AIN SHAMS UNIVERSITY
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QUANTUM ELECTRONIC TRANSPORT IN BALLISTIC MESOSCOPIC DEVICES

A Thesis Submitted in Partial Fulfillment of the Requirement of the Ph.D. in Engineering Physics

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"The LORD is my shepherd; I shall not want. He maketh me to lie down in green pastures: he leadeth me beside the still waters. He restoreth my soul: he leadeth me in the paths of righteousness for his name's sake. Yea, though I walk through the valley of the shadow of death, I will fear no evil: for thou art with me; thy rod and thy staff they comfort me."

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LIST OF PUBLICATIONS

[1] M. D. Asham, W. A. Zein, and A. H. Phillips, "Coherent Spin Polarization in an AC-Driven Mesoscopic Device", *Prog. Phys.* **1**, 40, (2012).

[2] M. D. Asham, W. A. Zein, and A. H. Phillips, "Photo-Induced Spin Dynamics in Nanoelectronic Devices", *Chin. Phys. Lett.* **29** (10), 108502, (2012).

[3] M. D. Asham, W. A. Zein, and A. H. Phillips, "Quantum Pumping Driven by an AC-field in Graphene Field Effect Transistor", *J. Am. Sci.* **8** (7), 374, (2012).

[4] M. D. Asham, W. A. Zein, and A. H. Phillips, "Spin-Dependent Thermoelectric Transport through Graphene Field Effect Transistor", *submitted to Physica Scripta Nov.(2012).*

ABSTRACT

Name: Mina Danial Asham

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This thesis is dedicated for investigating some of the spin-based electrical transport properties of two major types of nanostructures dominating nowadays mesoscopic devices physics research. The first device proposed consists of two-diluted magnetic semiconductor (DMS) leads and a nonmagnetic semiconducting quantum dot. The spin transport characteristics through such a device are investigated under the effect of an AC-field of a wide range of frequencies. The conductance for both spin parallel and antiparallel alignment in the two DMS leads with the corresponding equations for giant magnetoresistance (GMR) and spin polarization (SP) are deduced. Calculations show an oscillatory behavior of the studied parameters for both the cases of parallel and antiparallel spin alignment while the coherence property is shown in the results of SP and GMR. These oscillations are due to the coupling of photon energy and spin-up & spin-down subbands and also due to Fano-resonance. This research might be useful for developing single spin-based quantum bits (qubits) required for quantum information processing, quantum spin-telecommunication and other wide ranged spintronics device applications in general.

For the second proposed device, Spin dependent transport characteristics through normal graphene/ ferromagnetic graphene/ normal graphene junction is investigated. The conduction of this junction is derived by solving Dirac equation for both parallel and antiparallel spin alignments of electrons. Numerical calculations are performed for the conductance for both spin alignments. Oscillatory behavior of the conductance for the two cases is due to the interplay between the photons of the induced AC-signal with both spin-up and spin-down subbands. These oscillations are due to the modulation of the Fermi energy by the potential of the magnetic insulator and photon-energy. Also, the calculations of spin polarization and giant magnetoresistance show that these parameters could be modified by the barrier height and the angle of incidence of electrons on the corresponding region of the present device. Quantum pumping by induction of external photons could enhance spin transport mechanism through such investigated device. The present results show that the cutoff frequency for both parallel and antiparallel spin alignments varies strongly in the range of THz to 10^{19} Hz.

Also, Thermospin effects in the present device are investigated through studying the thermospin characteristics such as spin Seebeck coefficient, the thermal conductance, and spin figure of merit. These characteristics are expressed in terms of the tunneling probability of Dirac fermions for both parallel and antiparallel spin alignments of electrons. The obtained results show that the values of Seebeck coefficient, thermal conductance, and figure of merit are different for spin up and spin down. Their values are increased as the frequency of the induced AC-field increases, that is, the thermospin transport through such device is enhanced by the photon energy.

The present investigation could be used widely for designing very high speed nanoelectronic devices and applications in the field of nanobiotechnology, for example, imaging processing and sheds lights on spin caloritronics in the nanoscale systems providing deep insight on this field.

