Guest Editorial Special Issue on the Contributions of Women in Ferroelectrics Research and Development

STATISTICS worldwide show that women remain underrepresented in science, technology, engineering, and mathematics (STEM)-related fields relative to the total population. In the IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society (UFFC Society), members who identify as women remain below 10% of the total society members, suggesting that their underrepresentation persists in ferroelectrics research and development activities as well. Addressing this issue and shifting this gender imbalance will require multiple approaches and actions. The Guest Editors, as persistent volunteers and participants in UFFC Society administration and activities, proposed this Special Issue on the Contributions of Women in Ferroelectrics Research and Development as one of many initiatives to further promote diversity, equity, and inclusion in science, engineering, and the UFFC Society.

The purpose of this Special Issue is to promote and highlight the cutting-edge scientific and technological contributions from both established and emerging women scientists and engineers in the field of ferroelectrics. Authors in this Special Issue include women at all career stages—including undergraduate students, recent Ph.D. graduates, and those retired from the profession—the common link being the field of ferroelectrics. The Guest Editors believe that *everyone*—not just those who are a part of underrepresented groups—are responsible for successfully advancing diversity and inclusivity. Thus, while the work presented in each of the papers was either conducted or led by women, the Guest Editors and co-authors of the papers are diverse in gender as well as their nationality and career stage. This Special Issue serves as the UFFC Society's inaugural showcase of the contributions from individuals belonging to an underrepresented group in STEM.

The Special Issue opens with four review articles. In the first contribution, Mercadelli and Galassi comprehensively review processing routes and strategies for making porous piezoelectric materials with two application case studies that utilize porous piezoelectrics. The work of Ferson, Uhl, and Andrew (a CAREER award recipient from the U.S. National Science Foundation) reviews the potential and challenges associated with using magnetoelectric-based composites in biomedical applications. Liu, Lu, Dong, Wang, and Liu (a former Australian Research Council Queen Elizabeth II Future Fellow) review ferroelectric ceramics for pyroelectric-based temperature and infrared sensing/detection applications. A fourth review article by Bretos, Jiménez, and Ricote, led by Maria Lourdes Calzada as the corresponding author, focuses on low-temperature chemical solution deposition processing of ferroelectric thin films with a focus on integration and flexible electronics; regrettably, this manuscript was published early by the journal but is a valued contribution to this Special Issue. It is listed in the Table of Contents and can be found at the DOI: 10.1109/TUFFC.2020.2995287.

The collection of contributed articles in the Special Issue covers multiple aspects of processing, structure, theory, and properties of many different ferroelectric materials and devices. Neumayer, Susner, McGuire, Pantelides, Kalnaus, Maksymovych, and Balke (a past Feodor-Lynen Fellow of the Alexander von Humboldt Foundation) report the use of piezoresponse force microscopy and unsupervised machine learning to study the strain-induced lowering of the ferroelectric Curie temperature in $CuInP_2S_6$, a ferroelectric van der Waals material. Denis-Rotella, Esteves, Walker, Zhou, Jones, and Trolier-McKinstry (Fellow of IEEE, the American Ceramic Society, and the Materials Research Society, member of the U.S. National Academy of Engineering, and recipient of the IEEE UFFC Society Distinguished Service Award, IEEE UFFC Society Ferroelectrics Recognition Award, and IEEE Robert E. Newnham Ferroelectrics Award) present and apply a novel approach to quantitatively determine the contributions to dielectric permittivity using a combination of *in situ* X-ray diffraction experiments and Rayleigh analysis of dielectric properties. Glinchuck, Morozovska, and Yurchenko demonstrate, theoretically, how the newly emerged class of binary oxide ferroelectrics such as HfO_2 can be considered as new multiferroics, expanding their application potential even further than originally imagined. Horchidan, Curecheriu, Ciomaga, Lupu, and Mitoseriu (recipient of the Romanian Academy Award in Physics) present a comprehensive study of the synthesis, structure, and dielectric and ferroelectric properties of ceramics prepared across the entire compositional range of $xBaGeO_3$-(1-x)$BaTiO_3$. In a contribution by McQuade, Smith, and Dolgos, the $Na_{1/2}Bi_{1/2}TiO_3$-$BaTiO_3$ (NBT-BT) system near the morphotropic phase boundary was substituted with $BiGaO_3$, which allowed the determination of the compositions with the highest field-induced strain and its relation to the ergodic relaxor transition temperature. Tyunina presents

