Influence of intervalley scattering on the metallic behavior in Si MOSFETs

V. T. Renard[1], I. Duchemin[2], Y. Niida[3], A. Fujiwara[4], Y. Hirayama[3] and K. Takashina[5]

[1]*CEA-INAC/UJF-Grenoble 1, SPSMS, UMR-E 9001, 17 rue des martyrs, 38054 Grenoble cedex 9, France*
[2]*CEA-INAC/UJF-Grenoble 1, SP2M, UMR-E 9001, 17 rue des martyrs, 38054 Grenoble cedex 9, France*
[3]*Graduate School of Science, Tohoku University, 6-3 Aramakiaza Aoba, Aobaku, Sendai, 980-8578 Japan*
[4]*NTT BRL, NTT Corporation, Atsugi-shi, Kanagawa 243-0198, Japan*
[5]*Department of Physics, University of Bath, Bath BA2 7AY, UK*

Whether or not electrons confined to two dimensions conduct electricity when the temperature approaches absolute zero remains a subject of intense research and controversy. It is well established that the metallic behavior is stronger in systems like silicon where valley degeneracy enhances interactions. However, little is known about the role of valley splitting and inter-valley scattering, two processes associated with valley degeneracy. After demonstrating that valley splitting could be electrically controlled in Si quantum wells [1], we have recently shown that valley splitting suppresses the metallic behavior in this system [2]. Here, we address the problem of inter-valley scattering which has previously been disregarded because of the lack of theoretical description.

We implement a recent theory of weak-localization magneto-conductivity (MC) with inter-valley scattering [3] to extract the inter-valley scattering time in our sample. Doing so not only allows us to demonstrate for the first time that the metallic behavior can be observed even in presence of strong inter-valley scattering, but also to show that this observation can be quantitatively explained by the interplay of electron-electron interactions and weak localization [4]. Our analysis leads to the solution of a long standing pivotal paradox concerning weak-localization and the metallic behavior in Si. This paradox had arisen from the observation a MC typical of weak-localization, while its characteristic logarithmic temperature dependence in zero field conductivity had been illusive in the metallic state. We show that this is due to a coincidental cancellation by effects of interactions between electrons at B=0 T (Figure 1).

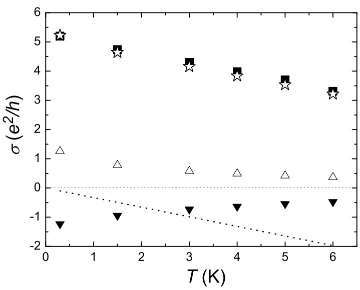

Figure 1: Measured conductivity (■) for $n = 3.9 \times 10^{15}$ m^{-2}, ballistic interaction correction (···), diffusive interaction correction (△), weak localization correction (▼) and the sum of Drude, WL, diffusive and ballistic contributions (☆).

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