilities reaching molecular level [1,2], the interest in realizing scalable electromechanical computing architecture has been rekindled. Considerable research is being undertaken to design leakage-free computing components [3-6]. Earlier efforts include mechanical (difference engine, 1822) and inductor-capacitor oscillator (PC-1, 1958) based computers; however these were rendered obsolete by transistors. Transistors are not suitable for harsh environment applications and do require complicated thermal management systems due to the excessive heat dissipation. Further, miniaturization of transistors to improve computational power has reached the ultimate physical limits. As a step towards overcoming the limitations of transistor-based computing, here we demonstrate a reprogrammable universal Boolean logic gate based on a nanoelectromechanical cantilever oscillator. All the fundamental logic gates are condensed in a single nanocantilever, thereby reducing interconnects. The device is dynamically switchable between any logic gates for a given drive frequency and is demonstrated to operate at elevated temperatures.

The nanoelectromechanical device consists of a standard in-plane silicon (Si) cantilever fabricated using CMOS compatible e-beam lithography and surface nanomachining. The device is designed with two sided electrostatic gate electrode configuration, where the device's logic function is defined by the gate inputs. The nanocantilever was characterized inside ST-500 temperature controlled vacuum probe station from Janis research. The chamber was pumped down to vacuum below 80 µTorr at all temperatures. The device was placed on a sample stage with resistive heaters for heating the device under test. The nanocantilever is electrically excited using an a.c. drive voltage in addition the DC voltage sources.

Ideally, a cantilever beam made of a single isotropic material is less prone to shift in resonance frequency with temperature, which may arise only due to the softening of the cantilever by thermoelastic response. Unlike clamped-clamped beams (bridges) [6], cantilever beams do not experience induced axial stresses due to temperature variation, making them almost immune to temperature induced frequency shifts. Here we experimentally demonstrate XOR/XNOR, NOT, NOR/OR and AND/NAND Boolean gates in a single nanocantilever oscillator operational up to 100 ^{o}C, thereby eliminating the need for thermal management systems.

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