Electrohydrodynamics

The report contains further considerations of the slip parameter for unsteady flow. Several important gas/particle combinations are represented and conclusions regarding electrical efficiency are given. Also, a computer study which solves the combines Laplace/Poisson equations for geometries representing the EHD channel is included. This program is used to predict the effect of voltage scheduling electrodes, and the predictions are checked out experimentally. (Author).
Excerpt from Electrohydrodynamics I: The Equilibrium of a Charged Gas in a Container The constant a in (1) is the ratio of electric charge density to mass density in the fluid. It is constant because we assume that the fluid is uniformly charged. If each molecule of the fluid has mass m and charge e than a e m which is the case when the fluid is an electron gas. About the Publisher Forgotten Books publishes hundreds of thousands of rare and classic books. Find more at www.forgottenbooks.com This book is a reproduction of an important historical work. Forgotten Books uses state-of-the-art technology to digitally reconstruct the work, preserving the original format whilst repairing imperfections present in the aged copy. In rare cases, an imperfection in the original, such as a blemish or missing page, may be replicated in our

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This thesis explores a route to induce and control the structure formation process in thin films by the use of strong electric fields. We investigate, establish and apply the use of the electrohydrodynamic (EHD) lithography as a versatile patterning tool on the sub-micrometre and nanometre length scales for functional materials. Thin films are ubiquitous, they are found in nature and used in almost every aspect of daily life. While film instabilities are often undesirable in nature and technology, they can be utilized to produce structures by precisely controlling the destabilization of the film. EHD lithography utilizes instabilities induced by means of an electric field to fabricate periodic structures. EHD patterning is set to become a competitive candidate for low-cost lithographic technology for a number of applications. Herein, the applied potential of this lithographic process is explored by expanding its applicability to a broad range of materials and by a simultaneous patterning of multilayer systems or functional polymers yielding hierarchical architectures with novel functionalities. EHD pattern formation enables for instance, the fabrication of multi-scale structured arrays as surface enhanced Raman scattering (SERS)-active platforms. Furthermore, crystalline and conductive polymers are patterned using the EHD approach and the underlying structure formation mechanisms are discussed. This extension towards functional material systems offers interesting prospects for potential applications. Findings of this thesis are very promising for use in optoelectronic devices.

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"The ever-increasing developments and advancements in the field of microfabrication technology for the past two decades have encouraged many applications geared towards miniaturized bioanalytical systems capable of performing independent or concurrent on-chip operations including, pumping, mixing, sample enrichment, thermal cycling and sensing. Reduced reagent consumption, enhanced spatiotemporal control over reaction conditions, the increased surface to volume ratios and ease of process parallelization are some key advantages of miniaturized bioanalytical systems over their counterpart conventional macroscale methods. Enabling physical mechanisms for many on-chip operations often include various gravitational, acoustics, magnetic and electric phenomena. Electrically-induced actuation mechanisms are becoming the method of choice for many specialized applications whereby low power, small footprint and absence of moving parts are desired. Applications of electrically induced actuation mechanisms encompassing classical electrokinetics and electrohydrodynamic forces are the subject of this thesis. Multiple novel biochips were designed, fabricated and characterized for performing cell enrichment, micromixing and nanoparticle synthesis. First, the principle of alternating current (AC) dielectrophoresis (DEP) was utilized for the tunable sorting of synthetic particles and cells. Next, the concepts of AC electroosmosis (ACEO) and electrohydrodynamic were investigated for the micromixing of monophasic and biphasic liquid systems. For the first time, the ACEO-induced fluid actuation mechanism was utilized for devising a phase-controlled field-effect micromixer. The phase-tunability of the micromixer was investigated experimentally and semi-analytically. Finally, electrohydrodynamic-based fluid instabilities were employed for the mixing of solvent and aqueous liquid phases in the context of nanoparticle synthesis. It was demonstrated that electrohydrodynamic-mediated micromixing can be leveraged for the synthesis of high-throughput and highly monodispersed liposomal batches intended for drug delivery applications. The devised platform and methodology can be applied across many nanoparticle chemistries relying on the principle of nanoprecipitation. Overall, the novel ideas and methodologies introduced in this thesis validated the utility of electrical-based methods for on-chip operations and demonstrated new applications with many potentials for nanoparticle synthesis and drug encapsulation"--

