# Tuning spin-charge interconversion with confinement in ultrathin Bi/Ge(111) films

C. Zucchetti,[a,b*] M.-T. Dau,[b] F. Bottegoni,[a] C. Vergnaud,[b] T. Guillet,[b] A. Marty,[b] C. Beigné,[b] A. Picone,[a] A. Calloni,[a] G. Bussetti,[a] A. Brambilla,[a] L. Duò,[a] F. Ciccacci,[a] P. K. Das,[c] J. Fujii,[c] I. Vobornik,[c] M. Finazzi,[a] and M. Jamet[b]

a. LNESS-Dipartimento di Fisica, Politecnico di Milano, 20133 Milano, Italy

b. Univ. Grenoble Alpes, CEA, CNRS, Grenoble INP (Institute of Engineering Univ. Grenoble Alpes), INAC-Spintec, 38000 Grenoble, France

c. CNR-IOM Laboratorio TASC, 34149 Trieste, Italy

∗ carlo.zucchetti@polimi.it

Spin-charge interconversion (SCI) phenomena have attracted a large interest in nowadays spintronics, since they represent an essential step towards the design and engineering of spintronic devices [1]. In this respect, the scalability down to the nanometer scale and the integrability with opto-electronic and spintronic devices are important features that drive the choice of the SCI platform [2]. Here, we investigate SCI in ultrathin Bi films epitaxially grown on Ge(111) as a function of the Bi thickness $t$. We use x-ray diffraction and scanning tunneling microscopy to obtain a clear picture of the morphology and crystallography of the system. Through spin- and angle-resolved photoemission we show that spin-polarized surface states crossing the Fermi level are present. Then, we directly probe the charge-to-spin conversion by detecting with magneto-optical Kerr effect the electrically-induced spin accumulation in Bi, and the spin-to-charge conversion by generating a spin current in the system with either optical or ferromagnetic resonance driven spin injection. We recover large SCI signals in the thickness range ($1 < t < 3$ nm) characterized by the presence of small Bi nanocrystals. We observe that the conversion efficiency drastically decreases as $t$ increases, when the Bi islands start to percolate. Since bulk SCI is small, the conversion is mainly related to the Rashba-Edelstein effect associated with electron transport in the spin-polarized surface states. In this frame, we tentatively explain the observed thickness dependence of SCI by reminding that the Bi conductivity can be strongly affected by quantum confinement effects [3]. In the high confinement conditions realized in the Bi nanoislands obtained for $1 < t < 3$ nm, the bulk resistivity is assumed to be high enough to electrically disentangle the upper and lower Bi surfaces, which otherwise would give rise to opposite contributions to SCI conversion that tends to cancel out, drastically decreasing the net SCI signal. Our results indicate that quantum size effects might be exploited as a tool to tune SCI and investigate a very rich spin-physics [4].

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