Dr. Braj Bhusan Singh
Assistant Professor
Department of Physics
Harcourt Butler Technical University (HBTU), Kanpur, Uttar Pradesh, India
E-mail: brajbhusan.s@hbtu.ac.in, Contact No. +91-8763374608, 6395462372
Google scholar: https://scholar.google.com/citations?user=TYRkkxAAAAAJ&hl=en

RESEARCH AREAS

- Magnetic tunnel junctions
- Topological insulator
- Spin pumping
- Skyrmions
- Antiferromagnetic spintronics

PROFESSIONAL EXPERIENCE

2022-till date Assistant Professor
Department of Physics
Harcourt Butler Technical University (HBTU), Kanpur, Uttar Pradesh, India

2017-2022 Innovation in Science Pursuit for Inspired Research (INSPIRE) Faculty
National Institute of Science Education and Research, Bhubaneswar, India

2016 -2017 Post-doctoral Fellow
National Institute of Science Education and Research, Bhubaneswar, India
Project: *Inverse Spin Hall effect study in Topological Insulator (Bi_2Se_3)*

2014 – 2016 Research Fellow
National University of Singapore, Singapore.
Project: *Spin Transport Study in Topological Insulator, 2D materials and Fe-based Superconductors.*

EDUCATION

2014 **Ph.D., Physics**
Indian Institute of Technology (IIT) Delhi, India
Title: *Spin Transport in Dual Ion Beam Sputtered Magnetic Tunnel Junctions with MgO Barrier*
Adviser: Prof. Sujeet Chaudhary

2006 **M.Sc., Physics**
Aligarh Muslim University, Aligarh, India
Project title: *Design and Fabrication of the Experimental Set-up for the Study of Compton Scattering of Gamma-ray*

2004 **B.Sc.(Hons.) Physics**
Aligarh Muslim University, Aligarh, India.

PEER REVIEWED PUBLICATIONS: 35
CONFERENCE PUBLICATIONS: 40
INVITED TALKS: 12

TEACHING & SUPERVISION EXPERIENCE

- Teaching undergraduate students and master students
- Programme and Laboratory coordinator of M.Sc. Physics (specialisation in materials science and nanotechnology) Programme
- Teaching a course on Spintronics: Fundamentals and Applications for M.Sc. students
- Undertook teaching of one undergraduate summer course on *Mechanics and Thermodynamics* at NISER, Bhubaneswar.
- Worked as a teaching assistant in M.Sc. Laboratory at Indian Institute of Technology Delhi, India.
- Supervised and mentored three Ph.D. and seven master students

CONFERENCES

- Ten invited talks in international conferences
- Guest editor of the *journal of superconductivity and novel magnetism*
- Organized an international conference International Conference on Emerging Trends in Magnetism & Magnetic Materials (ICETMM-2023)
- Part of organizing committee of two international conferences: International Conference on Magnetic Materials and Applications (ICMAGMA- 2018) and Bringing The Nanoworld Together (BTNT-2019).
- Co-convenor of an international webinar on spintronics (W2S), where we have invited very eminent speakers from the spintronics community.

GRANTS

- Principal investigator (PI) of the department of science and technology (DST), govt. of India-funded INSPIRE project 2017-2022 (amount 35 lacs INR).
- Co-PI of Indo-Japan workshop on spintronics funded by DST, Govt. of India, which will be held on Jan 2022 (amount 14.48 lacs INR).

RESEARCH LABORATORY AND INSTRUMENTS DEVELOPMENTS

During my Ph.D. at IIT Delhi

- *Modification of old dual ion beam sputtering system (*NORDIKO 3450), *which includes two rf coupled plasma sources by making functional both ion beam sources*
- *Designing of a load lock system for dual ion beam sputtering system*
- *Development of in situ mask system for fabrication of* ***8 magnetic tunnel junctions*** *without breaking the vacuum of the old dual ion beam sputtering system*
- *A probe station was designed and assembled for the measurements of magnetic tunnel junctions at room temperature*
- *Magnetic annealing system (T_{max} = 600 ℃, H_{max} = 5000 Oe, base pressure: 1.0×10^{-6} mbar) was designed and set up for exchange bias study*
- *Magneto-optic Kerr effect (MOKE) based magnetometer for hysteresis measurements of magnetic thin films was setup*
- *Design and fabrication of a low-temperature probe (T = 12 K) for magneto-transport measurement of 12 magnetic tunnel junctions*
- *Interfacing and data acquisition using TESTPOINT*

During research Fellow at NUS, Singapore

- *Designing of quad effusion cell for an old molecular beam system (MBE) for the fabrication of topological insulator thin films*
- *Set up a ferromagnetic resonance system*

During Postdoc and INSPIRE faculty at NISER, Bhubaneswar

- *Inverse spin Hall effect measurement system was set up in order to quantify spin Hall angle and spin diffusion length*
- *Leads installation of ferromagnetic resonance and magnetoresistance setup (Oxford instruments)*
- *Designing a unique hybrid sputtering-MBE system for organic spintronics devices*
- *Arrangement of pulsed magnetic field setup for domain wall motion measurements*
- *Involvement in procurement and installation of many equipment's, e.g., SQUID magnetometer (Quantum Design), pulsed laser deposition (Light machinery), Probe station, x-ray diffraction, vector network analyzer, and various pumping components.*