This concise and unified text reviews recent contributions to the principles of convective heat transfer for single and multi-phase systems. This valuable new edition has been updated throughout

and contains new examples and problems.
The objective of this research was the development of a mathematical model of the electrospinning process using dry spinning modeling principles as a basis. This model is directed at the identification of parameters which influence final fiber characteristics, e.g., solvent concentration, temperature, spin line tension, and electric field. Preliminary computer simulations were performed; however, the generated data was inconclusive and was determined to be due in part to the complexity of the modeled system and the subsequent computational difficulties encountered. Although a comprehensive computational model of the electrospinning process has not yet been demonstrated, the theoretical development that was undertaken provides a firm foundation for understanding and evaluating the electrospinning process. This development also provides a basis for the future development of a computational model based on this novel approach to electrospinning. Electrospinning is a method of spinning nanoscale fibers that employs an electric field to propel a stream of polymer solution to create the sub-micron diameter fiber. Although much research has been done on the process itself, its wide-scale adoption has been inhibited by a lack of predictive control on the fiber properties. By developing an accurate computational model, enhanced process control and the production of

fibers with desired properties can be attained. A mathematical model of electrospinning was developed that incorporates dry spinning and electrohydrodynamics principles. The model was based on the premise that the electrospinning of polymer solutions is, in many respects, an extension of dry spinning. Dry spinning is the fiber spinning process where a polymer solution is extruded through a spinneret into a body of circulating air. The air forces the solvent component to vaporize, forming a solid polymer fiber. The model was constructed by incorporating modified components of published 1-dimensional dry spinning and electrospinning models for their treatments of the mass, energy, and electrostatic transport equations. The momentum transport equation was derived independently in order to accurately describe the dynamic conditions unique to the electrospinning regime. This equation also includes terms for electrostatic stresses to account for the electrohydrodynamic interactions between the electrical charges residing on the filament surface and the electrical field. Initial modeling attempts were plagued with issues involving programming and the non-convergence of solutions. The challenge was to properly adapt the aspects of dry spinning to the electrospinning regime. In relation to dry spinning, electrospinning is characterized by high spin line velocities, high strain rates, increased solvent loss rates, and high air drag forces. The extreme changes these quantities undergo within a small length of space, particularly in the initial region just beyond the jet origin, may be a factor in contributing to the numerical instability of the model. Reevaluating the material property formulations and a more robust computational scheme will be considered. The novel incorporation of the principles of electrohydrodynamics (as a mechanism for fluid movement) coupled with very high solvent evaporation rate behavior contributed to a new and representative description of the extreme case of filament diameter reduction inherent in the electrospinning process.

The aim of this book is to provide, both the non-specialist and the specialist in EHD, with the ability to extract meaningful information from his/her experimental data and acquire a good physical understanding, by applying the ideas presented in this book. In addition to providing the scientific background, it is also intended to take the reader to the frontiers of research in this field, so they may go, without effort, into the specialized literature. This book may be considered as complementary to the excellent treatment of EHD made in the classical book "Continuum Electromechanics" by Melcher, in that care has been taken to avoid overlapping of the subjects. In case a topic is treated in both texts, the results presented in the book by Melcher serve as an introduction to the more advanced treatment presented in this book.

In this work a numerical method is presented to model the electrohydrodynamics of a three-dimensional vesicle. The objective of this study is to develop robust numerical algorithms to solve the physical governing equations of the vesicle in the presence of fluid flow and DC electric fields. Furthermore the model will be able to predict the fast dynamics of the vesicle exposed to strong fields for a wide range of material properties and deformations that cannot be easily captured in experimental settings. The vesicle membrane is modeled as an infinitesimally thin capacitive interface. The electric field calculations explicitly take into account the capacitive interface by an implicit Immersed Interface Method formulation, which computes the electric potential field and the trans-membrane potential simultaneously. The interface is tracked through the use of a semi-implicit, gradient-augmented level set method. The enclosed volume and surface area are conserved both locally and globally by a new Navier-Stokes projection method. The valdiation of the hydrodynamic model was examined in the light of experimental data and observations. The two major modes of the vesicle motion in the linear shear flow namely the tank-treading and tumbling regimes, were studied. Simulation results show a very good agreement between the present results and the experimental data. The electrohydrodynamic results also match well with previously published experimental, analytic and two-dimensional computational works and the model is capable of capturing the type of topological changes previously observed in experiments. A parameter study of different important material properties is carried out for the transition between oblate and prolate ellipsoidal shapes in order to estimate the critical parameter tresholds for this transition to happen. In addition, investigation of the vesicle behavior under the combined effects of shear flow and weak DC electric fields reveals the remarkable influence of the electric field in changing the standard behaviors of tank-treading and tumbling vesicles. If the electric field is strong enough the induced resistance caused by the electric field may alter the behavior of a tumbling vesicle into a tank-treading motion.

