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PROPOSAL No. - IDPHD2024009	
Title of the Proposal	**Development of 2D material heterostructures based Magnetic Random Access Memory**
Supervisor-1	Shubhadeep Bhattacharjee, *Electrical Engineering*
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Abstract	Despite two decades of development, material research has yielded limited optimal combinations, notably CoFeB/MgO, with no viable alternatives identified thus far. In recent years, a wide array of novel emerging two-dimensional materials (2DMs) and heterostructures have shown promise in addressing these challenges. This Ph.D. project aims to investigate the fundamental properties of atomically smooth interfaces, reduced material intermixing, crystal symmetries, and proximity effects to achieve disruptive enhancements in MRAM technology. The student will develop a transfer stage to facilitate the deterministic fabrication of 2D heterostructures. Subsequently, by assembling various 2D material heterostructures, we will assess their effectiveness in constructing synthetic antiferromagnetic (SAFs) layers to achieve high perpendicular magnetic anisotropy (PMA). Finally, we will fabricate devices in our cleanroom using the screened heterostructures to realize STT/SOT MRAM devices and quantify the tunnel magnetoresistance (TMR) ratios.
Keywords	2D heterostructures, Magnetic Random Access Memory, ferromagnetism, tunnel magnetoresistance
Background and Motivation	The rising power consumption in modern-day CMOS von-Neumann computing is a serious issue for environmental sustainability. Therefore there is an urgent need to explore novel CMOS-compatible electronic devices to support beyond von Neumann architectures such as neuromorphic and quantum computing. Non-volatile magnetic random-access memories, such as current-driven spin-transfer torque (STT) MRAMs and next-generation spin-orbit torque (SOT) MRAMs, play a crucial role in enabling low-power technologies not only for conventional memory but also for beyond von Neumann computing architectures. Though MRAM is already in production for niche applications, full-scale commercialization is hindered by several significant device and materials challenges, including scalability, thermal stability (endurance/reliability), and write speed/power consumption.
Relevant publications	1. Effect of seed layer thickness on the Ta crystalline phase and spin Hall angle K Sriram, J Pala, B Paikaray, A Haldar, C Murapaka Nanoscale 13 (47), 19985-19992 2. Analog and digital phase modulation and signal transmission with spin-torque nano-oscillators A Litvinenko, P Sethi, C Murapaka, A Jenkins, V Cros, P Bortolotti, ... Physical Review Applied 16 (2), 024048 3. Voltage-controlled magnetic anisotropy gradient-driven skyrmion-based half-adder and full-adder S Sara, C Murapaka, A Haldar Nanoscale 16 (4), 1843-1852 4. Interfacial ferroelectricity in marginally twisted 2D semiconductors A Weston, EG Castanon, V Enaldiev, F Ferreira, S Bhattacharjee, S Xu, ... Nature nanotechnology 17 (4), 390-395 5. Insights into Multilevel Resistive Switching in Monolayer MoS2 S Bhattacharjee, E Caruso, N McEvoy, C Ó Coileáin, K O'Neill, L Ansari, ... ACS applied materials & interfaces 12 (5), 6022-6029 6. Emulating synaptic response in n- and p-channel MoS2 transistors by utilizing charge trapping dynamics S Bhattacharjee, R Wigchering, HG Manning, JJ Boland, PK Hurley Scientific reports 10 (1), 12178
Essential qualifications	Mtech/MSc./BTech in ECE, Materials, Physics, Nanotechnology
Desirable qualifications	Hands on experience with device materials growth synthesis or device fabrication
Broad proposal objectives	https://drive.google.com/open?id=1js61cIIe1YblC7seSwkl8MQ4WOnPBPIq