Chapter

Introductory Chapter: Modern Applications of Electrostatics and Dielectrics

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1. Introduction

Electrostatics is one of the most basic, yet very important, branches of physics with applications in almost every domain. We observe how a plastic comb after its use on dry hair attracts small bits of paper. We are stunned by the power of lightning from dark rainy clouds during thunder storms. Time to time, we might have also experienced small electric shocks when we touch any metal after rubbing hands on certain materials. All these experiences have to do with the underlying phenomena of electrostatics.

Materials are broadly classified into two large groups based on their electrical properties. Some are called conductors and the others are termed as insulators (or dielectrics). In dielectrics, contrary to metals, all charges are attached to specific atoms and molecules. Such charges are known as bound charges. These charges can be displaced within an atom or a molecule. Compared to the dramatic rearrangements of charges in a conductor under electric field, charge displacements in dielectric materials are only microscopic in nature. However, these microscopic displacements can have cumulative effects that are responsible for several characteristic behaviours of dielectric materials.

Electrostatics-based applications are ubiquitous. Lightning conductors, surface coaters, electrostatic imagers, non-impact printers, industrial processes such as material separation, electrodialysis, static dischargers, etc., are some of the most common applications [1–5].

Dielectrics have been used for developing various devices particularly using their unique material properties. Recent advancements in material science have made it possible to develop and engineer devices for applications in elasto-optics, electro-optics, ultrasonic [6] and surface-mount electronics [7]. Dielectrics are also used to develop compact and efficient antennas [8]. There is an increase in the use of dielectrics for developing advanced defence applications [9]. Dielectric material properties can carefully engineered to develop artificial materials and coatings that can efficiently absorb or dampen incident electromagnetic waves. Such materials are both used in real-time stealth applications [10, 11] and modelling absorbing layers to truncate computational domains [12].

Accurate modelling of dielectric properties is one of the most challenging tasks. For basic applications like studying oil spills on ocean surface, one can easily model oil spills as dielectric with complex permittivity [13]. Other advanced applications require more detailed modelling of dielectric properties. For example, dielectric elastomers are actively studied for applications involving artificial muscle actuators for robots and solid-state optical devices for various electronic components [14].

These advanced applications of electrostatics and dielectrics rely on accurate modelling methods and tools. The choice of right electromagnetic tools for modelling is an important challenge for design and application engineers [15, 16]. Various advanced modelling tools are being developed for modelling such applications that includes some of the classical computational methods [17, 18], and non-mainstream computational methods [19, 20].

In this book, we have introduced seven advanced applications of electrostatics and dielectrics. These papers bring forth recent developments using electrostatics and dielectrics. In the first paper on electrostatic potential modulation of atoms by strong light field, Wang presents tunnelling ionization and single isolated attosecond light pulse application. In the second paper, Takahashi et al. discuss development of an electrostatic eliminator utilizing high-voltage AC power supply-driven by pulse width modulation (PWM) inverter. In the third paper, Osgouei shows how electrostatic friction mechanism can be used in display technology to enhance touchscreen experience. In the fourth paper, Wu and Yang investigate dielectric failure mechanism and property modification in inverter-fed motors. Mukhlisin and Saputra elaborate their dielectric analysis model for measuring soil moisture (water content) using electric capacitance volume tomography in the fifth paper. Menachem presents techniques for calculating dielectric maternal parameters for waveguide applications in the sixth paper. In the final paper of this book, Xiao and Zhao discuss research progress on synergistic effect between insulation gas mixtures.

I believe this compendium of research papers in the domain of electrostatics and dielectrics will open new opportunities for future research. I thank all the authors for their collaborative efforts and excellent contribution. Final words of gratitude are due to IntechOpen for making this work possible. Good luck!

