Foreword

Special Issue Featuring Papers from the 26th Topical Meeting on the Technology of Fusion Energy (TOFE 2024)

Editor

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The contemporary interest of the scientific community in searching for renewable, stable, and prospective energy sources, supported by public and private research organizations as well as governmental entities, called for the organization of an international conference focused on the key theme "The Public-Private Pivot to Fusion Energy." This theme served as the focus for the 26th edition in the American Nuclear Society (ANS) Technology of Fusion Energy (TOFE) topical meeting series. TOFE 2024 was held July 21–25, 2024, in Madison, Wisconsin, at the Madison Concourse Hotel and Governor's Club. Participants at TOFE 2024 experienced joyful face-to-face communications and networking, taking advantage of the opportunity to connect with other professionals in the field and learn about the latest advancements and research in fusion technology.

The editors of this special issue and the ANS staff deeply appreciate the responsible and tireless efforts of the TOFE 2024 organizers in managing all the intricate conference processes. The dedication and commitment of the organizers—specifically Dr. Ross Radel (general chair, SHINE Technologies) and Dr. Paul Wilson (technical program chair, University of Wisconsin–Madison)—contributed to a smooth and enjoyable experience for all attendees.

TOFE 2024 attracted specialists in fusion technological aspects from around the world. Its three plenary sessions featured the latest achievements in the international fusion program, the vision and status of the U.S. public programs, and founders' perspectives on the development of private fusion companies. The involved leaders represented central figures from the government department overseeing energy policy (U.S. Department of Energy), the major U.S. effort to build a large-scale fusion experiment (U.S. ITER), and the expert advisory body (the Fusion Energy Sciences Advisory Committee) that guides the entire U.S. fusion research strategy.

This special issue presents 38 peer-reviewed articles covering the broad scope of topics in cutting-edge fusion technology. The special issue content aligns with the topics of TOFE 2024 and is organized into six sections as described below, with the articles grouped to help readers navigate the rather extensive and thorough content presented in this issue:

1. Safety, Systems, and Perspectives for Fusion Energy Commercialization (articles 1–3).

2. Plasma Heating, Current Drive, and Alternative Concepts (articles 4–11).

3. Plasma-Facing Components and Heat Transfer (articles 12–19).

4. Blankets, Neutronics, and Magnetics (articles 20–27).

5. Tritium, Fuel Cycle, and Fueling (articles 28–36).

6. Materials and Irradiation Effects (articles 37–38).

In the first section, the issue opens with a review article addressing the recently recognized need for updated owner-operator requirements for fusion power plants. While 1980s and 1990s reports identified key needs (e.g., cost, safety, and readiness level assessment for operation license), ongoing global energy shifts

necessitate a refresh. To define these new requirements and ensure early design alignment for successful, timely commercial deployment, the U.S. Electric Power Research Institute (EPRI) is collaborating with utility stakeholders and the fusion community. In general, the papers in the first section focus on high-level issues such as regulatory frameworks, safety analysis, and operational requirements for future commercial fusion power plants.

The second section includes articles on plasma generation and heating, current drive, power delivery systems, and alternative non-tokamak fusion concepts.

The third section covers the design, thermal hydraulics, and diagnostics of plasma-facing components, specifically addressing items such as the divertor.

The fourth section groups papers on the breeding blanket and the various analyses required for designing fusion devices, including neutronic, thermal hydraulic, electromagnetic, and mechanical analyses. Additionally, research articles in this section cover radiation shielding of fusion facilities and electromagnetic effects on reactor structures.

The fifth section focuses on all aspects of the fusion fuel cycle, including tritium processing, pumping, storage, and plasma fueling systems.

The final section addresses the structural integrity and performance of materials under the harsh neutron radiation environment of a fusion reactor, including issues like corrosion and radiation damage.

This special issue targets a wide range of readers: fusion nuclear technology specialists, scientists, engineers, postgraduates, and educated people interested in the latest achievements in fusion technology. We hope this collection is thought-provoking, offering insight into the current state of the field and helping to shape the future direction of fusion energy development. This is particularly relevant as the industry responds to modern energy demands through effective public-private partnerships.

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