LIST OF PUBLICATIONS IN PEER-REVIEWED JOURNALS

1. **B. B. Singh**, K. Yuri, and S. Bedanta, Interfacial magnetism at YIG/Bi_2Se_3 bilayers probed by polarized neutron reflectivity, under review, 2026
2. **B. B. Singh,** Ion Beam Sputtering for the Growth of Magnetic Tunnel Junctions, Book Chapter, Wiley-VCH GmbH, 2026, in press
3. **B. B. Singh**, A.Thiaville, S. Rohart, M. Samanta, K. Biswas, and S. Bedanta, Interfacial Dzyaloshinskii-Moriya Interaction at Topological Insulator/Ferromagnetic Interface, Applied Physics Letter*, 2026,* Accepted
4. A. Mishra, P. Gupta, V. Thiruvengadam, **B. B. Singh**, Subhankar Bedanta, Spin pumping and inverse spin Hall effect in magnetron-sputtered large area MoS2/Co40Fe40B20 bilayers, Journal of Alloys and Compounds, 2024 DOI: https://doi.org/10.1016/j.jallcom.2023.172076
5. Unusual domain wall motion in the vicinity of the depinning field in a Pt/CoFeB/MgO film, B. Ojha**, B. B. Singh,** *et al.,* Applied Physics A, 129, 688 (2023), DOI: https://doi.org/10.1007/s00339-023-06947-w **IF: 2.7**
6. Spin pumping and inverse spin Hall effect in magnetron-sputtered large area $MoS_2/Co_{40}Fe_{40}B_{20}$ bilayers, A. Mishra, P. Gupta, V. Thiruvengadam, **B. B. Singh,** *et al.,* Journal of Alloys and Compounds, DOI: https://doi.org/10.1016/j.jallcom.2023.172076 **IF: 5.8**
7. Tailoring spin to charge conversion efficiency via microwave frequency in $La_{0.67}Sr_{0.33}MnO_3$/Pt bilayer system, P. Gupta, **B. B. Singh,** *et al.,* Journal: SPIN (2023) DOI: https://doi.org/10.1142/S2010324723400192 **IF: 1.3**
8. S Mohanty, M Sharma, AK Moharana, B Ojha, E Pandey, **B. B. Singh,** et. al., Magnetization reversal and domain structures in perpendicular synthetic antiferromagnets prepared on rigid and flexible substrates, JOM, 74(6), 2319 (2022), 10.1007/s11837-022-05300-5 **IF:2.6**
9. M Bhukta, **B. B. Singh**, S Mallick, S Rohart, S Bedanta, Degenerate skyrmionic states in synthetic antiferromagnets, Nanotechnology, 33**,** 385702 (2022) , 10.1088/1361-6528/ac7471 **IF:3.9**
10. S Nayak, S Mohanty, **B. B. Singh**, *et al.*, Magnetic properties in soft (CoFeB)/hard (Co) bilayers deposited under different Ar gas pressure, Journal of Physics: Condensed Matter, 34 385801 (2022) 10.1088/1361-648X/ac7f72 **IF:2.7**