Bringing together the world's leading researchers and practitioners of computational mechanics, these new volumes meet and build on the eight key challenges for research and development in computational mechanics. Researchers have recently identified eight critical research tasks facing the field of computational mechanics. These tasks have come about because it appears possible to reach a new level of mathematical modelling and numerical solution that will lead to a much deeper understanding of nature and to great improvements in engineering design. The eight tasks are: The automatic solution of mathematical models Effective numerical schemes for fluid flows The development of an effective mesh-free numerical solution method The development of numerical procedures for multiphysics problems The development of numerical procedures for multiscale problems The modelling of uncertainties The analysis of complete life cycles of systems Education - teaching sound engineering and scientific judgement Readers of Computational Fluid and Solid Mechanics 2003 will be able to apply the combined experience of many of the world's leading researchers to their own research needs. Those in academic environments will gain a better insight into the needs and constraints of the industries they are involved with; those in industry will gain a competitive advantage by gaining insight into the cutting edge research being carried out by colleagues in academia. Features Bridges the gap between academic researchers and practitioners in industry Outlines the eight main challenges facing Research and Design in Computational mechanics and offers new insights into the shifting the research agenda Provides a vision of how strong, basic and exciting education at university can be harmonized with life-long learning to obtain maximum value from the new powerful tools of analysis

In the first set of experiments, a Steel Film Drop

Impact setup was used to study the dynamics of drop impact and the evaporation behavior of the post-impact sessile drop at different impact Weber numbers. This setup allowed for both optical observation of the impacting drop as well as the infrared thermal observation of the substrate from the backside. A wire electrode held close to the substrate was used to generate the electric field. Experiments conducted using the dielectric fluid HFE-7100 generated data consistent with previous studies on the effect of We number on drop impact. Although drop evaporation time was found to vary with applied electric fields, consistent evaporation rate behavior could not be obtained due to the undesired effect of electric field on the size of the initial drop created by the dispensing needle. Further, the applied maximum voltage in this case was not very high (300 V) due to the unavailability of a highvoltage device.

The dynamics of dielectric liquid and liquid drops suspended in another fluid medium subjected to electric field has captivated researchers ever since electro-fluid dynamics was introduced in 17th century. While there has been much work in uniform electric field, recent trends have moved towards the study of how non-uniformity of electric field would induce the motion. The purpose of this thesis is to investigate the response of dielectric liquids and droplets under an ionization technique creating non-

uniform electric field. The method applied is corona discharge whose electrical parameters are first studied to understand the behavior of the source impulse. We advocate for the method for it is contactless and enlighten the area of applications considering the limitations of other methods. While studying the behavior of droplet to this electrical signal, their physical changes are tracked down to relate its intrinsic property to this extrinsic discharge phenomena. The dynamic behavior is modeled with the insights of spring-damper analogy and this model is found to capture the different states of deformation while droplet move from one place to other. One distinct feature of this works is to explain how the combined effects of electrophoresis and di-electrophoresis induce the motion and an analogy to differentiate them serves as valuable inputs to carry out electrohydrodynamic(EHD) research. We configured our geometry to address the applicability of this technique to drive very viscous liquids in attempts to see the potentials of the technique being used as EHD pumping. Apart from experiments, we have carried numeric simulations to conclude on the coupled interactions of Electro-Fluid dynamics.
The focus of this Ph. D. thesis is the theoretical, computational, and experimental analysis of electrohydrodynamics and ionization in the Array of Micromachined UltraSonic Electrospray (AMUSE) ion source. The AMUSE ion source, for mass

