66TH INTERNATIONAL

OPEN READINGS

CONFERENCE FOR STUDENTS OF PHYSICS AND NATURAL SCIENCES

ANNUAL ABSTRACT BOOK | 2023

Vilnius University

VILNIUS UNIVERSITY PRESS

Editors

Martynas Keršys
Šarūnas Mickus

Cover and Interior design
Milda Stancikaitė

Vilnius University Press
9 Saulėtekio Av., III Building, LT-10222 Vilnius
info@leidykla.vu.lt, www.leidykla.vu.lt/en/
www.knygynas.vu.lt, www.journals.vu.lt

Bibliographic information is available
on the Lithuanian Integral Library Information System (LIBIS) portal ibiblioteka.lt.
ISBN 978-609-07-0883-5 (ePDF)
DOI: https://doi.org/10.15388/IOR2023

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MICROSCOPIC ANALYSIS OF MAGNETISATION PROCESSES USING THE ISING MODEL

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In many different fields of science, analysis of physical problems using analytical mathematical models can be difficult. Inclusion of every single possible interaction causes mathematical equations to become too complicated, even for the best supercomputers to this day. In spintronics, effects such as magnetoresistance (MR) heavily depend not only on the selection of materials, but also on the magnetisation process [1][2], latter of which can be quite difficult to grasp even utilizing quantum mechanics. To simplify the problem, one way to analyse microscopic magnetisation processes is by using the Ising model [3], where an arbitrary volume is divided into some number of unit cells that have quantized spin (in the most common case, having spin $1/2$ or $-1/2$). These cells then interact with neighbouring cells and depending on the exchange coupling constant, cells either try to orient their spin in one direction or in opposite directions. Such model is usually solved using Monte Carlo methods, where the probability for a cell to change its spin value can be calculated using Boltzmann statistics. With this model one can analyse phase transition and magnetic hysteresis dynamically. The Ising model is also an approximation of the classical Heisenberg model and only one spin projection is considered.

In this work, some common examples are analysed, such as defects in ferromagnets and artificial antiferromagnet configuration using the Ising model (Fig. 1). By changing exchange coupling, interacting neighbour count, volume size and adding macroscopic effects, such as demagnetizing field or anisotropy, changes in phase diagrams and magnetic hystereses are explored.

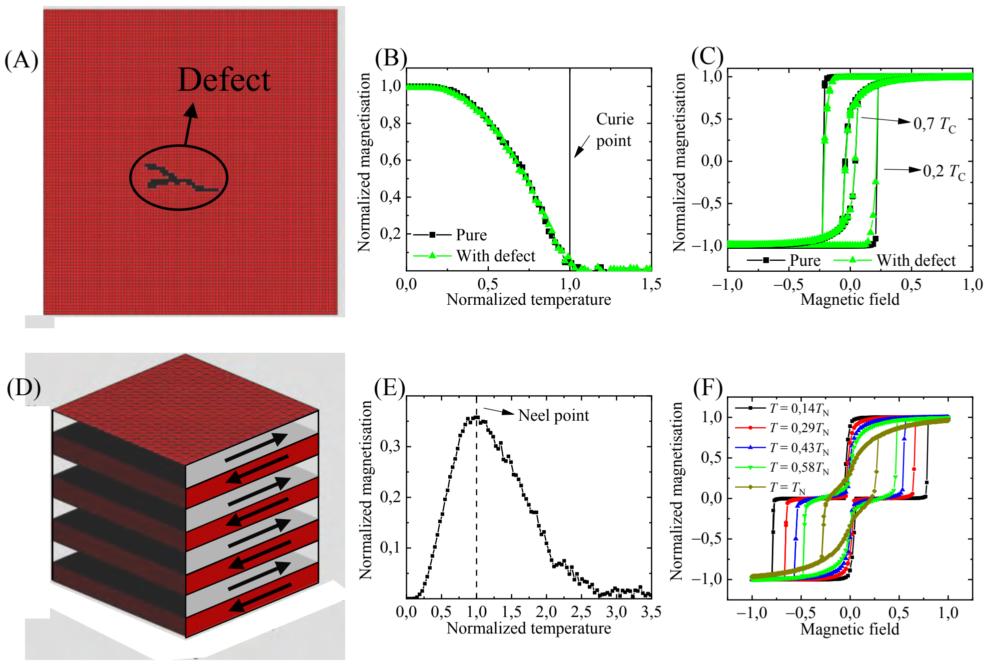

Fig. 1. Ising models for different kinds of magnetic structures. (A) – Ferromagnet with non-magnetic defect (crack). (B) – Normalized magnetisation vs temperature, normalized by Curie temperature, with and without the defect. (C) – Magnetic hystereses with and without the defect at two different temperatures (T_C – Curie temperature). (D) – Alternating magnetisation structure (artificial antiferromagnet), where red layers have 3 times stronger interaction than grey and both layers have antiferromagnetic coupling. (E) – Normalized magnetisation vs temperature, normalized by Neel point temperature. (F) – Magnetic hystereses at different temperatures (T_N – Neel temperature).

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