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evidence against the role of oxygen vacancies in the electrical conductivity of $BaTiO_3$ thin films, suggesting that electronic processes lead to coloration and degradation with electric field application. Halpin, Schmidt, Maity, Pemble, and Keeney explore how Fe^{3+} and Nb^{5+} substitution in an Aurivillius phase bismuth titanate compound influence the structural, optical, piezoelectric, and magnetic properties of chemical solution deposited thin films. Buixaderas (recipient of the Otto Wichterle Prize for Young Researchers) and Paściak provide new data to reinvestigate the local structure, phonons, and polarization dynamics in the tetragonal tungsten bronze family of ferroelectrics using scattering and spectroscopic techniques such as pair distribution function experiments. Ochoa-Pérez, González-Crespo, García-Lucas, Jiménez-Martínez, Vázquez-Rodríguez, and Pardo perform an analysis of the deformation modes and complex impedance of shear plates of composition NBT-BT using finite element analysis. Finally, an "In Memoriam" article contributed by Mike Glazer honors the life and scientific accomplishments of the late Helen Megaw, who was a pioneer in the early years of ferroelectrics research.

In addition to the women authors in this Special Issue, we pay tribute to senior and historical women and their impact in the field of ferroelectrics. In 1968, Anna Fousková, in collaboration with Eric Cross, revealed the unusual dielectric behavior of gadolinium molybdate, which led to substantial subsequent research in improper ferroelectrics. Starting in 1989, Nava Setter (IEEE Fellow and recipient of the IEEE UFFC Society Achievement Award and IEEE UFFC Ferroelectrics Recognition Award) led the research at École Polytechnique Fédérale de Lausanne (EPFL) on the fundamentals of ferroelectric and dielectric materials and their applications in novel devices and, during last years before retirement, focused on effects of domain-wall phenomena on the functioning of ferroelectrics and possible applications based on these effects. From the early 1980s to 2012, Marija Kosec (recipient of the IEEE UFFC Ferroelectrics Recognition Award) contributed significant advances in the chemical processing of ferroelectric ceramics, thick and thin films, and in particular lead-free ferroelectrics in her later years. Jing Zhu, Academician of the Chinese Academy of Sciences since 1995 and Professor at Tsinghua University, was a pioneer in analytical electron microscopy and application of aberration-corrected electron microscopy to functional materials, including in relaxor ferroelectrics to study their local structure and chemical ordering. Finally, among many other of her contributions, Helen Megaw determined the structure of barium titanate in 1945 and contributed to the field until her retirement in 1972, though she continued to serve as a journal referee throughout her retirement; the aforementioned article by Mike Glazer in this Special Issue provides much more information on Prof. Megaw's life and scientific accomplishments.

Many women ferroelectrics engineers also contributed substantially to industrial interests, for example, Wanda W. Wolny who worked at a piezoelectrics manufacturer in Europe for decades, retired in 2013. Wolny eventually became a Director and co-owner of the company as well as contributing leadership to the PiezoInstitute AISBL (President, 2008–2013) and an Honorary President of the PIEZO 2013 Conference.

Undoubtedly, many other women have given important and impactful ideas and contributions to the field of ferroelectrics—many more than can be highlighted in this Special Issue or opening editorial. It is our hope that their most impactful work can be highlighted and recognized by the scientific and industrial communities in future venues, journals, symposia, and awards.

The Guest Editors would like to take this opportunity to thank all contributing authors for their work, as well as the editorial board members and reviewers. They appreciate everyone's participation in this Special Issue as a means to disseminate their research and development contributions.

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