HINTS

Next Generation Hybrid Interface for Spintronic Applic

THE PROJECT NEWSLETTER

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HINTS Project | Issue 4 – Month 36 – Year 3 | May| 2014

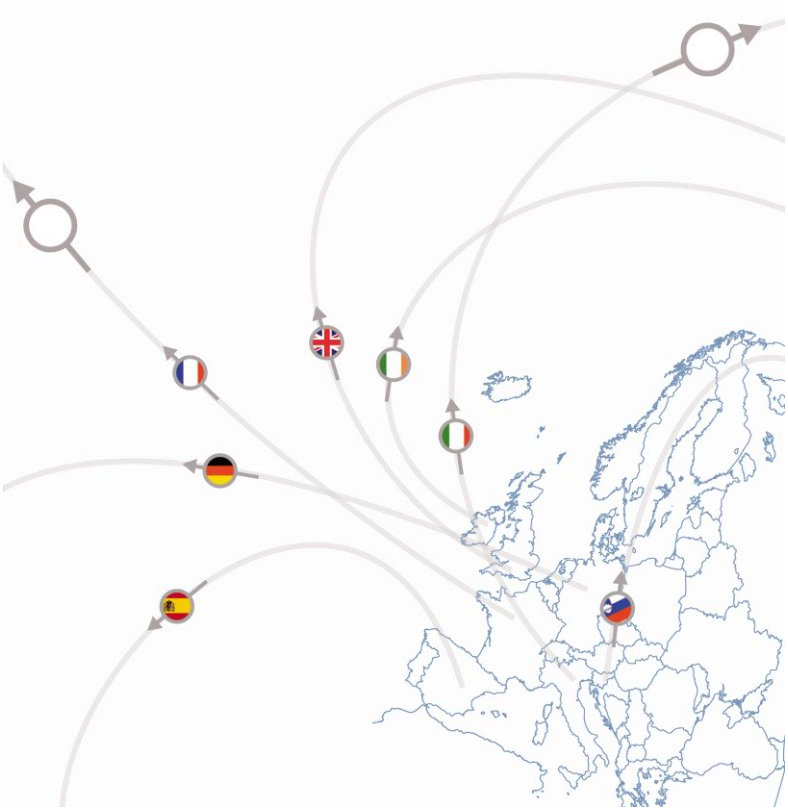
HINTS – Results and achievements

So far so good

The Consortium has succeeded to fulfil all the most important and ambitious objectives of the project. The extremely challenging objective of controlling the sign of the spin transfer at the interface (objective still critical in inorganic spintronics) has been achieved even in two different ways: by chemical tailoring of the interface (foreseen in the workplan) and by electric interfacial tuning (discovered by HINTS). While the former allows to select the sign during sample fabrication, the latter, attributable to a smart multifunctional interface behaviour, allows to change the sign during the device operation (reconfigurable operation). HINTS succeeded to bring to 11V the voltage interval where the magnetoresistance is detected, while the workplan objective was 3-5V. While highest voltage operation was detected at low T (<50 K), some materials maintained these properties up to 200-250K close to room temperature operation. This achievement paves the way for future detailed investigation of spin polarized effects on OLED behaviour, considering such parameters as efficiency, colour and other. Indeed, HINTS anticipated this by showing unequivocal and strong effect of spin polarization of driving currents on OLEDs (HyLEDs) electroluminescence. Realization of continuous interfacial tailoring layers and realization of HOI interfaces with sharpness of 1 nm (approximately one molecule size) have been achieved. This achievement exceeds the state-of –the art quality of interfaces in OLED and OFET devices and could be applied beyond organic spintronic applications. Interfacial proximity effect was found to embody the most powerful tailoring method for the control of spin transfer across HOI interfaces. The energy of this effect exceed room temperature promoting routes for conceptually new device paradigms. Innovative devices based on rich linear and nonlinear interface effects will definitely represent most proficient application and research line on the short and short-medium terms. The modification of interfacial spin transfer by insertion of magnetic molecules (high spin) was also achieved. While this fulfils the objectives of the project, the modification was generally negative. Revealing the full potential of merging together the fields of spintronics and molecular magnetism would represent the topic for a fully dedicated project or even number of projects and will for sure constitute one of the most advantageous future research lines. A disruptive progress was achieved by a joint experimental-theoretical effort concerning the basic rules governing the spin transfer at HOI interfaces. HINTS looked "inside the interface" revealing how the spin dependent residence time is distributed in the first 2-3 monolayers of the organic semiconductor. The spin dependent residence time at the interface was proposed as a key parameter for the spin filtering capability. The model, based on spin dependent band broadening and energy shifts, was strongly upgraded by HINTS. Both approaches indicate robust room temperature spin transfer and spin selectivity outcomes. On the theoretical side it has been revealed for the first time the enormous role in spin injection and transport of the resistance non-linearity in organic semiconductors. The built model defines the set of parameters, such as interface resistance, organic resistance, voltage and others, able to provide the detection of the magnetoresistance (similarly to conductivity mismatch effect in inorganic spintronic devices). The involvement of industrial partners in the main project objectives has further grown up. Thus, two equipment producing partners succeeded to develop useful modifications to their commercial products as stimulated by the needs of HINTS requirements to the interface.