11. K. Roy, A. Mishra, P. Gupta, S. Mohanty, **B. B. Singh**, *et al., Spin pumping and inverse spin Hall effect in CoFeB/IrMn heterostructures,* Journal of Physics D: Applied Physics, 54, 425001 (2021), 10.1088/1361-6463/ac153a **IF:3.2**
12. B. Sahoo, K. Roy, P. Gupta, A. Mishra, B. Satpati, **B. B. Singh**, *et al., Spin Pumping and Inverse Spin Hall Effect in Iridium Oxide,* Advanced Quantum Technologies, 2000146 (2021), 10.1002/qute.202000146
13. **B. B. Singh**, *et al., High spin mixing conductance and spin interface transparency at $Co_2Fe_{0.4}Mn_{0.6}Si$ Heusler alloy and Pt interface*, NPG Asia material **(Nature-Springer),** 13 (1), 1 (2021), 10.1038/s41427-020-00268-7, **IF:10.5**
    Highest spin mixing conductance and spin interface transparency ever reported.
14. A. K. Behera, C. Murapaka, S. Mallick, **B .B. Singh,** *et al., Skyrmion racetrack memory with an antidot*, Journal of Physics D: Applied Physics, 54, 025001 (2021), 10.1088/1361-6463/abb433, **IF: 3.2**
15. S. Nayak, P. K. Mannaa, **B. B. Singh**, *et al., Effect of spin glass frustration exchange bias in NiMn/CoFeB bilayers*, Physical Chemistry Chemical Physics, 23, 6481 (2021), 10.1039/D0CP05726F, **IF: 3.7**
16. P. Gupta, **B. B. Singh,** *et al., Simultaneous observation of anti-damping and the inverse spin Hall effect in the $La_{0.67}Sr_{0.33}MnO_3$/Pt bilayer system*, Nanoscale, 13, 2714 (2021), 10.1039/d0nr06228f, **IF:7.8**
17. M. K. Dalai, **B. B. Singh**, *et al., Superconductivity in Ag implanted Au thin film*, Physica B: Condensed Matter, 601, 412607 (2021), 10.1016/ j.physb.2020.412607, **IF:2.4**
    First report on superconductivity in Ag-Au
18. **B. B. Singh,** *et al. High Spin to Charge Conversion Efficiency in Electron Beam- Evaporated Topological Insulator Bi_2Se_3,* Applied materials and interfaces, *12, 47, 53409 (2020),* 10.1021/acsami.0c13540, **IF:9.2**
    Highest 2D spin to charge conversion efficiency in topological insulator Bi_2Se_3 ever reported.
19. **B. B. Singh,** *et al. Large Spin Hall Angle and Spin-Mixing Conductance in the Highly Resistive Antiferromagnet Mn_2Au*, Physical Review Applied, 13, 044020 (2020), 10.1103/PhysRevApplied.13.044020, **IF:5.0**
    Highest spin Hall angle in any collinear antiferromagnets ever reported
20. **B. B. Singh,** *et al. Inverse spin Hall effect and spin pumping in the polycrystalline noncollinear antiferromagnetic Mn_3Ga*, Physical Review B, 102, 174444 (2020), 10.1103/PhysRevB.102.174444, **IF:4.0**
    First report on study of inverse spin Hall effect on non collinear antiferromagnets Mn_3Ga
21. S. Nayak, S. S. Das, **B. B. Singh,** *et al., Study of the magnetic interface and its effect in Fe/NiFe bilayers of alternating order*, RSC Advances, 10, 234266 (2020), 10.1039/D0RA05429A, **IF:3.4**
22. S. Nayak, P. K. Mannaa, T. Vijayabaskaran, **B. B. Singh,** *et al., Exchange bias in Fe/$Ir_{20}Mn_{80}$ bilayers: Role of spin-glass like interface and 'bulk' antiferromagnet spins*, Journal of Magnetism and Magnetic Materials, 499, 166267 (2020). 10.1016/j.jmmm.2019.166267, **IF:3.0**
23. E. Pandey, **B. B. Singh**, *et al., Strain engineered domain structure and their relaxation in perpendicularly magnetized Co/Pt deposited on flexible polyimide*, Nano Express 1, 010037 (2020), 10.1088/2632-959X/ab90cb.
24. S. Nayak, **B. B. Singh,** *et al., Tuning of magnetic properties by alternating the order of hard/soft bilayers with various thicknesses*, Journal of Physics D: Applied Physics, 52, 305301 (2019), 10.1088/1361-6463/ab1c99, **IF:3.2**

25. T. Vijayabaskaran, **B. B. Singh,** *et al., Magnetization reversal, damping properties and magnetic anisotropy of L10-ordered FeNi thin films* , Applied Physics. Letter, 115, 202402 (2019), 10.1063/1.5126324, **IF:3.8**
26. **B. B. Singh,** *et al.*, *Inverse Spin Hall Effect in Electron Beam Evaporated Topological Insulator Bi_2Se_3 Thin Film*, Physica. Status Solidi RRL, 13, 1800492 (2019), 10.1002/ pssr.201800492, **IF:2.8**
Highest downloaded article in 2018-2019
27. A. K. Behera, S. S. Mishra, S. Mallick, **B. B. Singh** *et al., Size and shape of skyrmions for variable Dzyaloshinskii–Moriya interaction and uniaxial anisotropy* Journal of Physics D: Applied Physics, 51 285001 (2018), 10.1088/1361-6463/aac9a7, **IF:3.2**
28. S. Mallick, S. Mallik, **B. B. Singh,** *et al., Tuning the anisotropy and domain structure of Co films by variable growth conditions and seed layers*, Journal of Physics D: Applied Physics, 51, 275003 (2018), 10.1088/1361-6463/aac880, **IF:3.2**
29. S. Nayak, S. Mallick, **B. B. Singh,** *et al., Effect of sputtered flux direction on damping , properties in magnetic bilayers*, Journal of Physics D: Applied Physics, 51 055008 (2018), 10.1088/1361-6463/aaa3a6, **IF:3.2**
30. J. P. Singh, S. Gautam, W. C. Lim, K. Asokan, **B. B. Singh**, *et al., Electronic structure of magnetic Fe/MgO/Fe/Co multilayer stack by NEXAFS spectroscopy*, Vacuum, 138, 48 (2017), 10.1016/j.vacuum.2017.01.020 **,** **IF:3.6**
31. **B. B. Singh,** *et al., Study of spin pumping in Co thin films vis-à-vis seed and capping layer using ferromagnetic resonance spectroscopy,* Journal of Physics D: Applied Physics 50, 345001 (2017). 10.1088/1361-6463/aa7993, **IF: 3.2**
32. **B. B. Singh** *et al., Study of angular dependence of exchange bias and misalignment in uniaxial and unidirectional anisotropy in NiFe(111)/FeMn(111)/ CoFeB(amorphous) stack,* Journal of Magnetism and Magnetic Materials 385, 166 (2015). 10.1016/j.jmmm.2015.03.004. **IF: 3.0**
33. J. P. Singh, S. Gautam, **B. B. Singh,** *et al., Magnetic, electronic structure and interface study of Fe/MgO/Fe multilayer,* Advanced Material Letters, 5, 372 (2014). 10.5185/amlett.2013.105560.**IF: 1.2**
34. **B. B. Singh,** *et al. Effect of annealing on the temperature dependence of inelastic tunneling contributions vis-à-vis tunneling magnetoresistance and barrier parameters in CoFe/MgO/NiFe MTJ,* Journal of Applied Physics 115, 083904 (2014). 10.1063/1.4866078. **IF: 2.6**
35. **B. B. Singh,** *et al., Inelastic tunneling conductance and magnetoresistance investigations in dual ion-beam sputtered CoFeB(110) /MgO/CoFeB (110) magnetic tunnel junctions*, Journal of Applied Physics 115, 153903 (2014). 10.1063/1.4871679 **IF: 2.6**
Second research group in the world who have fabricated magnetic tunnel junctions using ion beam sputtering.
36. **B. B. Singh,** *et al., Tunneling behavior in ion-assist ion-beam sputtered CoFe/MgO/NiFe magnetic tunnel junctions*, Materials Research Bulletin, 47, 3786 (2012). 10.1016/j.materresbull.2012.06.020. **IF: 4.6**
37. **B. B. Singh,** *et al., X-ray photoelectron spectroscopy and conducting atomic force microscopy investigations on dual ion beam sputtered MgO ultra-thin films,* Thin Solid Films, 520, 6734 (2012), 10.1016/j.tsf.2012.06.078. **IF: 2.2**
38. **B. B. Singh,** *et al, Effect of MgO spacer and annealing on interface and magnetic properties of ion beam sputtered NiFe/Mg/MgO/CoFe multilayers,* Journal of Applied Physics 112, 063906 (2012), 10.1063/1.4752264, **IF: 2.6**

