Editorial

Novel Research in Low-Dimensional Systems

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Low-dimensional systems exhibit unique properties that have attracted considerable attention during the last few decades. Notably, fabrication of low-dimensional systems and devices with lengths that measure in the nanometer range has opened up investigations in a "new" type of science, nanoscience. The properties of a bulk three-dimensional system are typically insensitive to the size (as long as the size is macroscopic). However, all these considerations change when the size of such systems is reduced to the nanometer range. A known fact is that, unlike their bulk counterparts, many low-dimensional systems tend to exhibit novel and unique phenomena of great interest to many scientific disciplines. Furthermore, in the case of nanostructures, many of them manifest size-dependent properties as well as behavior that is strongly dictated by the rules of quantum mechanics. Therefore, understanding their properties is both highly interesting and rewarding because of various possible technological applications. A great deal of progress has been achieved in the field of of materials science with the fabrication of novel materials with length scales in the nanometer range [1–6]. Systems such as carbon nanotubes, nanowires, quantum dots, thin films, etc. manifest amazing properties and are already featuring in several emerging technologies and advanced applications. The application of new and extraordinary experimental tools in the field has created an urgent need for a better understanding of new physical phenomena that occur in such low-dimensional systems. This has drawn the interest of many experimental and theoritical groups around the world [7–12]. The aim of this Special Issue is to provide an overview of the current research in low-dimensional systems by attracting contributions from specialists in the field. This way, we try to provide important insights on the large variety of scientifically fascinating and technologically important phenomena that are being investigated. The covered topics include original research articles on the fundamental and applied aspects of the physics in various low-dimensional systems such as quantum dots, graphene nanosystems, ultrathin films, superconducting nanofilms, novel nanoscale devices, etc. The present Special Issue includes research papers from both theoretical and experimental groups with many phenomena studied from a multi-disciplinary perspective. There are ten research papers in this Special Issue which explore important developments in the field of low-dimensional systems.

The first paper by Metzke et al. [13] illustrates the use of atomic force microscopy (AFM)-based scanning thermal microscopy technique. to characterize the thermal properties of nanoscale systems. Specifically speaking, this work focuses on theoretical studies of ultrathin films with anisotropic thermal properties such as hexagonal boron nitride (h-BN) and compares the results with a bulk silicon (Si) sample. The second paper by Kapcia [14] investigate the charge-order on triangular lattices for fermionic particles that are described by an extended Hubbard model. A triangular lattice is formed by, e.g., a single layer of graphane or the graphite surfaces as well as (111) surface of face-cubic center crystals. The present work uses an extension of the lattice gas model to $S = 1/2$ fermionic particles on a two-dimensional triangular (hexagonal) lattice to analyze the system within the mean-field approximation. The qualitative differences with the model considered on hypercubic lattices are also discussed. The third paper by Ciftja [15] represents a theoretical study of the electric properties of a nanocapacitor. Such properties can be very different from the expected bulk properties due to finite-size effects for small length scales. A theoretical model for a circular parallel plate nanocapacitor is considered. Analytic expresssions for the electrostatic energy stored and capacitance of the nanocapacitor are derived. The results obtained can be easily used to incorporate the effects of a dielectric thin film in case the space between the circular plates of the nanocapacitor is filled with such a film. The fourth paper by Wu et al. [16] considers a graphene nanoribbon gap waveguide as a candidate system for guiding dispersionless gap surface plasmon polaritons with deep-subwavelength confinement and low loss. An analytical model is developed to analyze the system, in which a reflection phase shift is employed to successfully deal with the influence caused by the boundaries of the graphene nanoribbon. The proposed setup may be of great interest in studying dispersionless and low-loss nanophotonic devices and may have various possible technological potential applications. The fifth paper by Du et al. [17] focuses on the properties of graphene-based nanocomposite films. Nanocomposite films of this nature are in high demand due to their superior photoelectric and thermal properties, but their stability and mechanical properties pose challenges. Motivated by these facts, the current work illustrates a facile approach that can be used to prepare various nanocomposite films through the non-covalent self-assembly of graphene oxide and biocompatible proteins. Various characterization techniques were employed to characterize the properties of such nanocomposites and to track the interactions between graphen oxide and proteins. It is suggested that this strategy should be facile and effective for fabricating well-designed bio-nanocomposites for universal functional applications. The sixth paper by Wang et al. [18] reports the findings of a study on the influence of ink properties on the morphology of long-wave infrared HgSe quantum dot films. The main focus of the analysis were various factors affecting the morphology of the films including the likes of ink surface tension, particle size, and solute volume fraction. This work is important for the morphology control of the filter film arrays which are core components to many optoelectronic devices and for detecting targets by spectroscopic methods. Various properties of the system were analyzed in terms of different changing variables. The seventh paper by Alotabi et al. [19] studies the effect of TiO_2 film thickness on the stability of Au_9 Clusters with a CrO_x layer. The high purity TiO_2 films are fabricated via radio frequency magnetron sputtering techniques which allows reliable control of film thickness and uniform morphology. The change in surface roughness upon heating two TiO_2 films with different thicknesses was investigated. Chemically-synthesised phosphine-protected Au_9 clusters covered by a photodeposited CrO_x layer were used as a probe. It was found that the high mobility of the thick TiO_2 film after heating leads to a significant agglomeration of the Au_9 clusters even when protected by the CrO_x layer. The eighth paper by Abramkin and Atuchin [20] is a theoretical analysis of the hole states energy spectrum in novel InGaSb/AlP self-assembled III-V quantum dots. These materials may have possible applications in non-volatile memories. Material intermixing and formation of strained structures were also taken into account. Adjusting the values of various parameters allows one to find an optimal configuration of the device for possible non-volatile memory applications. The search for novel self-assembled quantum dots with hole localization energy that allows a long charge storage is very important to the field of non-volatile memory applications. The ninth paper by McNaughton et al. [21] studies causes and consequences of ordering and dynamic phases of confined vortex rows in superconducting nanostripes. Superconducting nanostripes are a fundamental component in superconducting electronics. They are crucial components for various applications in the field of quantum technology. Therefore, understanding the behaviour of vortices under nanoscale confinement in superconducting circuits is important for the development of superconducting electronics and quantum technologies. Numerical simulations based on the Ginzburg-Landau theory for non-homogeneous superconductivity in the presence of magnetic fields are carried out. The findings lead to the understanding of how lateral confinement organises vortices in a long superconducting nanostripe. A phase diagram of vortex configurations as a function of the stripe width and magnetic field is also presented. The tenth paper by Sharma et al. [22] sheds light on complex phase-fluctuation effects correlated with granularity in superconducting NbN nanofilms Superconducting nanofilms are tunable systems that can leading to the Berezinskii-Kosterlitz-Thouless superconducting transition when the system approaches the two-dimensional regime. Reducing the dimensionality further to quasi one-dimensional superconducting nanostructures with disorder, can generate quantum and thermal phase slips of the order parameter. Experimental studies of these phenomena are difficult. As a result, the characterization of superconducting NbN nanofilms under different conditions which was carried out in this study can be very useful for future work.

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