Numerical Simulation of the Electrical Characteristics of GeSn/Ge Semiconducting Heterostructures

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The group IV semiconductor alloy germanium tin ($Ge_{1-x}Sn_x$) is an attractive material for next-generation devices in nanoelectronics. The strain resulting from the lattice mismatch between the film and substrate materials provides a new tool for band structure engineering. An example of this design flexibility is to use $Ge_{1-x}Sn_x$ alloys as stressors for uniaxially compressive-strained Ge p-type channel metal-oxide-semiconductor (pMOS) to enhance the hole and electron mobilities compared to unstrained Ge.

However, $Ge_{1-x}Sn_x$ alloys started to receive attention only recently, with advances in epitaxial growth techniques allowing $Ge_{1-x}Sn_x$ epilayers to be grown with high crystalline quality[1]. The detailed electronic properties of $Ge_{1-x}Sn_x$ compounds are therefore not yet clearly understood[2]. This was our motivation to carry out a theoretical study of heterostructures based on $Ge_{1-x}Sn_x$ material.

A 1D numerical simulation method was developed, based on the solution of the basic semiconductor equations. Equations accounting for the presence of defects such as Shockley-Read-Hall (SRH) traps are explicitly included and then numerically treated without any further approximation. These equations are subsequently numerically solved in steady state regime as well as in small-signal ac regime. This gives us access to microscopic and macroscopic properties of the structure, and thereon, to an understanding of the electrical properties of $Ge_{1-x}Sn_x$ by linking quantities such as admittance spectra to microscopic variations in the structure. As an example of such results, Fig. 1 shows impedance spectra of a p-$Ge_{1-x}Sn_x$/n-Ge heterostructure ($x \approx 0.05$, see inset of Fig. 1 for structure dimensions) for several values of p doping concentrations in GeSn.

A two-dimensional simulation code is also being developed to take into account the effects of the coplanar position of the contacts on structures such as a pMOSFET device with strained Ge channel and GeSn source and drain (Fig. 2) and the resulting two dimensional variations of microscopic quantities.

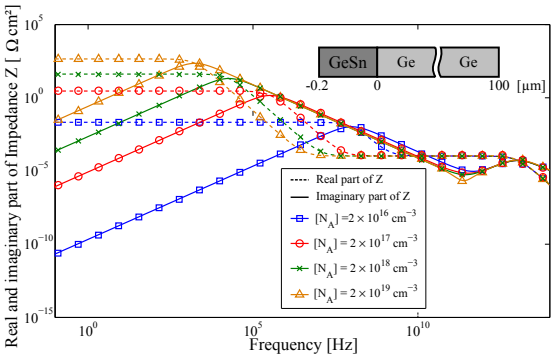

Figure 1: Real and imaginary parts of impedance Z for several p-doping concentrations ([N_A]) in GeSn, as a function of modulation frequency. Inset: schematic of the corresponding heterostructure.

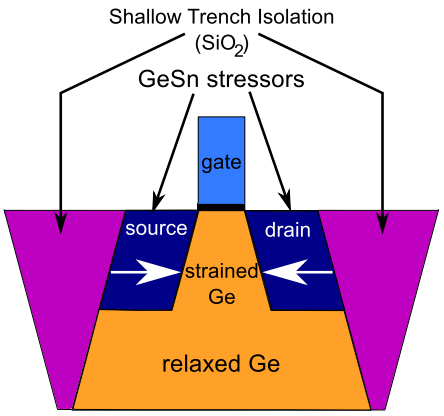

Figure 2: GeSn source and drain stressors in a pMOSFET device.

[1] B. Vincent et al., Appl. Phys. Lett., vol. 99, 152103, October 2011
[2] O. Nakatsuka et al., Jpn. J. Appl. Phys., vol. 49, no. 4, April 2010.