Details of the most significant research problems

Problem #1: Quantification of elastic and inelastic tunneling conductance in magnetic tunnel junctions

Magnetic tunnel junctions, where a thin insulating barrier separates two ferromagnetic (FM) layers, are essential building blocks of modern spintronics devices. This difference in resistance in the two states of parallel and antiparallel magnetizations of FM layers, is called tunnel magnetoresistance (TMR). Apart from FM layer, the barrier plays a crucial role in TMR. The presence of defects may induce localized states (LS) in the barrier, which leads to phonon/magnon excitations. Quantification of conductance due to elastic tunneling and inelastic tunneling *vis-à-vis* TMR was not explored. MTJs with structure $Ta(5)/Co_{60}Fe_{40}(10)/Mg(1)/MgO(t_{MgO}= 3.0,3.5,2.5)/Ni_{81}Fe_{19}(10)/ Ag(20)$ are fabricated through myself-developed an *in situ* shadow mask system using *dual ion beam sputtering*. These MTJs possessed ~12 % TMR)at 60 K. The temperature dependence of conductance behavior of these junctions has revealed inelastic tunneling through thirteen series LS present in the forbidden gap of the MgO barrier due to the presence of ionic interstitial defects in the MgO barrier. Further, the effect of annealing on the inelastic tunneling contributions in CoFe/MgO/NiFe MTJs has been investigated. The hopping through a number of series of LS present in the barrier increases from 9 (in as-deposited MTJ) to 18 after annealing (at 200 °C/1hr); although no changes in the interface roughness of CoFe-MgO and MgO-NiFe interfaces are observed as revealed by the x-ray reflectivity studies on planar MTJs. Since to obtain magnetic switching at nearly zero magnetic fields, which is important for device purposes, *exchange bias* is usually employed. MTJs comprising of $Ta(5)/Ni_{81}Fe_{19}(5)/Ir_{22}Mn_{78}(15)/ Co_{60}Fe_{20}B_{20}(5)/Mg(1)/MgO(3.5)/Co_{60}Fe_{20}B_{20}(5)/ Ta(5)/Ag(20)$ (thickness in nm) with (110) oriented CoFeB layers are therefore grown using *dual ion beam sputtering*. While the *exchange bias* could not be optimized in these MTJs, the TMR in these MTJs is significant bias dependent and exhibits zero-bias anomaly attributed either to the presence of magnetic impurities or to the diffusion of Mn from antiferromagnetic IrMn in the barrier. Ten series of LS are found to be involved in hopping conduction in the forbidden gap of MgO barrier. The effect of such inelastic channels is insignificant at low temperatures yielding sizeable enhancement in TMR at low temperatures.