HINTS is being funded by the EU Commission DG research within the VII Framework Programme for Research and Development

The Project was funded by the 7th Framework Programme, under the programme Cooperation, theme: nanosciences, nanotechnologies, materials & new production technologies (NMP).
The Project started the 1st June 2011 and ended the 31st May 2014, involving both academics and industrial partners focused on potential application, ensuring en effective exploitation of results.



http://cordis.europa.eu/fp7/cooperation/nanotechnology_en.html

The HINTS project has involved 14 entities from 8 Countries, each of them with specific roles and different levels of involvement.
The consortium was composed by 7 Universities, 3 Research Centers and four companies spread across Europe.

Follow us on
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HINTS consortium promoted and disseminated its project results through the participation at several events regarding the spintronics and the magnetic world. Two of these events are presented below:

Magnetism 2014 was a conference on magnetism, magnetic materials and spintronics. This brings a particular focus to research in the UK and Republic of Ireland but attendees from elsewhere are also welcome.
Magnetism 2014 included three main themes of thin films & nanostructures, correlated electrons and soft matter magnetism. However, the umbrella nature of the conference means we welcome all aspects of magnetic and spintronic related research. Furthermore, the conference included the annual Wohlfarth lecture which acknowledges the contribution made by Professor E P Wohlfarth to the study of magnetism in the UK and worldwide and his commitment to international collaboration in scientific research and magnetism in particular.

DPG Frühjahrstagung (Spring Meeting) of the Condensed Matter Section (SKM) was held in Dresden, from the 30th March to the 4th April 2014.

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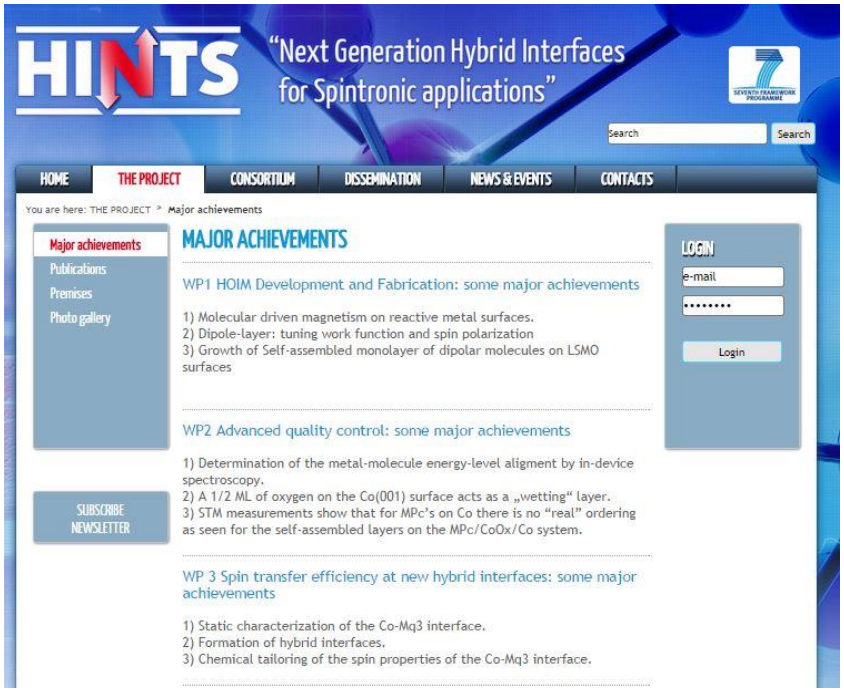
Project Status

The project was successfully finished on the 31st May 2014. All the results were achieved and they were got across to the European Commission via the elaboration of the II periodic report and via the Final report.
Moreover all the main project objectives were successfully achieved; below the milestones scheduled during the whole lifetime of HINTS project are reported.

