HORIZON 2020

# Spin-Orbit Coupling at Interfaces from Spintronics to new Superconducting effects

## Reporting

Project Information

**SOCISS**

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Project website

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10.3030/703195

Project closed

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€ 158 121,60

**Coordinated by**
UNIVERSIDAD DEL PAIS VASCO/ EUSKAL HERRIKO UNIBERTSITATEA
Spain

## Periodic Reporting for period 1 - SOCISS (Spin-Orbit Coupling at Interfaces from Spintronics to new Superconducting effects)

**Reporting period:** 2016-06-01 to 2018-05-31

### Summary of the context and overall objectives of the project

The main objective of the SOCISS project was to gain a deep understanding of how the spin-orbit coupling that arises at the interface of two different materials influences the spin transport properties of these junctions. During the realization of the project the researcher has been able to understand the nature of this interaction through the following results
- Description of the spin-to-charge and spin-to-spin conversion in metal-metal junctions in the presence of interfacial spin-orbit coupling. These results have been first calculated using a ballistic approach. Two unexpected results were found. First, a new spin-to-charge channel conversion due to the interaction between the incoming and the reflected by the interface wave functions. The second and more surprisingly was that interfacial spin-orbit coupling is responsible of spin-to-spin conversion.
- Extension of the Zaitsev's boundary conditions to the cases in which interfacial spin-orbit coupling is present. This work is almost finished and we expect to publish its results very soon. This approach allows us to explain all the different mechanisms of spin-to-charge and spin-to-spin conversions when interfacial spin-orbit coupling is present. It also allows us to explain how these effects depend on the thickness of the junction. Its extension to superconductivity will be hold in the next year.
- Study of the influence of interfacial spin-orbit coupling in Anomalous Hall effect experiments.
- Direct collaboration with experimental observations of the effect of interfacial spin-orbit coupling in the Anomalous Hall and Spin Hall effects in metal-oxide and ferromagnet-oxide junctions. This work has been done in collaboration with two different groups. One lead by Professor Félix Casanova at Nanogune in San Sebastián, and the one lead by Professor Otani in Tokio. This work is almost finished and we expect to publish its results very soon in three different papers.
- Realization of spin transport DFT based simulations including interfacial spin-orbit coupling. Unfortunately, these type of calculations require a huge number of k-points in order to converge and more effort will be required in order to obtain last results. Preliminary results tend to agree with the theoretical calculations previously discussed.

The researcher has also described of a new critical temperature to describe magnetic transition for magnetic molecules. This study was not first included in the project but the nice environment of the Nano-bio group allowed the researcher to discuss and collaborate with Dr. Joaquim Jornet-Somoza giving rise to this work.

All the results showed above allow us to gain a huge understanding on the effect of interfacial spin-orbit in spin transport phenomena. We have developed a very powerful theoretical tool which will allows us to complete define all the spin transport effects due to this crucial interaction. The collaborations with the experimental groups in order to test this theory is a great evidence of the strength of these results. The complete understanding of interfacial spin-orbit may play a very important role in obtaining very efficient spin-to-charge convertes one of the most important challenges of the spintronics community.

## Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

The project had three main objectives:
- Describe how interfacial SOC affects the most important spin transport phenomena through effective kinetic equations. This allows us to answer many open questions as the importance of thickness. (WP1)
- Develop DFT-based calculations in order to understand which are the key physical aspects ruling interfacial SOC. (WP2)
- Include interfacial SOC in order to understand how this interaction could play a central role in the appearance of long range triplet component superconductivity. (WP3)

The first objective has been completely achieved using two different methods. We have used a scattering matrix approach, in the same lines as the Landauer Büttiker approach, and developed the extended boundary conditions in order to use kinetic equations.
As it is has been previously explained the other two main objectives are still under current work at the moment. This is due to two different causes. Firstly during the study of the theoretical models of WP1 we have found very interesting and unexpected results which we had to deal with. It is worth to be noted the first description of spin-to-spin conversion due to interfacial spin-orbit coupling. The second cause is the difficulties we have found mostly due to the unexpected need of huge computational resources. However both WP2 and WP3 are on-going work and we expect to obtain the first results in the following months.

During the realization of the project, the researcher has dissiminated and communicated its result by the following ways:

- Through two peer-reviewed scientific publications.

- Through the realization of oral presentations in the 4 different conferences (APS March Meeting, Quantum Spintronics at interfaces, etc)

- Through the presentation of a poster in 4 different conferences, e.g. Spin Caloritronics 7

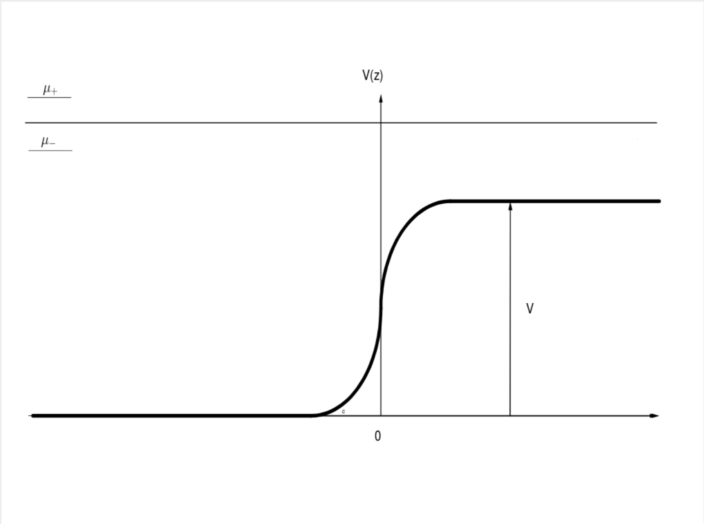
- Through the realization of 3 different seminars of one hour of duration in the following research institutions: SISSA (Trieste), ICN2 (Barcelona), The University of Missouri

- Through the participation in the Lanaldi program. The program consist on different meetings with high school students in order to explain them which is the work that researchers perform and try to make the science labour more accessible for them. The researcher has had several meetings with different students, most of them young women, helping the incorporation of women to science, one of the main objectives of H2020.

## Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider

societal implications of the project so far)

We have stablish a complete new descripton of interfacial spin-orbit coupling which may explain in a clean and easy way any spin transport phenomena concerning this interaction. The theory only requires to calculate some effective parameters, through ab-initio calculations or through experimental setups, and provides a very intuitive picture of the great possible influence of interfacial spin-orbit coupling. The discovery of not only great spin-to-charge conversion but spin-to-spin ones opens a new plethora of possibilities within the spintronics community. The experimental detection of this new transport channel represent a very potential impact in the near future.

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