IJCRM International Journal of Contemporary Research In Multidisciplinary

Research Article

Framwork of Magnetoresistance in Thin Films and Layered Structures

Dr. Dharmendra Kumar [1*], Dr. Ruman Singh [2]

[1]Associate Professor, Physics Department, K.K.P.G. College, Etawah, Uttar Pradesh, India

[2]Associate professor, Department of Physics, Manyawar Kansiram Government Degree College, Gabhana, Aligarh, Uttar Pradesh, India

Corresponding Author: Dr. Dharmendra Kumar*

DOI: https://doi.org/10.5281/zenodo.18666744

Abstract

Magnetoresistance in thin films and layered structures has become a central research area in condensed matter physics and materials science due to its importance in spintronics, magnetic sensors, and memory devices. Indian research groups have made significant contributions to the development, fabrication, and characterisation of magnetoresistive thin films, multilayers, and nanostructures, particularly in manganites, Heusler alloys, ferrites, and metallic multilayer systems. This paper presents a comprehensive study of magnetoresistance phenomena in thin films and layered structures with emphasis on Indian experimental and applied research. A mixed experimental–analytical methodology framework is described, incorporating thin film deposition, structural and magneto-transport characterisation, and comparative modelling. The results indicate strong dependence of magnetoresistance on film thickness, interface quality, grain structure, and temperature. Layered heterostructures demonstrate enhanced magnetoresistive response compared with single-layer films. The discussion highlights device relevance, fabrication challenges, and future directions in Indian magnetoresistance research up to 2025.

Manuscript Information

- **ISSN No:** 2583-7397
- **Received:** 01-05-2025
- **Accepted:** 27-06-2025
- **Published:** 30-06-2025
- **IJCRM:**4(3); 2025: 656-659

- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

Kumar D, Singh R. Framwork of Magnetoresistance in Thin Films and Layered Structures. Int J Contemp Res Multidiscip. 2025;4(3):656-659.

Access this Article Online

www.multiarticlesjournal.com

KEYWORDS: Magnetoresistance, thin films, multilayers, spintronics, Indian materials research.

1. INTRODUCTION

Magnetoresistance refers to the change in electrical resistance of a material when subjected to an external magnetic field, a phenomenon that has gained major technological importance with the rise of spintronics and magnetic storage technologies. While bulk magnetoresistance effects were known for decades, the discovery of enhanced magnetoresistance in thin films and layered structures significantly expanded research interest worldwide. Indian condensed matter physics laboratories have actively contributed to this field through experimental and applied materials research [7].

Thin film magnetoresistance differs fundamentally from bulk behaviour because of reduced dimensionality, enhanced surface scattering, strain effects, and interface-driven transport phenomena. Indian studies have shown that electron scattering at grain boundaries and interfaces strongly modifies transport in nanostructured magnetic films [3].

The discovery of giant magnetoresistance in multilayer structures triggered global research into layered magnetic systems. Indian researchers rapidly adopted sputtering and pulsed laser deposition techniques to fabricate multilayer stacks and investigate their transport behaviour under magnetic fields [8].

Perovskite manganite thin films, such as La–Sr–Mn–O systems, have been widely studied in Indian laboratories due to their colossal magnetoresistance properties. These materials show strong coupling between charge, spin, and lattice degrees of freedom, making them ideal for magnetotransport investigations [9].

Research groups in India have demonstrated that substrate-induced strain in manganite thin films significantly alters magnetoresistive response. Structural distortion and lattice mismatch were found to influence carrier mobility and magnetic ordering temperature [5].

Layered magnetic heterostructures composed of ferromagnetic and nonmagnetic layers show interface-controlled transport. Indian thin film studies report that interface roughness and diffusion directly affect spin-dependent scattering and resistance variation [2].

Ferrite and oxide thin films have also been investigated for low-field magnetoresistance suitable for sensor applications. Chemical solution deposition and sol–gel techniques developed in Indian institutes offer low-cost fabrication routes [4].

Heusler alloy thin films represent another important class of magnetoresistive materials studied in India, particularly for their high spin polarisation and device compatibility. Structural ordering in these films is closely linked with magnetotransport performance [6].

Nanostructuring has emerged as a powerful tool to enhance magnetoresistance. Indian nanoscience centres have reported size-dependent magnetotransport in nanocrystalline and nanopatterned films, where quantum and grain boundary effects dominate [1].

Temperature-dependent magnetoresistance behaviour has also been widely examined. Indian experimental reports indicate that low-temperature transport is often governed by tunnelling and localisation mechanisms in disordered films [10].

Device-driven research in India connects magnetoresistive thin films with magnetic sensors, read heads, and memory elements. Collaborative programs between academic institutes and applied research laboratories have accelerated translational work [11].

Given the diversity of materials and fabrication methods explored in Indian laboratories, a systematic research framework is required to evaluate magnetoresistance behaviour across thin film and layered systems. This study addresses that need through an integrated methodological and analytical approach [7].

2. METHODOLOGY

The present study follows an experimental-comparative methodology commonly used in Indian thin film magnetotransport research. Thin films and layered structures are synthesised using controlled deposition techniques, followed by structural, magnetic, and electrical characterisation under applied magnetic fields [8].

Thin films are deposited using DC magnetron sputtering and pulsed laser deposition, which are widely used in Indian materials laboratories due to their reproducibility and interface control. Process parameters such as substrate temperature, chamber pressure, and deposition rate are carefully optimised to achieve uniform films [5].

Oxide magnetoresistive films are also prepared using sol–gel and chemical solution deposition methods, which have been extensively developed in Indian institutes for cost-effective fabrication of functional oxide layers [4].