Milestone number	***Milestone name***	***Lead beneficiary number***
MS1	*Full set of protocols for the three tailoring approaches established.*	UVEG
MS2	*Evidence for the spin transfer enhancement by any of the tailoring approaches.*	LiU
MS3	*Optimization of the WP2 set of characterizations via an WP3 -> WP2 feedback*	UNIKL
MS4	*Expanding ICT quality HOI material deposition to Large 3" size*	MBEK
MS5	*Overcoming the 1V limitation for spintronic operation of HOI interfaces*	ISMN-CNR
MS6	*Identification of the most efficient tailoring approach for the interface spin transfer control*	QMUL
MS7	*Implementation of successful tailoring approach in nanoscale structures*	MLU

HINTS major achievements

Recently, a new interesting page has been created in the HINTS website (www.hintsproject.eu), summarizing the HINTS major achievements during the whole lifetime of the project (see public section area at the following URL: http://www.hintsproject.eu/2-eng-the-project.html).
The Project website will be kept alive for other 5 years.



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XXXVI month meeting – Bologna (Italy) – 16th and 17th June 2014

The **XXXVI month meeting** was held in Bologna (Italy) at the Consiglio Nazionale dell Ricerche (CNR) the last 16th and 17th June 2014.

The meeting day was dedicated to the presentation of the activities carried out so far by each partner and the presentation of the work performed for the Project during the second period, and the future plans for the exploitation of the results after the end of the project.

Beside the scientific issues, particular stress has been given to administrative/management aspects: the last deliverables before the end of the project, the finalization of the collection of the dissemination activities performed during the whole project and the realization of the project video at the end of the project.

HINTS group shot

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Spotlight

HINTS project video

The most interesting action carried out at the end of the project is the starting of the production of a project video that will be finalized after the end the project itself, when all the results will be collected. During the final meeting a relevant audio visual contribution was collected: all HINTS partners were interviewed. The video will collect the most relevant ideas related to the spintronic's world and to the most precious results that have been derived from the project exploitation. The target chosen for the video, are the students, and its aim is to raise attention towards the project in terms of potentialities of an European project. The key messages of the video will be related to the main results of the project, to its consortium and its framework of development. The video will be provided to all the partners, in order to be divulgated as much as possible, and will be published on the project website.

HINTS Top 10 Publications

HINTS succeeded to establish an impressive list of publications: while a number of papers is still under considerations in various journals and other papers are in preparation, about 58 papers have been published in peer reviewed journals generally with medium, high or very high impact factors. Among these 7 articles published in the Nature Publishing Group, 5 in Advanced Materials and Advanced Functional Materials, and other very important journals such as Chemical Society Reviews, ACS Nano, PRL, MRS Buletin, Nanoscale etc. HINTS publications have attracted a considerable attention of the spintronic and magnetic communities and promoted seminal role in a number of topics, stimulating new research and application interests. Thus, revealing internal interface spin related properties has brought the understanding of interfacial spintronics well beyond the state of the art and even beyond the project expectation. It definitely put Europe in the clear leading role worldwide in spintronic interfacial research. The discovery of the lacking Hanle effect has stimulated a very intense theoretical and experimental research and has the chance to reveal conceptually new effects and device paradigms. Cheap fabrication technologies have been for the first time so massively investigated for organic

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spintronic devices – and this has been convincingly disseminated and publicized, where available.

1. **Spin-dependent trapping of electrons at spinterfaces**, Steil, S., Großmann, N., Laux, M., Ruffing, A., Steil, D., Wiesenmayer, M., et al., Nature Physics, Volume 2013, Issue 9 (4), 17th February 2013, Nature Publishing Group.

2. **Determination of energy level alignment at metal/molecule interfaces by in-device electrical spectroscopy**, M. Gobbi, L. Pietrobon, A. Atxabal, A. Bedoya-Pinto, X. Sun, F. Golmar, R. Llopis, F. Casanova & L. E. Hueso, Nature Communications 5, 20th June 2014, Nature Publishing Group.