B. B. Singh, *et al.,* Journal of Applied Physics 115, 083904 (2014) 10.1063/1.4866078.
B. B. Singh, *et al.,* Journal of Applied Physics 115, 153903 (2014) 10.1063/1.4871679
B. B. Singh, *et al.,* Materials Research Bulletin, 47, 3786 (2012) 10.1016/j.materresbull.2012.06.020

Problem#2: Misalignment of uniaxial and uniaxial anisotropy in NiFe(111)/FeMn (111)/CoFeB(amorphous) stack

The horizontal shifting of the magnetic hysteresis(M–H) loop of FM layer interracially coupled to antiferromagnetic (AF) layer, subsequent to cooling in the presence of magnetic field from above the Neel temperature of the AF layer, is known as exchange bias (EB). The large EB is crucial for the spin valve-based MTJs. The fundamental requirement of inducing the EB is the higher magnetic anisotropy of the AF layer compared to the uniaxial anisotropy of the FM layer. The understanding of the magnetization reversal and asymmetry in uniaxial and unidirectional anisotropy is lacking in exchange bias systems, particularly having an amorphous FM layer.

For this the multilayers consisting of $Ta(10)/Ni_{81}Fe_{19}(7,10)/Fe_{46}Mn_{54}(10)/Co_{60}Fe_{20}B_{20}(5)/Ta(5)$ and $Ta(5)/Ni_{81}Fe_{19}(10)/Fe_{46}Mn_{54} (10)/Co_{60}Fe_{20}B_{20}(5)/Ta(5)$ (nm) were deposited on glass using *ion beam sputtering* at room temperature (RT). The 5 nm Ta with 10 nm NiFe layer combination is found to be optimal for inducing the desired (111) orientation of *fcc* FeMn layer. These stacks clearly exhibited a moderate *exchange bias* (at RT) of 20 Oe in as-deposited and 56 Oe in the magnetically annealed state. The *exchange bias* showed the *cosine dependence* on the azimuthal angle, consistent with the Meiklejohn and Bean model. Training effect studies revealed that the coercivity increases after the first cycle of the hysteresis loop, while the *exchange bias* degrades sharply, and for subsequent cycles, the exchange bias field follows the empirical relation based on the energy dissipation of AF layer.The misalignment angle between the uniaxial and unidirectional anisotropy, as measured by FMR,is found to be10° and 14° for CoFeB and NiFe, respectively. This misalignment is attributed to the interface roughness as revealed by x-ray reflectance measurements.

B. B. Singh *et al.,* Journal of Magnetism and Magnetic Materials 385, 166 (2015). 10.1016/j.jmmm.2015.03.004.

Problem#3: High spin to charge conversion efficiency in electron beam evaporated topological insulator Bi_2Se_3

Topological insulators (TIs) are new state of quantum materials due to unique band topology. Presence of spin momentum locked surface states and insulating ground states of TIs may be provide efficient spin to charge conversion. The fundamental mechanism for efficient spin to charge conversion in TIs are mainly inverse spin Hall effect (ISHE) and inverse Rashba Edelstein effect (IREE). For the spin to charge conversion study, one needs good structural quality of Bi_2Se_3/ ferromagnetic (FM) heterostructure. In most of the studies, state of art technique *viz*. molecular beam epitaxy (MBE) has been used for the fabrication of epitaxial Bi_2Se_3. However, spin to charge conversion is not investigated in polycrystalline TIs.

Spin to charge conversion efficiency (SCCE) in Bi_2Se_3/CoFeB heterostructures by performing simultaneous measurements of ferromagnetic resonance (FMR) and ISHE has been investigated. Here, Bi_2Se_3 and CoFeB are fabricated by electron beam evaporation and sputtering in the same vacuum chamber, respectively. The SCCE in TI is characterized by an inverse Edelstein effect length (λ_{IREE}). The $\lambda_{IREE.}$ ~ 0.36 nm has been reported, which is highest ever observed in Bi_2Se_3. The Bi_2Se_3 thickness dependence of $\lambda_{IREE,}$ perpendicular surface anisotropy (K_S), spin mixing conductance and spin Hall angle confirmed that spin to charge conversion is due to spin momentum locked Dirac surface states. We propose that the role of surface states in SCCE can be understood by the evaluation of $K_{S.}$ The SCCE is found to be high when the value of K_S is small.

B. B. Singh, *et al.,* ACS Applied materials and interfaces, *12, 53409 (2020),* 10.1021/acsami.0c13540

Problem#4: Inverse spin Hall effect and spin pumping in non collinear antiferromagnets

High spin to charge conversion efficiency or vice versa is a requirement for switching of magnetization in a spintronics device at lower power. Spin to charge conversion efficiency is measured by a spin Hall angle i.e θ_{SH} = spin current density (J_S)/charge current density (J_C). The value of θ_{SH} primarily depends on the strength of spin orbit coupling (SOC) of NM layer. In recent years most of the elemental heavy metals have been attempted for the spin pumping study. Antiferromagnetic (AFM) materials is another family of materials which possess high SOC, zero net magnetization, zero stray field, and insensitivity to high magnetic field. In this context, chiral noncollinear AFMs of the family Mn_3X (X = Sn, Ge, Ga, Ir, Pt, Rh) are emerging as a promising candidates because of their unique topology, large anomalous Hall effect (AHE) due to Berry curvature, and magnetic spin Hall effect. There is no report on the spin to charge conversion in Mn_3Ga, however, $IrMn_3$ and Mn_3Sn have been explored.

