

University of Groningen

Spin transport across oxide semiconductors and antiferromagnetic oxide interfaces

Das, Arijit

DOI:
[10.33612/diss.150692255](https://doi.org/10.33612/diss.150692255)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2021

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Das, A. (2021). *Spin transport across oxide semiconductors and antiferromagnetic oxide interfaces*. [Thesis fully internal (DIV), University of Groningen]. University of Groningen.
<https://doi.org/10.33612/diss.150692255>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Acknowledgements

I have spent over 6 years in the group of Physics of Nanodevices (FND) starting as a master student in the group of *Spintronics of Functional Materials* and still continuing a Post-doctoral researcher in the same group. In this chapter I extend my thanks and appreciation for all members in the group, that are follows.

Prof. Tamalika Banerjee (Tamalika di) : Our first conversation started in 2013 in the month of February when Prof. Somak Raychaudhury, the then Head of Dept. in Physics in Presidency University, introduced me to you over an email conversation for a prospective Ph.D. or masters in The Netherlands. Looking into my CV you immediately suggested for a Top-masters program in Nanoscience at University of Groningen. We though started amidst a lot of misunderstanding over social network of which I will be ashamed of the rest of my life, we managed to be in the same pitch and I started of with my academic voyage at University of Groningen. Just a 'thank you' is far too little. I started my masters project in your group from 2014 September. I think before that the idea of research was very vague for me, that was solidified as I joined your group. I learnt that how a scientific research is carried out in the group and what a research group means. Starting from Group meetings to Journal club I think I had an extensive training to be a researcher in the beginning. This took some time and even the whole of my masters to change myself from a student to a more academic and scientific researcher. I appreciate the time and energy that you have invested in making me a researcher and I promise you that I

have/ will never forget my development since then. I also extend my thanks for the opportunity to work with you as a Ph.D. researcher and the freedom that you have given me to explore different directions of Spintronics that was beneficial for extending my knowledge and for my career. I will always remember our meetings when you used pin down any half baked ideas that I put forward and urging me to acquire more ideas with more reading that a scientific researcher should do. A research is not about finding answers always, its also about how you find answers without any shortcuts. I learnt it from you and I will remember and relish these learning for the rest of my life. I wish you my heartiest congratulations on your new home and completion of your 50 years. I have been fortunate to be present during these milestones of your life. I have never felt away from home. I wish you more success with research and will read all the publications coming out from your group with a lot of pride and happiness.

Prof. Bart van Wees : Thank you for all the discussion and insight that you contributed in my research during group meetings.

Prof. Caspar van der Wal : Thank for the support and positivity that you have given me since the time of the Topmasters.

Dr. Marcos Guimaraes : Thank you for the various discussion starting from science and regarding academic career in the hall way. We will have more of such in the near future. I wish you all the best with your research group that you formed recently in the FND.

Then I extend my thanks to the Ph.D. assessment committee:

Prof. Beatriz Noheda : Thank you for the time and effort that you put in to read my thesis and providing useful feedback. I wish you all the best with research and the newly formed CogniGron.

Prof. Gertjan Koster : Thank you for the time and effort that you put in to read my thesis and providing useful feedback. We had a lot of scientific discussion in numerous conferences, that was very useful during my Ph.D. career.

Prof. Kathrin Doerr : Thank you for the time and effort that you put in to read my thesis and providing useful feedback. I still remember the scientific discussion regarding manganites and SrRuO_3 at Cost To-Be meeting at Ljubljana and in JEMS 2018 at Mainz. That was very insightful that

Acknowledgements

eventually helped the course of my thesis.

During my masters and Ph.D. research, I have been benefited with scientific discussion also outside FND. I also extend my thanks to them.

Dr. Graeme Blake : Thank you for the support since Topmasters. I always enjoyed your class during the masters program. I also extend my thanks to allow me to be a part of your research group during the Short Masters Project. Since then we had a lot of scientific discussions during Vlieland Conference and Physics at Veldhoven that I cherish. Wishing you a lot of success with research.

Prof. Bart Kooi: We had a lot of discussion regarding operation of Pulsed Laser deposition (PLD) system and possible measurements that could be performed using High resolution Transmission electron microscopy (TEM). I am happy to see finally those are gradually getting materialized. I wish you a lot of success in future research.