3. **Organic spintronics: inside the interface**, V. A. Dediu, Nature Physics 109, 17 February 2013, Nature.

4. **Room-temperature air-stable spin transport in bathocuproine-based spin valves**, X. Sun, M. Gobbi, A. Bedoya-Pinto, O. Txoperena, F. Golmar, R. Llopis, A. Chuvilin, F. Casanova & L. Hueso, Nature Communications, Vol. 4 Art n. 2794 Nature Publishing Group.

5. **Tuning the magneto-structural properties of non-porous coordination polymers by HCl chemisorptionr**, E. Coronado, M. Giménez-Marqués, G. Mínguez Espallargas, L. Brammer, Nature Communications 3, Volume 2012, Issue 828 (3), 8th May 2014, Nature Publishing Group.

6. **More than Spectroscopy**, V. A. Dediu and A. Riminucci, Nature Nanotechnology, 8, 4th December 2012, Nature Publishing Group.

7. **Unveiling Self-Assembled Monolayers' Potential for Molecular Spintronics: Spin Transport at High Voltage**, M. Galbiati, C. Barraud, S. Tatay, K. Bouzehouane, C. Deranlot, E. Jacquet, A. Fert, P. Seneor, R. Mattana, and F. Petroff, Advanced Materials, Vol. 24, Issue 43, 11 October 2012.

8. **Magneto-Optical Properties of Electrodeposited Thin Films of the Molecule-Based Magnet Cr5.5(CN)12•11.5H2O**, E. Coronado, M. Makarewicz, J.P. Prieto-Ruiz, H. Prima-García, F.M. Romero , Advanced Materials 23/37, 10 August 2011.

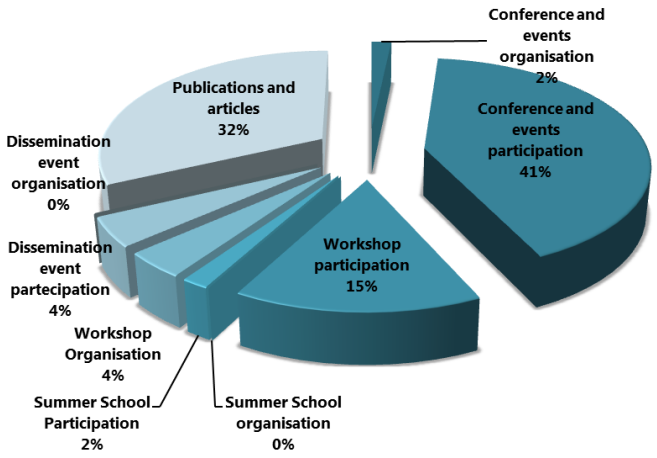
9. **A Single-Device Universal Logic Gate Based on a Magnetically Enhanced Memristor**, M. Prezioso, A. Riminucci, P. Graziosi, I. Bergenti, R. Rakshit, R. Cecchini, A. Vianelli, F. Borgatti, N. Haag, M. Willis, Alan J. Drew, William P. Gillin, and V. A. Dediu, Advanced Materials, 25 January 2013.

10. **Hopping magneto-transport via nonzero orbital momentum states and organic magnetoresistance**, A. S. Alexandrov, V. A. Dediu, V. V. Kabanov, Physical Review Letters 108, 22 October 2011, Materials Science.

Dissemination and Events

The project was successfully finished at the end of May! Noteworthy is the dissemination progress acquired by the consortium during the whole duration of the project. An assessment of the dissemination progress has been realized throughout a quantitative analysis in terms of quantity and kind of dissemination performed.
The dissemination performed in terms of quantity and kind of activities, is well distributed during the whole course of the project as shown in the figure and in the table below. The kind of dissemination activities in which HINTS partners have been more active is the participation at conferences and other international events (75), during which the project has been disseminated, as well as the participation at workshops (27). While publications remains the second favored channel to promote the work performed and the results achieved (58).

	Quantity	%
Conference and events organisation	3	2%
Conference and events participation	75	41%
Workshop participation	27	15%
Summer School organisation	0	0%
Summer School participation	3	2%
Workshop organisation	7	4%
Dissemination event participation	8	4%
Dissemination event organisation	0	0%
Publications and articles	58	32%
Totals	**181**	



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Project partners

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