spectrometry (MS), is a mechanically-driven, droplet-based ion source that can independently control charge separation and droplet formation, thereby conceptually differing from electrospray ionization (ESI). This aspect allows for low voltage soft ionization of a variety of analytes and flexibility in the choice of solvents, providing a multifunctional interface between liquid chromatography and mass spectrometry for bioanalysis. AMUSE is a versatile device that operates in an array format, enabling a wide range of configurations, including high-throughput and multiplexed modes of operation. This thesis establishes an in-depth understanding of the fundamental physics of analyte charging and electrokinetic charge separation in order to enhance droplet charging and ionization efficiency. A detailed electrohydrodynamic (EHD) computational model of charge transport during the droplet formation cycle in the AMUSE ion source is developed, coupling fluid dynamics, pressure and electric fields, and charge transport in multiphase flow. The developed EHD model presents a powerful tool for optimal design and operation of the AMUSE ion source, providing insight into the microscopic details of physicochemical phenomena, on the microsecond time scale. Analyte charging and electrohydrodynamics in AMUSE are characterized using dynamic charge generation measurements and high-spatial-resolution stroboscopic visualization of ejection phenomena. Specific regimes of charge transport, which control the final droplet charging, have been identified through experimental characterization and simulations. A scale analysis of the ejection phenomena provides a parametric regime map for AMUSE ejection modes in the presence of an external electric field. This analysis identifies the transition between inertia-dominated (mechanical) and electrically-dominated (electrospraying) ejection, where inertial and electric forces are comparable, producing coupled electromechanical atomization. The understanding of analyte charging and charge separation developed through complimentary theoretical and experimental investigations is utilized to improve signal abundance, sensitivity, and stability of the AMUSE-MS response. Finally, these tools and fundamental understanding provide a sound groundwork for the optimization of the AMUSE ion source and future MS investigations.

Electrohydrodynamics is the study of the interaction between fluids and electric fields, and is used to model phenomena like fuel atomization or the mixing of multiphase flows under the influence of electric fields. Increasing interest is being placed in using electric fields to vary multiphase behaviour, one example is combustion processes, where finer droplets and wider sprays are created to increase engine efficiency. Another example can be seen in

the pharmaceutical industry, where micro-encapsulation of compounds is achieved through the use of electrified coaxial liquid jets. In this work, the Ghost Fluid Method (GFM), and the Continuum Surface Force (CSF) approach will be used to discretize the electric potential Poisson equation for multiphase problems with arbitrary interfaces and discontinuous physical properties. A new scheme has also been derived to solve this problem, in the Finite Volume (FV) framework, and an extensive error analysis has been carried out to gauge the accuracy and properties of these schemes. These tools, coupled with NGA, the Computational Fluid Dynamics (CFD) code used in Dr. Olivier Desjardins' research group will allow the study of, among others, the two phase mixing of two dielectric liquids under the influence of an electric field, of interest to the chemical engineering industry, where an alternative non-mechanical way of mixing corrosive liquids is sought out, or the atomization of drops during fuel injection when an electric field is applied.
This is the second volume of a two-volume set presenting a unified approach to the electrodynamics of continua, based on the principles of contemporary continuum of physics. The first volume was devoted mainly to the development of the theory and applications to deformable solid media. This volume extends the developments of the first volume to richer and newer grounds. It contains discussions on

fluid media, magnetohydrodynamics, eletrohydrodynamics and media with more complicated structures. With the discussion, in the last two chapters, of memory-dependent materials and non-local E-M theory, the authors account for the nonlocal effects arising from motions and fields of material points at past times and at spatially distant points. This discussion is included here to stimulate further research in these important fields, which are presently in development stages. The second volume is self-contained and can be studied without the help of volume I. A section summarizing the constitutive equations and the underlying physical ideas, which were presented in more detail in the first volume, is included. This volume may be used as a basis for several graduate courses in engineering schools, applied mathematics and physics departments. It also contains fresh ideas and will stimulate further research in the directions the authors outline.

This monograph is the first book exclusively devoted to Electrohydrodynamics in Dusty and Dirty Plasmas with extended Electrodynamics and Gravito-Electrodynamics with Electric Mirrors. The book incorporates novel concepts of Electro Cusp-Reconnection and Generalized Critical Ionization Velocities as well as modern concepts of Self-Organization and Chaos. Therefore, the book is special and quite different from the previous edition in the field of plasma physics in terms of scope, object, and approach. The scope of the present work is much broader and much more general with space and laboratory applications, including collisional neutral and partially ionized gases in electric and space-charge fields, thereby accompanying electrical charging, electrification, discharge, ionization and recombination. The book will serve as a text book, text-related or reference book for graduate students, post graduates, and scientists in geo-astro, space, and laboratory plasma physics, electromagnetics and fluid dynamics. In addition, it will be useful for researchers outside the plasma community who wish to obtain new physical insights, aspects, and points of view.

