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Suppressed Incomplete Ionization of Shallow Donors in Germanium[1] JOSE MENENDEZ, CHI XU, CHARUTHA SENARATNE, JOHN KOUVETAKIS, Arizona State Univ — For doping levels $N_d > 10^{17}$ cm^{-3}, an elementary analysis indicates that shallow donors should not be completely ionized in germanium at room temperature. The predicted degree of incomplete ionization (I.I.) represents a fundamental limitation in the quest for ultra-low sheet resistances, as required in Ge-based nMOS devices. Unfortunately, the experimental verification of the predictions is made difficult by the possible presence of inactive dopants, which also lead to free carrier concentrations $n < N_d$. In this work, we prepared n-type Ge films on Ge-buffered Si substrates using novel synthetic approaches that are expected to minimize the presence of inactive dopants. Higher-order germanes (Ge_3H_8 and Ge_4H_{10}) were used as the source of Ge for growth at low temperatures. Phosphorus atoms were furnished via $P(MH_3)_3$ (M = Ge, Si) compounds in which the P atom is already bonded to three group-IV atoms in a way that is expected to promote substitutional incorporation. Spectroscopic ellipsometry and SIMS were used to determine n and N_d, respectively. The results indicate no observable I.I. Within experimental error, $n = N_d$, in contradiction with the elementary theory. These findings are compatible with the model developed by Altermatt *et al.* to explain I.I. phenomena in silicon.

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Jose Menendez
Arizona State Univ

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