Mn_3Ga is a noncollinear AFM in which the order of Mn magnetic moments is arranged in inverse triangular configuration on a Kagome lattice. A noncollinear Mn_3Ga thin films was fabricated by taking β-W buffer layer. Spin pumping and inverse spin Hall effect in Mn_3Ga/CoFeB heterostructures have been studied. After separation of different spin galvanometric effect, we have observed that spin pumping voltage is dominating, which is further confirmed by enhancement in Gilbert damping. The key parameters viz. spin mixing conductance and spin Hall angle have been evaluated, which is a new information for noncollinear Mn_3Ga-CoFeB system. Spin mixing conductance ($g_{eff}^{\uparrow\downarrow}$), spin Hall angle ($\theta_{SH}$) and spin Hall conductivity (σ_{SH}) are evaluated to be $(5.0 \pm 1.8)\times 10^{18}$ m^{-2},, 0.31 ± 0.01, and 7.5×10^5 $(\hbar/2e)$ $\Omega^{-1}m^{-1}$, respectively. The observed value of θ_{SH} is higher than Mn_3Sn and comparable to the $IrMn_3$, which is also a noncollinear AFM. The value of spin Hall angle is 0.31 which is much higher than Pt, but spin Hall conductivity is comparable to the Pt. Such a high value of spin Hall angle and spin Hall conductivity makes Mn_3Ga-CoFeB system suitable for spin orbit torque based spintronics devices.

B. B. Singh, *et al.,* Physical Review B, 102, 174444 (2020), 10.1103/PhysRevB.102.174444

Problem#5: High spin mixing conductance and spin interface transparency at $Co_2Fe_{0.4}Mn_{0.6}Si$ Heusler alloy and Pt interface

Spin pumping is an efficient method to produce pure spin current ($\vec{J_s}$), which is the flow of spin angular momentum, and investigate the spin propagation across FM/HM interfaces. The efficiency of spin transport at FM/HM interfaces is understandable by the factors known as effective spin mixing conductance ($g_r^{\uparrow\downarrow}$) and spin interface transparency (T). Large value of $g_r^{\uparrow\downarrow}$ and T are the key requirement for the development of power efficient pure spin current based devices. Efficient interfacial spin transport critically depends on the type of interfaces and its associated FM and HM materials, and FM materials with low magnetic damping (α) are important to generate large spin current and hence high $g_r^{\uparrow\downarrow}$.

Full Heusler alloys *e.g.* $Co_2Fe_{0.4}Mn_{0.6}Si$ (CFMS), which are predicted to be 100% spin polarized, possess low α. However, the $g_r^{\uparrow\downarrow}$at the interface between CFMS and a paramagnet has not fully been understood. The spin pumping and inverse spin Hall effect in CFMS/Pt bilayers have been investigated. Damping analysis indicates the presence of significant spin pumping at the interface of CFMS and Pt, which is also confirmed by the detection of inverse spin Hall voltage. The $g_r^{\uparrow\downarrow}$ (1.70×10^{20} m^{-2}) and interface transparency (83%) have been reported, which are higher compared to values reported for other ferromagnetic/heavy metal systems.
B. B. Singh, *et al.,* NPG Asia material **(Nature-Springer),** 13 (1), 1 (2021), 10.1038/s41427-020-00268-7,

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LIST OF CONFERENCE PUBLICATIONS
International

1. **B. B. Singh**, IEEE-ICEE 2020 conference, IIT Delhi, India, oral presentation
2. M. Sharma, **B. B. Singh**, *et al.*, *Pulsed magnetic field driven domain wall dynamics in Pt/Co multilayers*, Bringing The Nanoworld Together (BTNT), December, 2019.
3. E. Pandey, **B. B. Singh**, *et al., Effect of Strain on the Perpendicular Magnetic Anisotropy and Domains in Co/Pt Thin Films on Polyimide: For Flexible Spintronics*, Bringing The Nanoworld Together (BTNT), December, 2019