Prof. Maxim Mostovoy : I was always enthralled by the way you taught us the Theoretical Condensed Matter and Many particle systems courses during my masters. How you used to use the black board with complicated theoretical analysis of a certain problem without even referring to any notes. Finally we had a fruitful scientific collaboration for the SrRuO₃ project where I enjoyed and learnt a lot on recent advancements in skyrmions and topological textures from your scientific discussion.

Prof. George Palasantzas : I loved your lectures on the course of Scanning Probe Microscopy. I was fortunate to work on the paper research and knowing more on Casimir forces. Thank you for your constant support and encouragement to all students in academia.

Prof. Biplab Sanyal : Thank you for all the engaging scientific discussion that we had. Thank you for hosting me at Uppsala and also making me a part of the Uppsala Indian choir. I enjoyed my stay with you, Prof. Suparna Sanyal (Suparna di) and Ruku. My love and regards to all of you.

Prof. Gerrit Bauer : Thank you for the discussion I had with you regarding my final project on detection of spin currents in SrMnO₃ and understanding of Spin Hall Magnetoresistance and Spin Seebeck effect.

Prof. Manuel Bibes : Thank you for sharing a lot of insight on complex oxides and towards its application in different electrical transport. Hope-

fully we work someday together.

I have been grateful to all my contemporary researchers to have fruitful discussion and I have been fortunate to work with them together.

Dr. Alexander Kamerbeek (Sander): Indeed we started of with a relatively tougher interaction. But I have been a silent observer of how you use to intepret data and contribute your insights with phenomenal reading and understanding to other colleagues. Trust me, this art I am still learning and I found this to be a crucial parameter for our group when you left. I proudly say I have been trained by the best and I have tried my best to all propagate this art to the next generation in the Tamspin group. Thank you for your contributions in Nb:STO project. Will always miss those strong scientific discussion in Tamspin meetings.

Dr. Saurabh Roy (Saurabh da): Thank you for your patience and perseverance in teaching me PLD. We had a lot of scientific and personal discussion outside tuna salad and I thank you for that. Your words of wisdom will always be remembered and are well taken.

Dr. Eric de Vries : Thank you for your help when we started out working together for understanding of spin diffusion length in SRO thin films. Though we did not finish the project but I always observed and acknowledged your discipline and willingness to help everyone.

Anouk : If I say how an ideal researcher should be, you are always my example. If it is needed to understand some complex things I will always rely on you. I am happy and proud on how you supplemented the research on semiconductors in memristive devices for neuromorphic computing. It was always an excitement to work with you since your bachelor days. I wish you all the best for your Ph.D. and I am sure you will have a wonderful thesis ahead. Its an honor to have you as my paranymph. Thanking you for translating my summary in Dutch and also your valuable comments and correction in my English both written and verbal. I would gladly donate my brain for your research in neuromorphic computation but sadly, I am sure you wont a get a good publication with that.

Si Chen (Crystal) : You are a lovely human being and a very careful and a analytical researcher. I always enjoyed discussing science with you.

Acknowledgements

Thank you for all the dinner and lovely time we had in conferences. I wish you all the best with future job search and successful completion of your Ph.D. thesis. It was an honor to have you as my paranymph.

Ping : I am sorry for the tougher interaction in the beginning. You are a fantastic person and a very good intuitive researcher. It was your intuition that brought the SRO project a highlight and one of the most important contributions from our group in recent times. I will cherish your friendship and thank you for hosting a lot of dinners. All the very best for completion of your Ph.D. My best wishes to you, Gang and little Zhilan.

Job : When you were here during the masters, I relished discussing Physics with you. With your strong teaching skills you have already demonstrated how good of a presenter you are. Your masters talk was one of my best talks I witnessed in recent times. It was strong in data and science. I am sure you had a wonderful time at IMEC and you came with all those work-force as you joined as a Ph.D. researcher in our group. You are already spearheading the SMO project and already advanced with optimized growth and spin transport. I wish you all the best in your Ph.D. and no doubt that you will have a wonderful one, Thank you for investing time in making me learn EBL and for all those strong scientific discussions and challenges we are facing together.

Dr. Eswara Vallabhaneni (Eswar) : We had a lot of technical challenges in the beginning of this SMO project. It is commendable the way you picked up and started producing first hand results in NGO. We had a short but wonderful time at Denver, where an APS meeting turned out to be a weekend getaway. Thank you for being there silently as a friend. My best wishes and heartiest congratulations to you and Sahitya.

