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3.2 ms effective minority-carrier lifetime in *n*-type silicon grown by the noncontact crucible method

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We evaluate gettering response of n-type photovoltaic silicon grown by the noncontact crucible method (NOC-Si). As-grown effective minority-carrier lifetime is low (~150 µs) and relatively homogeneous, despite low concentrations of bulk impurity content (below one part per million) and low structural defect density (<10^3 cm^{-2} average). We employ industrial-standard and extended phosphorus gettering schemes to expound the as-grown lifetime-limiting defects. For the first generation of materials, wafers from the ingot-top (first to solidify), effective minority carrier lifetime >750 and >1800 µs are achieved for industrial-standard and extended gettering profiles respectively. Relatively lower improvement is achieved in the middle and bottom parts of the ingot, where concentric-swirl patterns of low lifetime are revealed after gettering. We hypothesize that as grown lifetime is mostly limited by fast-diffusing recombination-active impurities, which can be efficiently removed by gettering. However, swirl microdefect regions similar to Czochralski silicon intrinsic point defects can locally limit gettering response and cause inhomogeneity in lifetime. Effective lifetime of up to 3.2 ms is achieved for the second generation of materials, demonstrating the potential of NOC-Si to support high-efficiency solar cells upon application of appropriate bulk microdefect and impurity control during growth and/or gettering.

Key words: Defects; Impurities; Gettering; Non contact crucible method, Minority career lifetime