



High mobility 2D holes in strained epitaxial Germanium quantum well heterostructures

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Carrier mobility is one of the most important parameters of any semiconductor material, determining its suitability for applications in a large variety of electronic devices including field effect transistors (FETs). Bulk or 3D, Germanium (Ge), with its very high intrinsic hole and electron mobilities of 1900 and 3900 cm²V⁻¹s⁻¹ at room temperature, respectively, is the most promising candidate material to replace Si channels in future complementary metal oxide semiconductor (CMOS) devices. When one or more of the dimensions of a solid are reduced sufficiently to nanometer range, its physicochemical characteristics notably depart from those of the bulk solid. With reduction in size, novel electrical, mechanical, chemical, magnetic, and optical properties can be introduced. The resulting structure is then called a low-dimensional structure or system.

Biaxial compressive strain in nm scale thick Ge epilayer narrows its band gap and causes the appearance of a quantum well (QW) in the valence band. Holes confined in the strained Ge QW form a two-dimensional hole gas (2DHG) and have an increased mobility due both to their lower effective mass and reduced scattering factors in this material system. During the recent years a major breakthrough have been achieved in enhancement of carrier mobility in strained epitaxial Ge grown on a standard Si(001) substrate. Extremely high room- and low-temperature 2DHG mobilities of up to 4,500 cm²V⁻¹s⁻¹ [1] and 1,500,000 cm²V⁻¹s⁻¹ [2], respectively, have been demonstrated. These hole mobilities are the highest not only among the group-IV Si, SiGe, Ge, SiC and Diamond semiconductors, but also among p-type III–V, II–VI and emerging 2D materials.

Appearance of so high 2DHG mobility in strained epitaxial Ge has already led to demonstration, for the first time, of various quantum phenomena and unique properties in it. They include strong Rashba SO interaction [3], fractional quantum Hall effect [4], Terahertz quantum Hall effect [2], quantum ballistic transport [5], self-organised fractional quantisation [6], electronic transport anisotropy [7], ballistic holes with strong g-factor anisotropy [8] and 2DHG with very low effective mass of 0.035m₀ [7]. The obtained effective mass is not only the lowest for holes among all known semiconductor materials, but also lower than electron effective mass in GaAs. Without any doubts, epitaxial strained Ge material will be an excellent platform for scientists and engineers to discover new quantum phenomena and applications.

References

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