Azminul : You are newest member in our group. We already had a lot of conversation on Science, friendly talks. You have a strong base in Spintronics and I am sure you will be settled with your projects. I wish you all the best with your Ph.D. and I am sure you will have a lovely stay at our group and Groningen.

I have been fortunate to be a member of FND where I had fruitful discussion and fortunate to share office space with all of you : **Dr. Sidhartha Omar (Pagla) :** I had most of my scientific discussion with you as to have

that I did not have to walk around as you were just behind me in the office. I enjoyed the time you were here with all physics and food. Thank you for your time and effort towards a constructive friendship.

Geert : The way you pulled the Antiferromagnetic spintronics research in challenging NiO and DyFeO₃ was really commendable. I relished your friendship and thank you for teaching me SMR and SSE and development of this field in spintronics. I wish you all the best with completion of your Ph.D and future job search. We are still friends.

Dr. Kumar Saurav Das : Thank you for your discussion and friendship. My best wishes to you, Mrinalini and little Aastika.

Dr. Mallikarjuna Gurram : Thank you for all insightful questions and discussion that we shared during our FND meetings. You are a wonderful person.

Dr. Alexey Kaverzin : You are just the oldest person before me existing now in FND. Thank you for your discussion and help that I got during my Ph.D.

Dr. Juan Shan : Thank you for your discussion on SMR and SSE, during my initial phase.

Pep and Christian : We had a lovely time together. Thank you for your help towards the beginning of my Ph.D. with introduction to different set ups and spintronics. **Dr. Paul Vermeulen :** I enjoyed the time we worked together with the PLD system. I learnt a lot from you. Thank you for the friendly times we shared in that PLD room and in Twente during the workshop at TSST. I wish you all the best with ASML. **Dr. Jamo Momand :** You are a true scientist. I loved discussing Science with you. I wish you all the best. **Atul :** I enjoyed discussion with you both science and games. You are a wonderful person and I wish you all the best with your Ph.D.

Atreya : You were my first student during my Ph.D. period. We managed to make our work in APL. I loved and learnt a lot from you. You are a very good person and I wish you all the best with Ph.D. in France.

Symen : You are a lovely human being. It was fortunate to have you as my student and a friend. Vibrant people like you should be a core member in any professional group. Keep your spirit high and toast for our two

Acknowledgements

publications together.

Ruben : Thank you for your contributions during the short stay in our research group. Your different way of viewing things were well received by me. I wish you all the best with Ph.D.

Hina : Thank you for your contribution towards electrostatic modelling across the Schottky interface of Nb:STO. I wish all the best with the completion of your masters at Delft.

Vincent : It was a pleasure working with you. You had a short stay during your bachelor's project. In that short stay, you have along with myself and Anouk, characterized a Schottky interface with Ni and Nb:STO both experimentally and by modelling. Additionally, you observed a bias modulation of TAMR response. This was commendable. I wish you all the best for your future endeavors.

Adam : Thank you for your contribution towards the development of SMR and SSE in manganites. Indeed it was a challenging project and we stumbled upon a lot of problems in the understanding of the subject technically and scientifically. But the gain is the knowledge and the understanding of the development of such phenomena in the bigger aspect. You have largely helped us in the initial phase with strong acumen in Physics. I wish you all the best with your Ph.D.

I am also thankful for having strong scientific discussion with Arjan Burrema, Dr. Julian Peiro, Talieh, Dr. Xu Yang, Yahia, Miina, Bart Zillen, Frank (we had nice time in Switzerland), Silvia, Mart, Jordi, Dr. Yingfen Wei, Xiangyang, Tian, Dr. Lei Liang, Dr. Jing Liu, Dr. Nynke Vliestra, Jan, Dr. Paul Vermeulen, Dr. Jamo Momand, Tom (Bosma) : All the best with finishing your Ph.D. and my best wishes to you and Macteld with you new life at Copenhagen .

