Electron scattering in the presence of spin-orbit interaction: the $BiAg_2$ surface alloy

S. Schirone,[1,2] G. Peschel,[1] R. Piquerel,[1] P. Gambardella,[1,3,4] A. Mugarza[1]

[1] Catalan Institute of Nanotecnology (ICN), UAB Campus, E-08193 Bellaterra, Spain
[2]Dipartimento di Fisica, Università di Roma "La Sapienza", P.le Aldo Moro 2, 00185 Roma, Italy
[3]Instituciò Catalana de Recerca i Estudis Avancats (ICREA), E-08193 Barcelona, Spain
[4]Departament de Física, UAB Campus, E-08193 Barcelona, Spain
stefano.schirone@icn.cat

Abstract

Spin-orbit interaction (SOI) in metallic surfaces can lead, via the Rashba effect, to a splitting of the spin degeneracy and the emergence of particular spin textures where the latter appears correlated with the wave vector k. The consequent entanglement between spin and orbit leads to the suppression of backscattering, which can give rise to exotic transport phenomena such as the induction of dissipationless charge and spin currents [1,2].

Here we use the $BiAg_2$ alloy, which is characterized by the strongest to date Rashba effect [3,4], to study the effect of SOI on scattering. The alloy is formed on the $Ag(111)$ surface after the deposition of $\frac{1}{3}$ monolayer of Bismuth, which induces a $(\sqrt{3}\times\sqrt{3})R30°$ reconstruction. The scattering has been studied using Scanning Tunnelling Microscopy (STM) and Spectroscopy (STS). In this way we have studied electron confinement by measuring the interference patterns formed by surface electrons scattered from monoatomic steps. The negligible leakage we observe across the steps indicate a strong confinement effect, comparable to that observed in metals with marginal SOI such as Ag(111) [5]. This is in agreement with the quantized energy levels measured for electrons confined between a pair of steps, comparable to that of infinite quantum wells. Surprisingly, confinement is strong even at energy regions where backscattering is predicted to be prohibited by the spin texture of the electronic states, and where previous STM studies failed to observe interference patterns [6]. Additionally, the effect of the atomic structure of the scatterer has been explored by using two different types of step, where substantial differences have been found both in the scattering strength and asymmetry of the step potential. The latter indicates that, for particular step configurations, scattering is significantly different for electrons going upwards or downwards across the steps.

The results describe a scenario that is far more complex than that of a simple two dimensional free-electron gas in the presence of a strong SOC.

Reference

[1] D. Pesin and A. H. MacDonald, Nature Materials **11**, 409 (2012).

[2] M. Franz, Nature **466**, 323 (2010).

[3] C. Ast, J. Henk, A. Ernst, L. Moreschini, M. C. Falub, D. Pacile, P. Bruno, K. Kern, and M. Grioni, Physical Review Letters **98**, 186807 (2007).

[4] G. Bihlmayer, S. Blügel, and E. V Chulkov, Physical Review B **75**, 195414 (2007).

[5] J. E. Ortega, J. Lobo-Checa, G. Peschel, S. Schirone, Z. M. Abd-El-Fattah, M. Matena, F. Schiller, P. Borghetti, P. Gambardella, and A. Mugarza, Submitted 1 (2013).

[6] H. Hirayama, Y. Aoki, and C. Kato, Physical Review Letters **107**, 027204 (2011).

Figures

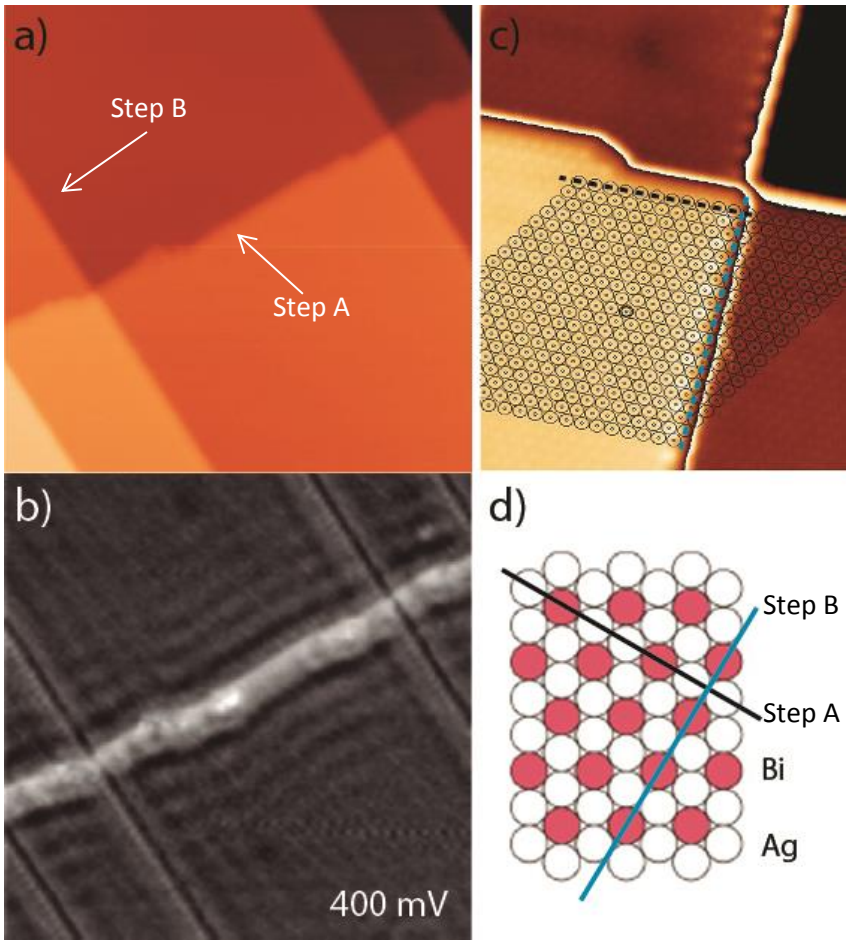

Figure 1: (a) Topographic image of a zone of the sample with different type of monoatomical step, acquired with $I_t = 0.59$ nA and $V_{\text{bias}} = 0.2$ V. Image size: 406×406 Å^2. (b) dI/dV-map acquired acquired at $V_{\text{bias}} = +0.4$ V. Note that the intensity of the standing wave scattered from the two kind of steps is different. (c) Topographic image performed with $I_0 = 0.59$ nA. $V_{bias} = 28$ mV Image size: 164×110 Å^2. The surface lattice structure is resolved in the image, and the different termination of each step type can be distinguished. (d) Schematics of the lattice of the surface alloy. Solid lines indicate the direction of each step type.