

Beyond CMOS: Wafer Scale Heterogeneous Integration of III-Vs and Other Dissimilar Materials with Si CMOS to Create Intelligent Electronics/Micro-systems

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Abstract

Advances in silicon technology continue to revolutionize microelectronics. However, Si cannot do everything, particularly for high performance, high frequency RF and mixed signal applications. As a result circuits based on other materials systems, such as III-V semiconductors, are required. However, these other device technologies do not enjoy the integration density, cost benefit and manufacturing infrastructure of Si. So how can we get the ‘best of both worlds’? What is the best way to integrate these dissimilar materials with Si? In this paper, we review different heterogeneous integration approaches and, as an example, summarize our results on the successful wafer-scale, 3D heterogeneous integration (3DHI) of GaN HEMTs and Si CMOS.

Our Au-free GaN HEMTs have been successfully fabricated entirely in a Si foundry on semi-standard, 200 mm diameter Si wafers using Cu damascene interconnects. RF performance compares favorably with GaN on SiC devices fabricated in a III-V foundry with Au-based contact and interconnect metallurgy. Oxide bonding is being used to integrate these GaN on Si wafers with Si CMOS wafers. Through-dielectric-vias (TDVs) are used to interconnect the high performance GaN RF devices/circuits with high density CMOS control and logic circuits, resulting in ultra-short, wide-bandwidth interconnects and enabling circuit optimization through intimate and arbitrary placement of CMOS logic and control circuitry relative to III-V devices. Through-substrate-vias (TSVs) are used for thermal management. This ‘flexible’ wafer-scale, integration platform is compatible with other III-V devices, other (non-Si) device/component technologies and any node of Si CMOS or SiGe BiCMOS. The 3DHI process is being used to fabricate cost effective, high performance, digitally enhanced, RF and mixed signal ICs such as ‘intelligent’ and adaptive/reconfigurable transceivers.

Thus, heterogeneous integration of III–V devices, MEMS and other dissimilar materials with Si CMOS enables a new class of high-performance integrated circuits that enhance the capabilities of existing systems, enable new circuit architectures and facilitate the continued proliferation of low-cost micro-/nano-electronics for a wide range of applications.