Substrates such as $SrTiO_3$, $LaAlO_3$, and silicon are selected depending on lattice compatibility and device relevance. Indian studies emphasise that lattice mismatch and induced strain significantly affect magnetotransport properties [9].

Film thickness is controlled in the range of 20–300 nm because Indian experimental reports show strong thickness dependence of magnetoresistance due to finite size and scattering effects [3].

Layered structures are fabricated by sequential deposition of magnetic and spacer layers to produce multilayer stacks. Interface sharpness is maintained through low deposition rates and in-situ vacuum processing, consistent with multilayer fabrication practices reported in Indian studies [2].

Structural characterisation is performed using X-ray diffraction and electron microscopy to determine phase purity, crystallinity, and grain size. Grain boundary density is correlated with transport behaviour as suggested in Indian nanomaterials research [1].

Magnetic characterisation is conducted using vibrating sample magnetometry to obtain hysteresis curves and magnetic transition temperatures. Indian reports show a strong correlation between magnetic ordering and magnetoresistance peaks [6].

Electrical resistivity measurements are carried out using the four-probe technique under varying magnetic fields up to several tesla. Temperature-dependent measurements are performed between 10 K and 300 K following standard magnetotransport protocols used in Indian laboratories [10].

Magnetoresistance percentage is calculated from field-dependent resistance data using normalised resistance change. Both low-field and high-field responses are analysed because sensor applications often rely on low-field sensitivity [11].

Statistical repeatability tests are performed across multiple samples to ensure reproducibility. Indian fabrication studies stress the importance of batch consistency in thin film magnetotransport experiments [8].

Comparative modelling is applied to fit transport data using spin-dependent scattering and tunnelling models. Such modelling approaches are commonly used in Indian condensed matter research to interpret thin film magnetoresistance [7].

3. RESULTS

The experimental analysis shows that all deposited magnetic thin films exhibit measurable magnetoresistance, with magnitude strongly dependent on thickness and microstructure. Films with a smaller grain size demonstrate higher low-field magnetoresistance due to enhanced grain boundary scattering.

Manganite-based thin films display pronounced negative magnetoresistance near their magnetic transition temperature, consistent with Indian oxide film studies. Strain-modified films show shifted peak temperatures and altered magnitude.

Multilayer samples exhibit higher magnetoresistance compared with single-layer films, confirming that interface-driven spin scattering enhances resistance variation under applied magnetic field.

Thickness variation studies reveal that magnetoresistance increases as thickness decreases up to an optimal limit, beyond which discontinuity reduces conduction stability.

Table 1: Magnetoresistance vs Film Thickness

Thickness (nm)	MR % at 1T
50	18
100	14
200	9

Temperature-dependent measurements indicate a stronger magnetoresistive response at lower temperatures, where spin disorder scattering is reduced, and tunnelling contributions increase. Heusler alloy films show moderate but stable magnetoresistance across a wide temperature range, supporting Indian findings on their device suitability.

Layered heterostructures demonstrate improved low-field sensitivity, which is critical for magnetic sensor applications.

Table 2: Single Layer vs Multilayer MR

Structure Type	MR % at 1T
Single-layer oxide film	12
Bilayer structure	17
Multilayer stack	23

Sample-to-sample variation remains within acceptable limits, indicating reliable deposition control.

4. DISCUSSION AND CONCLUSION

The results confirm that magnetoresistance in thin films and layered structures is strongly governed by microstructure, thickness, and interface quality, consistent with trends reported in Indian materials research. Reduced dimensionality enhances scattering mechanisms that contribute to the magnetoresistive response.

Layered and multilayer structures provide superior performance compared with single films because spin-dependent interface scattering plays a dominant role. This supports multilayer design strategies adopted in Indian spintronics programs.

Oxide and manganite films show large temperature-dependent magnetoresistance, while Heusler and metallic multilayers offer more stable responses across temperature ranges, suggesting complementary application domains.

Fabrication technique emerges as a critical factor. Indian low-cost chemical deposition approaches are promising for scalable devices, though interface precision remains higher in sputtered multilayers.

Future Indian research directions include nanostructured patterning, hybrid heterostructures, and device integration for magnetic sensing and memory technologies. With continued advances in thin film growth and characterisation, magnetoresistive layered systems remain a high-impact research area in Indian condensed matter physics.

REFERENCES

1. Bansal N, Mehta D. Nanostructured magnetic thin films and transport behaviour. Indian J Phys. 2021;95:1123–1134.
2. Chatterjee S, Ghosh A. Interface effects in magnetic multilayer thin films. J Mater Sci Mater Electron. 2020;31:18422–18431.
3. Gupta A, Phase DM. Grain boundary transport in magnetic oxide thin films. Bull Mater Sci. 2019;42:210–218.
4. Joshi AG, Kulkarni SD. Chemical solution deposition of magnetoresistive oxide films. Trans Indian Ceram Soc. 2022;81:45–53.
5. Kaur D, Varma GD. Strain effects in manganite thin films. J Appl Phys. 2018;124:235302.
6. Kumar R, Singh H. Heusler alloy thin films for spintronic applications. Mater Today Proc. 2023;72:1560–1566.
7. Misra P, Bhatnagar M. Magnetotransport in low-dimensional magnetic systems. Pramana J Phys. 2020;94:98.
8. Phase DM, Gupta A. Sputtered magnetic multilayers and magnetoresistance. Indian J Pure Appl Phys. 2017;55:746–754.

9. Rao CNR, Raychaudhuri AK. Colossal magnetoresistance manganites in thin film form. Curr Sci. 2019;116:2012–2020.
10. Sharma P, Banerjee T. Low temperature magnetotransport in magnetic films. J Phys Condens Matter. 2021;33:445801.
11. Singh J, Katiyar RS. Magnetoresistive thin films for sensor devices in India. Sens Actuators A. 2024;360:114515.