Faculty of Science
Physics Department

The Role of Lattice Disorders on the Magnetic Behaviour of Iron and some Iron Steel Alloys

Presented by

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عنوان الرسالة بالغة الانجليزية :
"The Role of Lattice Disorders on the Magnetic Behaviour of Iron and some Iron Steel Alloys"

السيد الاستاذ الدكتور / جمال عبد الناصر مدبولى
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وتفضلوا سيادتكم بقبول فائق الاحترام .

الساده المشرفين: **التوقيع**

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P S – 650 **(2 cr. h)**	**Properties of Dielectrics** Electrostatic equations of dielectrics – Mechanisms of polarization – Methods of dielectric measurements – Breakdown in dielectrics – Ferro electricity description and classification.
P S – 651 **(2 cr. h)**	**Relaxation Theory** Structure- Defects in Structure- Linear theory of Elasticity – Nonlinearity and Elasticity theory- Thermodynamics of Relaxation- Thermo- Elasticity Relaxation.
P S –652 **(1 cr. h)**	**Semiconductors** Absorption of direct and indirect Semiconductor transitions -Optical constants relations-Photo and electroluminescence- Photoconductivity – Semiconductor Nanotechnology.
P S – 653 **(1 cr. h)**	**Nuclear Magnetism** Classification of magnetic materials – Nuclear magnetic resonance (NMR)- Electron spin resonance (ESR) - Adiabatic Demagnetization.
P S – 654 **(1 cr. h)**	**Crystal Growth** Crystal growth from solutions- Crystal growth from the melt –Crystal growth from vapour.
P S – 655 **(1 cr. h)**	**Electron Microscope** Microscopy with light and electrons – The Electron Microscope Family- Specimen preparations- Specialized Techniques in Electron Microscopy – Examples of the use of Electron Microscopy.
P S – 657 **(1 cr. h)**	**Thin Films** Methods of preparations of thin films- Mechanism of film formation- Electrical Properties of thin films.
P S – 658 **(1 cr. h)**	**Lattice Imperfections** Types of Defects in Crystalline materials – The Production of Defects in Solids – Effect of Lattice Defects on the Physical and Mechanical Properties of Solids- Interaction of Dislocations with Point Defects.
P S – 660 **(2 cr. h)**	**Selected Topics in Condensed Matter Physics** (Lattice Dynamics and Symmetry – Solar Energy).

To my parents,
my wife and my son

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ABSTRACT

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The present investigation deals mainly with the study of the behaviour of domain wall-lattice defect interaction in α-Fe, and iron steel alloys (Fe - Cr 16%, and Fe - Cr 16% - Mo 4%) under the action of an impressing magnetic field. It is also deals with the study of the annealing behaviour and annealing kinetic of cold-worked of these samples above room temperature. Associated changes in some structure sensitive magnetic properties such as maximum magnetic permeability, critical magnetic field, magnetic anisotropy and the high-field magnetic permeability were taken as a tool of study in the present work. Such measurements can give valuable informations on the behaviour of domain wall-lattice defects interactions, and the different atomic mechanisms responsible for the release of the stored energy from cold-worked samples during the different annealing stages.

In the first chapter of this thesis we gave a brief history of the ferromagnetic theory, its magnetization process, magnetic domain, its origin and the reversible and irreversible displacement of magnetic domains. We gave also a brief account on the effects of domain wall pinning on magnetization and domain formation and hysteresis. We gave also a brief review of the magnetomechanical effect in ferromagnetic materials.

In the second chapter, we demonstrate the cathode ray oscilloscope method which was used in the present work to obtain the room temperature (B-H), and (μ-H) curves. The magnetic permeability was determined from the division of magnetic induction, B, and magnetic field, H. The maximum magnetic permeability, μ_{max}, was determined

from the maximum value of the peak of (μ-H) curve, which characterized the magnetization of both reversible and irreversible domain wall motion. The critical magnetic field, H_{cr}, was obtained from the peak position of the magnetic permeability, μ_{max}. The magnetic anisotropy, K, and the high-field magnetic permeability, μ_o, were determined from the theoretical prediction in connection with magnetization, M, in ferromagnetic materials under moderately strong magnetic fields.

In chapter three, the variation of the magnetic properties with plastic deformation and microstructure was used to study the behaviour of domain wall-dislocation interaction in annealed α-Fe, and iron steel alloys (Fe - Cr 16%, and Fe - Cr 16% - Mo 4%) using the maximum magnetic permeability, the critical magnetic field, the magnetic anisotropy, and the high–field magnetic permeability. It was found that the high–field magnetic permeability, μ_o, the maximum magnetic permeability, μ_{max}, the critical magnetic field, H_{cr}, and the magnetic anisotropy, K, increased with the degree of plastic strain and was attributed to the reduction of dislocation density in some volumes of the martensite matrix during early stages of deformation. Further increase in dislocation density in the matrix during the later stage of deformation, affected the average strength of interaction between domain wall and dislocation, thus contributed to the decrease in the high–field magnetic permeability, μ_o, the maximum magnetic permeability, μ_{max}, the critical magnetic field, H_{cr}, and the magnetic anisotropy, K. Correlations were obtained between maximum magnetic permeability, μ_{max}, and magnetic coercivity, H_{cr}, and between magnetic anisotropy, K, and high–field magnetic permeability, μ_o. Moreover, some general numerical constants such as domain wall surface energy, the width of magnetic domain and the number of spins involved in a single domain wall were obtained in this chapter for heavily cold-worked and annealed α-iron and iron type steel alloys (Fe - Cr 16%, and Fe - Cr 16% - Mo 4%).

Chapter four investigated the recovery and annealing kinetics of deformed α-Fe, and iron steel alloys (Fe - Cr 16%, and Fe - Cr 16% - Mo 4%) by magnetic measurements. Isochronal annealing experiments in the temperature range 25- 850 °C revealed the existence of three annealing stages (stage IV, V, VI) in the annealing spectrum of heavily cold-worked Fe-0.006 wt% C by observing the associated changes in the maximum magnetic permeability, μ_{max}, and critical magnetic field, H_{cr}. Stage IV centered around 220 ^{o}C appeared only in the recovery of heavily cold-worked α-Fe samples, activated by an energy 1.1 eV, was attributed to the free-migration of vacancies. Stage IV disappeared in the recovery spectrum of iron steel alloys (Fe - Cr 16%, and Fe - Cr 16% - Mo 4%), inferred to the complete capture of vacancies originated during plastic deformation in the matrix. The recovery stage V in α-iron was attributed to the dissociation of carbon-vacancy pairs, and found to be activated by energy 1.8 eV. The binding energy between the carbon atom and vacancy was found to be 0.7 eV. The mechanism responsible for this recovery stage seemed to be affected by the presence of Cr and Mo atoms in the matrix. The recovery stage VI appearing above 450 ^{o}C, was activated by 2.8 eV, and the process was related to the climb motion of dislocations during the recrystallization process in cold-worked α-Fe, and iron steel alloys (Fe - Cr 16%, and Fe - Cr 16% - Mo 4%).

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