Emergence of the highest mobility holes in a 2D system epitaxially grown on a silicon wafer

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A new technological breakthrough in epitaxial growth of the highest quality group IV semiconductor material 2D system, attractive for new fundamental research and also suitable for large-scale practical applications, will be presented. Mobility of free carriers in conduction (electrons) or valance (holes) bands, along with a reasonably large energy band gap, is one of important quality figures of any semiconductor material, which determines its suitability for advanced applications in a large variety of classical electronic and sensor devices, as well as for novel applications in emerging quantum electronics.

Recently, a record-high mobility of holes, reaching 4.3×10^6 $cm^2V^{-1}s^{-1}$ in an epitaxial compressively strained germanium (cs-Ge) quantum well semiconductor 2D system, grown on a standard silicon (Si) wafer ,with (001) crystallographic orientation, was reported.[1] This significant increase of the mobility by over four times, compared to the previous state of the art, allows for the first time hole devices to outperform electron ones in the group IV semiconductor materials.

In order to appreciate the archived breakthrough, the historic evolution of hole mobility in the group IV semiconductors at low temperatures is shown in Fig. 1. For comparison, the highest mobility of electrons in tensile strained Si (ts-Si) quantum well is shown.[2] The demonstrated hole mobility in cs-Ge on Si (cs-GoS) material system is twice larger of the best mobility of electrons reported up to date in the state of the art ts-Si.

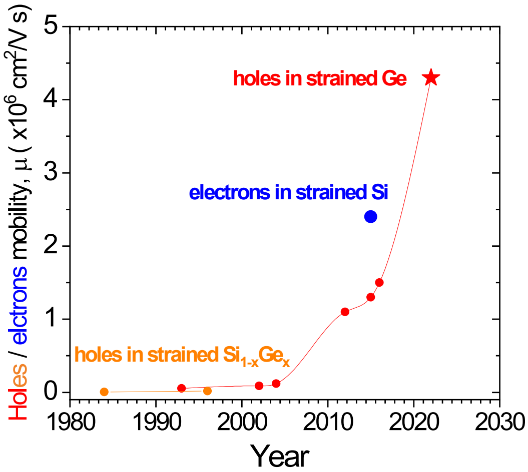

Fig. 1. The historic evolution of the highest hole mobility in the group IV semiconductors at low temperatures, i.e. ≤4.2 K. The star marks hole mobility in strained Ge of this work. The highest electron mobility in ts-Si QW is shown for comparison (blue solid point).

Furthermore, this achievement reduces the gap between the highest hole mobility in gallium arsenide (GaAs) 2D system modulation doped heterostructures grown on the same material substrate, i.e. GaAs, which was recently increased from 2.3×10^6 $cm^2V^{-1}s^{-1}$ to 5.8 $cm^2V^{-1}s^{-1}$.[3,4] It should be noted, III-V materials are more complicated to process, are much more expensive, not widely abundant in the Earth's crust, compared to Si and Ge. In addition, unfortunately III-V do not exist in isotopically pure forms, and are not compatible with the advanced Si technologies for mass production opportunities. All other known semiconductors, including III-V, II-VI, perovskites, 2D materials, etc. show substantially lower carrier mobility than in the cs-GoS and GaAs heterostructures.

This reported breakthrough in the enhancement of hole mobility in cs-GoS was achieved due to the development of state-of-the-art epitaxial growth technology culminating in superior monocrystalline quality of this material system with a very low density of background impurities and other imperfections. This superior material system with the combination of unique properties opens new opportunities for innovative quantum device technologies and applications in quantum as well as in classical electronics, and sensors.

References

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