Magnetotransport in highly enriched ^{28}Si for quantum information processing devices

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Elimination of unpaired nuclear spins can result in low error rates for quantum computation; therefore, isotopically enriched ^{28}Si is regarded as an ideal environment for quantum information processing devices. Using mass selected ion beam deposition technique, we *in-situ* enrich and deposit epitaxial ^{28}Si achieving better than $99.99998\ \%$ ^{28}Si isotope fractions [1]. To explore the electrical properties and optimize the growth conditions of *in-situ* enriched ^{28}Si, we fabricate top gated Hall bar devices, and investigate the magnetotransport in this material at magnetic fields as high as $12\ \mathrm{T}$ and temperatures ranging from $10\ \mathrm{K}$ to $1.2\ \mathrm{K}$. A schematic of the cross-sectional view and an optical micrograph of the fabricated device is shown in fig.1 (a) and (b), respectively. At a temperature $1.9\ \mathrm{K}$, we measure maximum mobilities of approximately $(1740 \pm 2)\ \mathrm{cm^2/(V \cdot s)}$ and $(6040 \pm 3)\ \mathrm{cm^2/(V \cdot s)}$ at an electron density of $\approx 1.2 \times 10^{12}\ \mathrm{cm^{-2}}$ for devices fabricated on ^{28}Si and natural Si, respectively. For magnetic fields $B > 2\ \mathrm{T}$, both types of devices demonstrate well developed Shubnikov-de Haas oscillations on the longitudinal magnetoresistance (see fig2 and fig3). In contrast to the device on isotopically enriched ^{28}Si epi-layer, the device on natural Si demonstrates spin-splitting for $B > 3\ \mathrm{T}$ (see fig2). Furthermore, relative to the device on $^{\mathrm{nat.}}$Si, the weak-localization is stronger for the device fabricated on isotopically enriched ^{28}Si. Based on the T dependence of the Shubnikov-de Haas oscillations and weak-localization, the dominant scattering mechanism in these devices appears to be background impurity scattering and/or interface roughness scattering. We believe that the relatively lower mobility and stronger weak-localization observed for the devices fabricated on ^{28}Si may be due to the dilute adventitious C, N and O in deposited ^{28}Si.

[1] K. J. Dwyer, J. M. Pomeroy, D. S. Simons, K. L. Steffens, and J. W. Lau, Journal of Physics D: Applied Physics **47**, 345105 (2014).

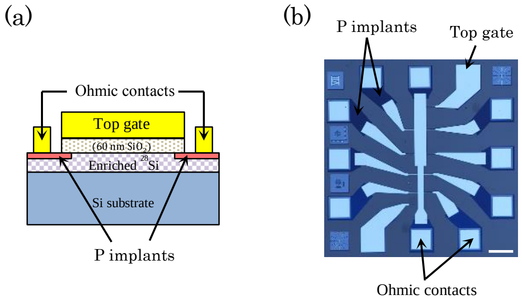

Fig.1: (a) Schematic representations of the gated Hall bar devices fabricated on [28]Si and (b) An optical micrograph of a gated multi terminal Hall bar device fabricated on [28]Si are shown.

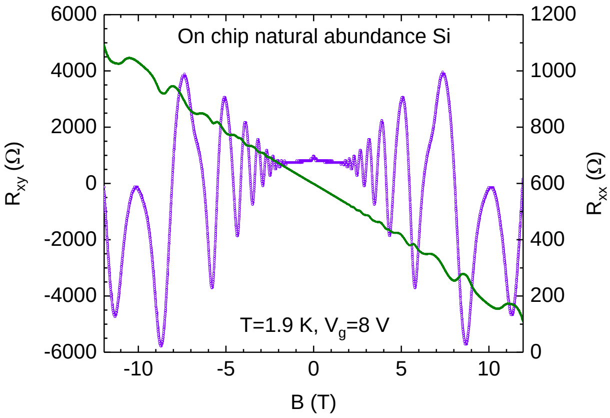

Fig.2: Magnetoresistance R_{xx} (right-axis) and Hall resistance R_{xy} (left-axis) measured for the device fabricated on natural Si substrate are shown. Note that the device on [nat.]Si and [28]Si are fabricated on the same Si substrate. Therefore, both have the same processing history.

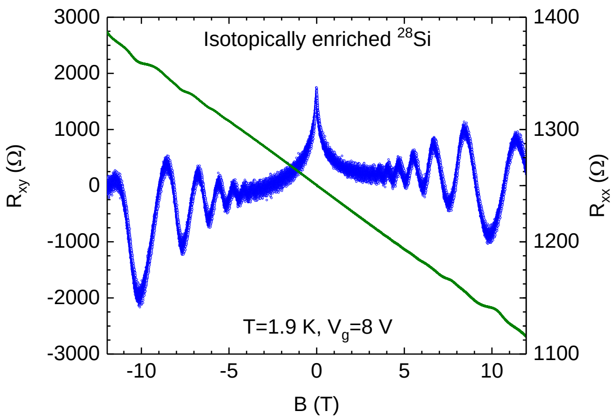

Fig.3: Magnetoresistance R_{xx} (right-axis) and Hall resistance R_{xy} (left-axis) measured for the device fabricated on isotopically enriched [28]Si epi-layer are shown.