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References

[1] Bright AW. Modern electrostatics. Physics Education. 1974;**9**(6):381. DOI: 10.1088/0031-9120/9/6/303

[2] Sharp KA, Honig B. Electrostatic interactions in macromolecules: Theory and applications. Annual Review of Biophysics and Biophysical Chemistry. 1990;**19**(1):301-332. DOI: 10.1146/annurev.bb.19.060190.001505

[3] Haga K, Chang JS, Kelly AJ, Crowley JM. Applications of the electrostatic separation technique. In: Handbook of Electrostatic Processes. New York: Marcel Dekker; 1995. pp. 365-386

[4] Jeon JU, Higuchi T. Electrostatic suspension of dielectrics. IEEE Transactions on Industrial Electronics. 1998;**45**(6):938-946. DOI: 10.1109/41.735338

[5] Castle GS. Industrial applications of electrostatics: The past, present and future. Journal of Electrostatics. 2001;**51**:1-7. DOI: 10.1016/S0304-3886(01)00068-7

[6] Spencer EG, Lenzo PV, Ballman AA. Dielectric materials for electrooptic, elastooptic, and ultrasonic device applications. Proceedings of the IEEE. 1967;**55**(12):2074-2108. DOI: 10.1109/PROC.1967.6087

[7] Hennings D, Klee M, Waser R. Advanced dielectrics: Bulk ceramics and thin films. Advanced Materials. 1991;**3**(7-8):334-340. DOI: 10.1002/adma.19910030703

[8] Fumeaux C, Almpanis G, Sankaran K, Baumann D, Vahldieck R. Finite-volume time-domain modeling of the mutual coupling between dielectric resonator antennas in array configurations. In: The Second European Conference on Antennas and Propagation (EuCAP). 2007. pp. 1-4. DOI: 10.1049/ic.2007.0909

[9] Sankaran K. Recent trends in computational electromagnetics for defence applications. Defence Science Journal. 2019;**69**(1):65-73. DOI: 10.14429/dsj.69.13275

[10] Musal HM, Hahn HT. Thin-layer electromagnetic absorber design. IEEE Transactions on magnetics. 1989;**25**(5):3851-3853. DOI: 10.1109/20.42454

[11] Abbas SM, Chandra M, Verma A, Chatterjee R, Goel TC. Complex permittivity and microwave absorption properties of a composite dielectric absorber. Composites Part A: Applied Science and Manufacturing. 2006;**37**(11):2148-2154. DOI: 10.1016/j.compositesa.2005.11.006

[12] Sankaran K, Kaufmann T, Fumeaux C, Vahldieck R. Different perfectly matched absorbers for conformal time-domain method: A finite-volume time-domain perspective. In: 23rd Annual Review of Progress in Applied Computational Electromagnetics. 2007. pp. 1712-1718

[13] Sankaran K, Fortuny-Guasch J. Radar remote sensing for oil spill classification (optimization for enhanced classification). In: Proceedings of the 12th IEEE Mediterranean Electrotechnical Conference MELECON. 2004. pp. 511-514. DOI: 10.1109/MELCON.2004.1346979

[14] Pelrine R, Sommer-Larsen P, Kornbluh RD, Heydt R, Kofod G, Pei Q, et al. Applications of dielectric elastomer actuators. In: Smart Structures and Materials 2001: Electroactive Polymer Actuators and Devices. Vol. 4329. International Society for Optics and Photonics; 2001. pp. 335-349. DOI: 10.1117/12.432665

[15] Sankaran K. Are you using the right tools in computational

electromagnetics? Engineering Reports. 2019;**1**(3):1-19. DOI: 10.1002/eng2.12041

[16] Aakash, Bhatt A, Sankaran K. Transcending limits: Recent trends & challenges in computational electromagnetics. In: Proceedings of IEEE-INAE Workshop on Electromagnetics–IIWE. 2018

[17] Yu W, Mittra R. A conformal finite difference time domain technique for modeling curved dielectric surfaces. IEEE Microwave and Wireless Components Letters. 2001;**11**(1):25-27. DOI: 10.1109/7260.905957

[18] Brosseau C, Beroual A. Computational electromagnetics and the rational design of new dielectric heterostructures. Progress in Materials Science. 2003;**48**(5):373-456. DOI: 10.1016/S0079-6425(02)00013-0

[19] Sankaran K. Beyond DIV, CURL and GRAD: Modelling electromagnetic problems using algebraic topology. Journal of Electromagnetic Waves and Applications. 2017;**31**(2):121-149. DOI: 10.1080/09205071.2016.1257397

[20] Aakash, Bhatt A, Sankaran K. How to model electromagnetic problems without using vector calculus and differential equations? IETE Journal of Education. 2018;**59**(2):85-92. DOI: 10.1080/09747338.2018.1554456