This Ph.D. research was strongly supported by all the technicians in the group. Thank you **Johan** for your support and being a silent guardian of all of us during our stay in the group. **Martijn** : Thank you for your help with wire bonding numerous samples of mine. I still remember that I used to give you a high-five after the devices worked. Thank you for prompt action with any problems faced in the cleanroom, Temescal and PLD system. I enjoyed our occasional drinks and casual chats. I wish you all the best in

Trondheim. **Hans** : It was void space that you needed fill as Martijn left. Very quickly you became as favorite as him. Thank you for your support also with prompt action at any problems in cleanroom and PLD system. **Tom Schouten** : Thank you for your organized support with Helium vessels. That was indeed necessary to organize amidst a number Helium vessel requests. I wish you all the peace with your retired life. **Herman Adema** : Thank you for any help with electrical measurement set up. You are an important person to for your prompt actions. **Dr. Arjun Joshua** : Thank you for your help with EBL. We had a lovely time discussing science while returning from Veldhoven in the bus under a dim light. My stay at Groningen was largely supported with strong scientific community and social life. First of all I extedn my thanks and best wishes to all my Topmaster cohorts : **Tenzin, Wytse, Hendrik, Jing, Sasha, Xu, Natasha, Dima, Yuchen, Azadeh, Heinreike and Geert**. For all my friends in Groningen in one word : **Ankur** : 'remarkable'. **Ashish** : True friend, **Pulkesh** : Friend and 'Bro' . Thank you all for your support and I will relish your friendship now and beyond. My best wishes to all of you. Ashish all the best with 'Townprobe'. **Shubham and Alok** : Indeed we met during lockdown. We connected quickly. You both are truly remarkable and true friends. I wish both of you all the best with prosperous life ahead. **Utsa** : You have a big heart and one of the most caring friends. Will relish your friendship all time. Wish you all the best with Thermo Fisher. **Manvi** : We never met at Presidency. Doesn't matter, we were destined to be friends anywhere. Thank you for your constant support just across my building. I wish you all the best with your future endeavors. My best wishes and congratulations to you and Sharbatanu. **Aritra Ghosh** : You are a truly remarkable researcher and wonderful friend. I wish you all the best with your Ph.D. **Arijit Laik** : It was a perk of having a friend right from Presidency to here. All the best buddy with completion of your Ph.D. **Aritro Mukherjee** : Come soon as I miss you bro. **Saikat** : Thank you for all the support from Presidency to here. I think whenever we will meet it will be an important day for both of us. Thats how we connect and will be like that. You are a true scientist and vocalist, a quality that is not very common. I wish you all the best.

Acknowledgements

My best wishes to **Tarun, RP, Nilesh, Sumedh, Sumit, Tavi, George, Sivasudhan, Greeshma, Saurabh, Ketan, Subir, Kushagra, Aditya, Shreyansh, Aiswariya, Devlina, Antara, Sangeeta**. Thank you for all the lovely times we had.

Thank you **Subir da** for the early times. We had fun in Amsterdam and it was wonderful to witness your defense for the first time in Groningen. You are a true researcher and I wish you all the best at ASM.

Thank you **Pallab da and Rumki di** : For hosting lovely times at your place in Groningen. Indeed we are distant due to distance but my best wishes to both of you.

Harshad : it was a pleasure knowing you bhai. I wish you all the best in your future endeavors. Thank you **Milon da** : for hosting countless dinner and introducing me to cricket once again here. You are a champion.

Thank you **Dipayan da** for always sharing your wisdom on lot of things as we interacted. Congratulations on your new house and my best wishes to **Swati di**. Thank you **Swarnadeep da and Tanaya di** for hosting saraswati pujo. We all enjoyed. Best wishes for your new house. **Ishiro** : You are a really enthusiastic physicist. I wish you all the best with your higher studies. Thank you **Vincent (Bergsma)** for being very patient with my numerous iterations before the final print was done. I wish you all the best with Boekdruken.com.

Finally, I would like to express my deepest gratitude to my parents (Ma and baba), Boro Mama, Kakai-kakimoni, PhulMama, Phulmami, Dadabhai, Rima, Pishimoni, Mashimoni, Mantu Pishi, Sayuz, Shubhra dada, Rishi, chottu, Shilpa, Papai. My school and college friends : Abshishek, Hirak, Subhashsish, Sagnik, Somnath, Ayon, Biswajit, Saptashwa, Deep, Rome, Sumanta, Debalina, Basundhara, Senjuti. All my mentors- Suman Sir, Nirmallya Sir, Preetam Ruia, Surojit Da, Mukdish Sir, Somak Sir, Late Prof. Abhijit Mookerjee. My thesis is dedicated to all of you. **Maa and Baba** thank you for everything, for being a constant support and more importantly a friend.

Arijit Das

Groningen