4. S. Mohanty, M. Sharma, **B. B. Singh,** *et al., Effect of Ir spacer layer on perpendicular synthetic antiferromagnetic coupling in Co/Pt multilayers,* Bringing The Nanoworld Together (BTNT), December, 2019
5. M. M. M. Bhukta, **B. B. Singh**, *et al., Skyrmionic States in Synthetic Antiferromagnets*, Bringing The Nanoworld Together (BTNT), December, 2019
6. P. Gupta, **B. B. Singh**, *et al.,* Observation of antidamping and inverse spin Hall effect in $La_{0.67}Sr_{0.33}MnO_3$/Pt bilayers, Bringing The Nanoworld Together (BTNT), December, 2019
7. V. Thiruvengadam, **B. B. Singh**, *et al., Magnetization reversal, damping properties and magnetic anisotropy of* $L1_0$*-ordered FeNi thin films,* Bringing The Nanoworld Together (BTNT), December, 2019
8. K. Roy, P. Gupta, A. Mishra, **B. B. Singh**, *et al., Spin pumping and inverse spin Hall effect (ISHE) study in CoFeB/ IrMn bilayers*, Bringing The Nanoworld Together (BTNT), December, 2019
9. M. Azharudheen, **B. B. Singh**, *et al., Fabrication of magnetic nanostructures by nanosphere lithography*, Bringing The Nanoworld Together (BTNT), December, 2019
10. A. Mishra, V. Thiruvengadam , **B. B. Singh**, *et al., Inverse spin Hall effect in sputter deposited* MoS_2*/CoFeB bilayers,* Bringing The Nanoworld Together (BTNT), December, 2019
11. B. Ojha, S. Mallick, M. Sharma, **B. B. Singh**, *et al., Skyrmion in Pt/CoFeB heterostructure at room temperature* Bringing The Nanoworld Together (BTNT), December, 2019
12. **B. B. Singh**, *et al., Spin to charge current conversion efficiency: role of topological insulator, antiferromagnetic and Heusler alloy,* Bringing The Nanoworld Together (BTNT), December, 2019
13. **B. B. Singh,** *et al., Dependency of Spin Pumping on Seed and Capping Layers in Co Ultrathin Films*, INTERMAG 2018, Singapore.
14. **B. B. Singh,** *et al, Inverse spin Hall effect in topological insulator* Bi_2Se_3 *thin films*, ICMAGMA 2018, NISER, Bhubaneswar, India.
15. K. Roy, **B. B. Singh**, *et al., Detection of spin Hall effect (SHE) using magneto-optic Kerr effect (MOKE)*, ICMAGMA 2018, NISER, Bhubaneswar, India.
16. P. Gupta, **B. B. Singh**, *et al., Study of Damping Properties and Inverse Spin Hall Effect in LSMO Based System,* ICMAGMA 2018, NISER, Bhubaneswar, India.
17. S. Nayak, **B. B. Singh**, *et al., Effect of magnetic interfaces on magnetic properties in Fe/NiFe layers,* ICMAGMA 2018, NISER, Bhubaneswar, India.
18. V. Thiruvengadam, **B. B. Singh**, *et al., Investigations of effect of anisotropy strength on domain structure and magnetization dynamics of L10-ordered FeNi thin films*, ICMAGMA 2018, NISER, Bhubaneswar, India.
19. S. Nayak, S. Mallick, **B. B. Singh,** *et al., Tuning the Magnetic Anisotropy and Domains in Co thin films by varying growth conditions,* International Conference on Magnetic Materials and Applications (ICMAGMA-2017), (Poster Presentation), 1 - 3 2017, Hyderabad Paper Presented.
20. **B. B. Singh,** *et al., Spin Pumping in Nonmagnetic/Ferromagnetic/ Nonmagnetic multilayer Structures*, International conference on Nanotechnology: Ideas, Innovations & Initiatives-2017 (ICN:31-2017), December 6, Invited talk.
21. **B. B. Singh,** *et al, Investigations of Negative Exchange Bias in Ion beam Sputtered Ta/NiFe/FeMn/CoFeB/Ta Multilayers,* 7th International Conference on Materials for Advanced Technologies, (Oral Presentation), 30 June to 5 July, 2013, Suntec Singapore.
22. **B. B. Singh,** *et al*, *Tunneling Conductance Behavior With Temperature In Ion-Assist Ion Beam Sputtered CoFe/Mg/MgO/NiFe Magnetic Tunnel Junctions,* AIP Conf. Proc. 1536, 1079 (2013), (Poster Presentation), February 2013, International Conference on Recent Trends in Applied Physics & Material Science, Govt. College of Engineering & Technology, Bikaner, India.

23. **B. B. Singh,** *et al*, *Anomalous Tunnel Magnetoresistance in CoFe/Mg/ MgO/NiFe Magnetic tunnel junctions* (Oral Presentation), December 2011, International Conference on Nanomaterials and Nanotechnology, University of Delhi, New Delhi.
24. **B. B. Singh,** *et al*, *Dual ion beam sputter deposition and investigations of Fe thin films on Si(100) and MgO(100) and Fe/MgO/Fe tunnel junctions*, NSTI-Nanotech 2010, California USA, ISBN 978-1-4398-3402-2 Vol 2, 2010.

