Two-Dimensional Electron System at $SrTiO_3$ Films Grown Epitaxially on p-Si(001)

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Introduction

We demonstrate that a two-dimensional (2d) electron system is present in $SrTiO_{3-\delta}$ thin films coherently grown on p-Si (001) by Molecular Beam Epitaxy (MBE). We investigate the electronic properties of $SrTiO_{3-\delta}$/ Si (001) using magnetotransport measurements at low temperatures.

Experimental

Epitaxial $SrTiO_3$ films are grown by oxide MBE on p-Si(001) at an O_2 partial pressure of 4×10^{-8} Torr resulting in slightly Oxygen deficient films. The resistance is measured in a Van der Pauw configuration using the general purpose 18/20 T, Superconductor Magnet System (SCM-2) at the DC facility of the NHMFL.

Results and Discussion

The resistance of a single-crystal, 23.6 nm thick $SrTiO_3$ film on p-Si(001) measured at a temperature *T*=0.28 K as a function of a magnetic field (*B*) applied perpendicular to the film plane is shown on **Fig.1a** for *B*>7 T and on **Fig.1d** for -4 T<*B*<4 T. We observed Shubnikov-de Haas (SdH) oscillations in the high-*B* magnetoresistance (MR) after subtracting a polynomial background. **Fig.1b** shows the SdH oscillations as a function of the inverse magnetic field 1/*B*. The SdH oscillation period as a function of the peak index gives the SdH carrier concentration as shown on **Fig.1c**. The MR at low B is negative pointing to a 2d system (**Fig.1d**) and is consistent with the MR at *T*=2 K. The measured magnetoconductivity is due to 2d quantum interference effects and is fitted to a 1-parameter expression from Ref. 1 (**Fig.1e**). The phase decoherence length is smaller than the film thickness; electrons appear to be confined within a few nanometers. The carrier concentration determined from Hall measurements (**Fig.1f**) and SdH oscillations differ less than a factor of two. The SdH carrier concentration is equal to the Hall carrier concentration at *T*=10 K.

Conclusions

Magnetoresistance (SdH) oscillations were observed. Our results demonstrate that the unique electronic properties of the $SrTiO_{3-}\delta$ oxide system can be directly integrated with Si, the workhorse of semiconductor industry.

Acknowledgements

This project was supported by the NSF-CAREER award DMR-1255629. The National High Magnetic Field Laboratory is supported by the National Science Foundation through NSF/DMR-1157490/1644779 and the State of Florida.

References

[1] S. Hikami et al., Progress of Theoretical Physics, 1980. **63**(2): p. 707-710.

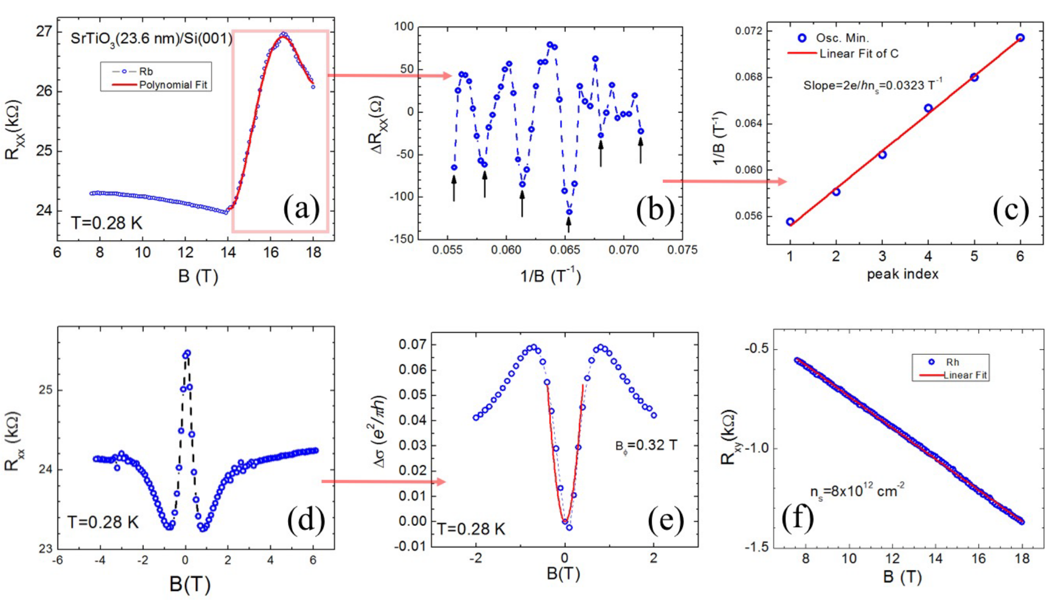

Figure 1: (a) High-*B* MR and polynomial fit for *B*>14 T, (b) subtraction of the polynomial fit from the data results in resistance oscillations in 1/*B* (SdH oscillations); the arrows point to the position of the oscillation minima, (c) the indices of the MR minima are plotted on the x-axis, the corresponding values of 1/B are plotted on the y-axis; the SdH electron density is determined from the linear fit (shown in red) with a slope of 2|e|/h n_s, n_s(SdH)= $1.5x10^{13}$ cm^{-2}, (d) the low-*B* MR is negative due to quantum interference effects, (e) the low-*B* conductance (=1/R_S) is fitted to the HLN expression (red line) using one parameter, $B\phi$ (f) the Hall carrier concentration is determined from the Hall resistance, n_s(Hall)= $8x10^{12}$ cm^{-2}