Photovoltage versus microprobe sheet resistance measurements on ultrashallow structures

Earlier work [T. Clarysse, Mater. Sci. Eng., B 114-115, 166 (2004); T. Clarysse, Mater. Res. Soc. Symp. Proc. 912, 197 (2006)] has shown that only few contemporary tools are able to measure reliably (within the international technology roadmap for semiconductors specifications) sheet resistances on ultrashallow (sub-50-nm) chemical-vapor-deposited layers [T. Clarysse, Mater. Res. Soc. Symp. Proc. 912, 197 (2006)], especially in the presence of medium/highly doped underlying layers (representative for well/halo implants). Here the authors examine more closely the sheet resistance anomalies which have recently been observed between junction photovoltage (JPV) based tools and a micrometer-resolution four-point probe (M4PP) tool on a variety of difficult, state-of-the-art sub-32-nm complementary metal-oxide semiconductor structures (low energy and cluster implants, with/without halo, flash- and laser-based millisecond anneal). Conventional four-point probe tools fail on almost all of these samples due to excessive probe penetration, whereas in several cases variable probe spacing (using a conventional spreading resistance probe tool) [T. Clarysse, Mater. Sci. Eng. R. 47, 123 (2004)] still gives useful values to within about 20%-35% due to its limited probe penetration (5-10 nm at 5 g load). M4PP measurements give systematically a sensible and reproducible result. This is also the case for JPV-based sheet resistance measurements, although these appear to be prone to correct calibration procedures and are not designed for the characterization of multijunctions. Moreover, in a significant number of cases, residual damage and/or unexpected junction-leakage currents appear to induce a strong signal reduction, limiting the applicability of the JPV technique. This has been further investigated by transmission-electron microscopy, high carrier-injection photomodulated optical-reflectance, and Synopsis-Sentaurus device simulations.

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