CONTENTS

ACKNOWLEDGMENT i

LIST OF PUBLICATIONS ii

ABSTRACT iii

CONTENTS vi

List of Figures viii

LIST OF SYMBOLS AND ABBREVIATIONS xiii

CHAPTER I. INTRODUCTION 1

I.1 The Importance of Spintronics 1

I.2 Basic Concepts of Spin 4

I.3 Spin Interactions 4

I.4 Diluted Magnetic Semiconductors 5

I.5 Magnetic Multilayers and Magnetoresistance Phenomena 11

I.6 Electrical Spin Injection and Spin Transport 14

I.7 Semiconductor Heterostructures 17

I.8 Graphene 23

CHAPTER II. THEORETICAL FORMULATION OF SPINTRONIC MESOSCOPIC DEVICES 35

II.1 First Device Model: Semiconductor Quantum Dot. ... 35

II.2 Second Device Model: Graphene Field Effect Transistor 43

II.2.a. Spin Polarized Transport Through Graphene Field Effect Transistor 43

II.2.b. Spin Dependent Thermoelectric Transport Through Graphene Field Effect Transistor.....52

CHAPTER III. NUMERICAL RESULTS AND DISCUSSION 56

III.1 Results and Discussion of the First Model: (Semiconductor Quantum Dot).....56

III.2 Results and Discussion of the second model (Graphene Field Effect Transistor).....65

CHAPTER IV. CONCLUSION 74

IV.1 The First Model: Semiconductor Quantum Dot 75

IV.2 Second Device Model: Graphene Field Effect Transistor.....77

REFERENCES 80

LIST OF FIGURES

Fig. I-1 Schematic illustration of carrier mediated ferromagnetism. The itinerant holes (blue circles) couple antiferromagnetically to the local Mn moments via the exchange interaction due to the overlap of the hole wave function with the d-orbitals of the local Mn electrons. For high enough hole densities a long range ferromagnetic order is established. The bordered boxes illustrate the flipping of a local Mn-moment caused by the kinetic exchange interaction with a passing-by hole. 8
Fig. I-2 Schematic densities of states N(E) for a concentrated magnetic semiconductor below T_C 10
Fig. I-3 Schematic densities of states N(E) for the half-metallic ferromagnet CrO_2 10
Fig. I-4 Schematic figure of magnetic multilayers with ferromagnetic A and non-magnetic B layers. d and d' indicate the layer thickness. 12
Fig. I-5 Resistivity change due to an external magnetic field for Fe/Cr multilayers 12
Fig. I-6 Band line-up of conduction and valence band edges of two materials at a hetero-interface of type I, II, and III. 18
Fig. I-7 Schematic diagram of a quantum dot in a lateral (a) and a vertical (b) geometry. The quantum dot (represented by a disk) is connected to source and drain contacts via tunnel barriers, allowing the current through the device, I, to be measured in response to a bias voltage, V_{SD} and a gate voltage, V_g. 19
Fig. I-8(a) Schematic representation of a quantum dot system with source and drain contacts and a plunger gate. (b) Energy level structure of the system in the Coulomb blockade. (c) Position of the energy levels that allows a current to flow between source and drain if a very small bias voltage is applied. 21

Fig. I-9 Quantum dot linear conductance as a function of the plunger gate voltage. Inset: split gate structure used to define the quantum dot. The conductance is measured by applying a small voltage between source (S) and drain (D), and recording the source drain current [66]. 21
Fig. I-10 Coulomb blockade diamonds measured on a quantum dot realized on a parabolic quantum well. The grayscale represents the differential conductance dI/dV_{SD} with zero encoded in black. Numbers 1–4 label zero source–drain voltage conductance peaks. One particular diamond is highlighted with a dotted boundary, the horizontal dotted line indicates $V_{SD} = 0$ [66]. 22
Fig. I-11 A schematic diagram showing the hexagon structure of the honeycomb-like graphene layer. 24
Fig. I-12 Left: Lattice structure of graphene, made out of two interpenetrating triangular lattices (a_1 and a_2 are the lattice unit vectors, and δ_i, i= 1, 2, 3 are the nearest neighbor vectors); Right: corresponding Brillouin zone. 24
Fig. I-13 Left: Full energy spectrum of graphene (in units of the hopping energy). Right: zoom-in of the energy bands to one of the Dirac points (Adapted after permission from [85, 86]). 25
Fig. I-14 (a) Charge carriers in condensed matter physics are normally described by the Schrödinger equation with an effective mass m* different from the free electron mass. (b) Relativistic particles in the limit of zero rest mass follow the Dirac equation. (c) Charge carriers in graphene are called massless Dirac fermions and are described by a 2D analog of the Dirac equation, with the Fermi velocity v_F playing the role of the speed of light and a 2D pseudospin matrix describing two sublattices of the honeycomb lattice. Similar to the real spin that can change its direction between, say, left and right, the pseudospin is an index that indicates on which of the two