National

1. **B. B. Singh**, *et al., High spin mixing conductance and spin interface transparency at $Co_2Fe_{0.4}Mn_{0.6}Si$ Heusler alloy and Pt interface,* DASSPS, 2019, poster presented.
2. E. Pandey, P. Sharangi, **B. B. Singh**, *et al., Strain Assisted Magnetization Relaxation and Domain Wall Dynamics of Co/Pt Thin Film Deposited on Flexible Polyimide*, DASSPS, 2019, Paper Presented.
3. **B. B. Singh,** *Inverse spin Hall effect in topological insulator/ferromagnetic system,* CMP meet 2018, NISER, Bhubaneswar, India, Invited talk
4. **B. B. Singh,** *Spin Pumping and Inverse spin Hall effect in topological insulator/ferromagnetic* layer, PSCES, April 02, 2018, IIT Mandi, Invited Talk.
5. **B. B. Singh,** *et al., Study of Spin Pumping and Damping in Magnetic Thin Films,* DAE Solid State Physics Symposium (DAE-SSPS), 2017, poster presented.
6. S. Nayak, S. Mallick, **B. B. Singh**, *et al., Magnetization reversal and domain analysis in the hard ($Co_{40}Fe_{40}B_{20}$)/soft (Co) exchange spring system*, 8th Asia-Oceania Neutron Scattering Association (AONSA) Neutron School, (Poster Presentation), 2016, Mumbai, Paper Presented
7. **B. B. Singh**, *et al., Magnetic Tunnel Junctions for Spintronics Applications* (Poster presentation), 24 April 2010 "OPEN HOUSE 2010" held in Department of Physics, Indian Institute of Technology Delhi, New Delhi, India.
8. **B. B. Singh**, *et al., Magnetic Tunnel Junctions and nano-multilayers for high density data storage* (Poster Presentation). 13 March 2010, Symposium on Nanoscienec and Nanotechnology, Indian Institute of Technology Delhi, New Delhi, India.
9. **B. B. Singh**, *et al., Growth and investigations of ion beam Sputtered Co/Cu GMR multilayer* (Oral Presentation), 26 Feb 2009, National Conference on Recent Advances in Surface Engineering (RASE 09), National Aerospace Laboratories, Bangalore.
10. U. Singh, **B. B. Singh**, *et al., Effects of annealing on the giant magnetoresistance in the ion-beam sputtered Cu/Co multilayers* (Oral Presentation), 26 Feb 2009, National Conference on Recent Advances in Surface Engineering (RASE 09), National Aerospace Laboratories, Bangalore, India.

EXPERIMENTAL TECHNIQUES USED

- Expertise in growth of topological insulator/Fe-based superconductor thin films using molecular beam epitaxy.
- Expertise in growth of ultrathin films (upto1 monolayer) of metals, insulator materials using ion beam sputtering, magnetron sputtering (rf and dc).
- *In situ* growth of patterned magnetic tunnel junctions of area $60 \times 60\ \mu m^2$ using ion beam sputtering.
- Low temperature (1.5 K, 7 Tesla) magneto-transport measurements.
- Magneto-optic Kerr effect (MOKE) and Kerr microscopy measurement
- Interface studies of multilayers using x-ray reflectivity.
- SQUID magnetometer
- Pulsed laser deposition
- Chemical vapour deposition

- Electron beam evaporation.
- *In situ* electrical characterization of devices in UHV environment on Omicron SEMPA system.
- Lithography (Laser writer) and ion milling.
- Scanning electron microscopy (SEM).
- Topographical studies using atomic force microscopy (AFM), near field scan microscopy (NSOM), and magneto-Kerr effect imaging using Nanonics system.
- Ferromagnetic resonance (FMR) measurements.
- In-depth knowledge of x-ray photoelectron spectroscopy (XPS), conducting atomic force microscopy (CAFM), secondary ion mass spectroscopy (SIMS).
- Familiar with reflection high energy electron diffraction (RHEED).

AWARDS, FELLOWSHIPS, AND RECOGNITIONS

- INSPIRE faculty fellowship, Department of Science and Technology (DST), India
- Post-doctoral Fellowship, National Institute of Science Education and Research (NISER), Bhubaneswar, India.
- Award of Senior Research Fellowship (SRF), Council of Scientific & Industrial Research (CSIR), 2011.
- Award of Junior Research Fellowship (JRF), Council of Scientific & Industrial Research (CSIR), 2008.
- National Eligibility Test (NET) for lectureship 2007, Qualified, conducted by Council of Scientific & Industrial Research.
- Graduate Aptitude Test in Engineering (GATE) 2007, Physics; All India Rank: 365, Score: 395, Organized by Indian Institute of Technology Madras, India.
- Travel Grant from Indian Institute of Technology Delhi, India, to present a research paper in ICMAT2013, Singapore.
- First prize in the model display of "Light Photometer" on National Science Day 2005.
- First prize in model display "Concentration measurement of a liquid using Light photometer" on National Science Day 2006.
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COLLABORATION AND VISITS TO NATIONAL LABORATORIES/ RESEARCH INSTITUTES

- Visit for experiments to MLZ Heinz Mair- Leibnitz Zentrum, Germany for polarized neutron reflectivity experiments
- Visit the university of Université Paris-Saclay, France, for collaborative work on skyrmion
- National Physical Laboratory, New Delhi, India.
- Inter-University Accelerator Centre (IUAC), New Delhi, India.
- Raja Ramanna Centre for Advanced Technology (RRCAT), Indore, India.
- Indian Institute of Technology Bombay, Mumbai, India.
- Teaching Assistant in M.Sc. Physics Laboratory from July 2009 to May 2012.