Electron Inversion Layer Mobility in Strained-Si $n$-MOSFETs with High Channel Doping Concentration Achieved by Ion Implantation

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Inversion layer mobility measurements in strained-Si $n$-MOSFETs fabricated using a typical MOSFET process including high temperature steps and with various channel doping concentrations, achieved by boron ion implantation, are compared with co-processed bulk-Si $n$-MOSFETs. It is found that a near-universal mobility relationship with vertical effective electric field, $E_{\text{eff}}$, exists for strained-Si and bulk-Si $n$-MOSFETs for all channel implant doses in this study. Significant mobility enhancement for $E_{\text{eff}}$ up to 2 MV/cm (1.5-1.7 $x$) is obtained for channel doping concentrations ranging from $10^{17}$-6x$10^{18}$ cm$^{-3}$.

Long-channel $n$-MOSFET devices were fabricated and measured with various ion implant doses in strained-Si and bulk-Si (unstrained) channels. The devices were fabricated using a typical MOSFET process including high temperature steps of gate oxidation and reoxidation at 800°C and a 1000°C spike anneal for source/drain and polysilicon-gate doping activation. Electron mobility measurements on 50x50 µm$^2$ $n$-MOSFETs with oxide thickness of 5 nm were extracted for boron ion implant concentrations in the range $10^{17}$-6x$10^{18}$ cm$^{-3}$ as shown in Figure 42. Significant mobility enhancement for all channel doping concentrations for the entire $E_{\text{eff}}$ range measured (1.5-1.7 $x$) are observed. Furthermore, a near-universal mobility relationship with $E_{\text{eff}}$ is found. The conclusion from this study is that strained-Si $n$-MOSFETs, with channel doping concentration required to meet the off-current requirement for the ITRS 40 nm technology node ($L_{\text{gate}}$=28 nm), can be fabricated with little if any loss of low-field mobility enhancement using conventional MOSFET processes with ion-implanted channels and high temperature steps.

**Fig. 42:** Effective electron mobility in strained-Si and bulk-Si $n$-MOSFETs vs. effective vertical electric field, $E_{\text{eff}}$ for varying channel doping concentrations.