Hyperdoping of semiconductors by ion implantation and ultrafast annealing: solid vs. liquid phase epitaxy

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Hyperdoped semiconductors exhibit exotic physical properties opening new routes for the fabrication of highly-sensitive photodetectors, intermediate band solar cells and ultra-fast nanoelectronics. The engineering of the electronic band structure in semiconductors by hyperdoping allows the strong enhancement of the below-band-gap photocurrent generation, insulator-to-metal transition (IMT) or creation of new magneto-optoelectronic devices. Hyperdoping requires an incorporation of foreign elements into the lattice side of the semiconductor far above the solid solubility limits. To this day the hyperdoping was realised either by the low-temperature molecular beam epitaxy or by the femtosecond or nanosecond liquid phase epitaxy during laser annealing. Here, we propose the novel millisecond range solid phase epitaxy performed by the flash lamp annealing (FLA) technique with a time range in between rapid thermal annealing and laser melting. The FLA was successfully utilised to fabricate ferromagnetic GaMnAs alloys with excellent optical properties, an IMT in the chalcogen doped Si with a substitutional rate higher than 70% or highly-conductive TCO (aluminium doped ZnO). Experimental data show that ion implantation followed by the millisecond range FLA is a cost-effective and high-throughput alternative for the processing of the hyperdoped semiconductors with outstanding properties.