This monograph examines multidimensional stability of strong discontinuities (e.g. shock waves) for systems of conservation laws and surveys the author's results for models of ideal magnetohydrodynamics (classical, 'pressure anisotropic', relativistic) and electrohydrodynamics. The primary attention is concentrated on linearised stability analysis, especially on the issue of uniform stability in the sense of the uniform Kreiss-Lopatinski condition. A so-called 'equational' approach based on obtaining, by the dissipative integrals technique, a priori estimates without loss of smoothness for corresponding linearised stability problems in the domains of uniform stability is described. Recent results for ideal models of MHD (classical MHD, 'pressure anisotropic' MHD of Chew, Goldberger and Low, relativistic MHD) and also for a certain non-hyperbolic model are presented as the system of electrohydrodynamics (EHD).

The dynamics of dielectric rigid particles and liquid drops suspended in another liquid medium and subject to a uniform DC electric field, the study of which forms the field of electrohydrodynamics (EHD), has fascinated scientists for decades. This phenomena is described by the much celebrated Melcher-Taylor leaky dielectric model. The model hypothesises development of interfacial charge on the application of an electric field and prescribes a balance between transient charge, jump in normal Ohmic currents due to finite conductivities of the medium and charge convection arising from interfacial velocity. While there have been numerous studies on the dynamics of particles and drops more conducting than the surrounding liquid medium, weakly conducting particles and drops in strong electric fields, known to undergo symmetry-breaking bifurcations leading to steady rotation known as Quincke electrorotation has received much less attention. Recent experiments have reported a decrease in the effective viscosity of particle under Quincke rotation, thereby providing a means to tune the rheological properties of these suspensions. However, existing models based on an isolated particle, valid for dilute suspension, have been shown to be inaccurate as the density of particles increases. Motivated to resolve these discrepancies, we develop a theoretical model to account for electrohydrodynamic interactions between a pair of spherical particles. We then turn our attention to many particles free to roll on an electrode due to Quincke rotation. Using numerical simulations, we show that electrohydrodynamic interactions between particles give rise to collective motion of these colloidal suspensions. We find emergence of a polar liquid state with large vortical structure in circular confinement. Finally, we address the problem of electrohydrodynamics of deformable liquid drops, first studied by Taylor in 1966. We develop a transient small deformation theory for axisymmetric drops while including the nonlinear charge convection term neglected by previous researchers. We also use numerical simulations based on a novel three-dimensional boundary element method to capture large deformations. These simulations are the first to capture Quincke rotation due to inclusion of the nonlinear charge convection term and show excellent agreement with existing experimental data and theoretical predictions in the small

deformation regime.
Rheology of Emulsions, Volume 22: Electrohydrodynamics Principles studies phenomena at liquid-liquid interfaces, including finely dispersed particles or structures, in particular emulsions, double emulsions and biological cells. The book considers the forces of electrical origin that participate in the physical events at liquid-liquid interfaces, taking into account electron transfer phenomenon and electrodynamics principles. Topics covered are of interest to a broad range of scientists, researchers and graduate students with a basic knowledge of physical chemistry, electromagnetism, fluid mechanics, classical and quantum electrodynamics. The implications and applications of the material presented in the book contribute to the advanced fundamental, applied and engineering research of interfacial electroviscoelastic phenomena. Features a multidisciplinary approach to electron transfer phenomena Introduces a new constitutive model of liquids and a theory of electroviscoelasticity Addresses a broad range of subject field examples that make it useful to various research communities
Among the most promising techniques to handle small objects at the micrometer scale are those that employ electrical forces, which have the advantages of voltage-based control and dominance over other forces. The book provides a state-of-the-art knowledge on both theoretical and applied aspects of the electrical manipulation of colloidal particles and fluids in microsystems and covers the following topics: dielectrophoresis, electrowetting, electrohydrodynamics in microsystems, and electrokinetics of fluids and particles. The book is addressed to doctoral students, young or senior researchers, chemical engineers and/or biotechnologists with an interest in microfluidics, lab-on-chip or MEMS.
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