frontiers | Frontiers in Materials

TYPE Editorial
PUBLISHED 28 August 2025
DOI 10.3389/fmats.2025.1685638

OPEN ACCESS

EDITED AND REVIEWED BY
Peide Ye,
Purdue University, United States

*CORRESPONDENCE
Dmytro Solonenko,
dmytro.solonenko@silicon-austria.com
Stefano Leone,
stefano.leone@iaf.fraunhofer.de

RECEIVED 14 August 2025
ACCEPTED 18 August 2025
PUBLISHED 28 August 2025

CITATION
Solonenko D and Leone S (2025) Editorial: Advancing transition metal nitride semiconductors: overcoming integration challenges and exploring applications". *Front. Mater.* 12:1685638.
doi: 10.3389/fmats.2025.1685638

Editorial: Advancing transition metal nitride semiconductors: overcoming integration challenges and exploring applications"

Dmytro Solonenko[1]* and Stefano Leone[2]*

[1]Silicon Austria Labs GmbH, Villach, Austria, [2]Fraunhofer IAF, Freiburg, Germany

KEYWORDS

transition metal, films, AlScN, AlYN, HfN, epitaxy, semiconductor

Editorial on the Research Topic
"Advancing transition metal nitride semiconductors: overcoming integration challenges and exploring applications"

The growing demand for high-performance, energy-efficient, and scalable device technologies is driving intensive research into nitride-based functional materials. Among these, new emerging transition metal nitride semiconductors and their alloys such as aluminum scandium nitride (AlScN), aluminium yttrium nitride (AlYN) and transition metal nitrides (TMNs) such as ScN, TiN, and HfN have emerged as front-runners due to their unique electrical, mechanical, and structural properties. This has mainly been enabled by recent research developments focused on growth and deeper understanding of their characteristics. The integration of novel nitrides into semiconductor technology is rapidly advancing the performance and functionality of electronic and optoelectronic devices, with the strong contribution from the range from RF communications and MEMS to power electronics (with high electron mobility transistors–HEMTs) and ferroelectric memory. As the demand for high-efficiency, high-power, and miniaturized components continues to grow, researchers are exploring new materials and growth techniques that offer an improved combination of piezoelectric, ferroelectric, and electrical properties. Together, these studies illustrate a multifaceted approach to engineering next-generation nitride-based materials and heterostructures. By combining precise materials characterization, innovative deposition techniques, and crystal structure engineering, the research supports the scalable development of high-performance devices that bridge the gap between materials science and semiconductor technology. This Research Topic features 4 papers that focus on the aspects of the growth and integration challenges of these novel advanced nitride semiconductors.

The paper titled *"Piezoelectric and ferroelectric measurements on casted target-deposited $Al_{0.45}Sc_{0.45}B_{0.1}N$ thin films"* by Saha et al. highlights the potential of co-doping AlN with both Sc and B to improve piezoelectric and ferroelectric responses

(Saha et al.). The study optimized deposition parameters—target-substrate distance, nitrogen flow rate, and temperature—to achieve high crystallinity and low film stress when Si-rich alloy is sputtered on 200 mm Si wafers. The stabilization of the ternary alloy lattice by incorporating B atoms was thus proven by demonstration of the films with lower stress and fewer abnormally oriented grains yielding a piezoelectric coefficient of ~25 p.m./V and a remnant polarization of 280 μC/cm^2. These results show that AlScN can be pushed even further to yield enhanced performance at the limits of its stability, where it begins to demonstrate coercive fields' asymmetry and higher leakages.

The review article by Afshar et al. takes on the current knowledge of the AlYN ternary nitride compound and its potential device applications. The work reviews the physical properties of the alloy starting from the analysis of its structure and its impact on the elastic, thermal, optical, piezo- and ferroelectric characteristics, which have been addressed theoretically and partly experimentally uncovering numerous discrepancies by comparison. The overview concludes that AlYN poses all the qualities necessary to substitute its predecessor, AlScN, in most of MEMS- and HEMT-related applications if current advancement remains equally timely. Moreover, AlYN can potentially handle higher mixing ratio prior to the wurtzite-to-rocksalt phase switching enabling wider tunability range.

The current research on AlYN rapidly takes off and spans over the purely material science or thin film technology research proving its maturity in the HEMT application as shown in the work by Stanishev et al. Two transistor structures based on AlScN/GaN and AlYN/GaN layer stacks were characterized in the broad temperature range using the novel terahertz optical Hall effect technique for the properties of two-dimensional electron gas. The investigation confirmed previous reports stating the suitability of the Y-containing alloy demonstrating higher charge carrier mobility and lower effective mass than the ones of AlScN/GaN structure at lower temperatures. The results help establishing both alloys as viable barrier layers in GaN-based HEMTs on par with the classic AlGaN layers, enabling more efficient high-frequency transistor operation.

The paper titled "*Epitaxial growth of transition metal nitrides by reactive sputtering*" by Hörich et al. reports on the latest advances in the reactive sputtering of epitaxial thin nitride films on Si (111). The work tackles several binary compounds such as TiN, HfN, and ScN as well as the esteemed ternary AlScN alloy, showing that magnetron sputter epitaxy is a powerful method of obtaining high-quality film on technology-relevant substrates when the growth principles are well understood. It was demonstrated that cubic AlScN with the dominant (111) orientation is obtained when grown on ScN/Si(111) underlayer showing the highest crystallinity after sputtering of metallic Sc interlayer onto Si surface. The use of thin metallic buffers is also beneficial for HfN and TiN growth. The latter enables true conduction in the out-of-plane direction for Si-based devices.

In conclusion, we find this Research Topic an important milestone in the progress of advancement of transition metal nitrides as the basis for the devices with enhanced mechanical, electronic, and optical properties. The contributions to this Research Topic cover timely aspects of the current state of research and development on both fundamental and high-TRL stages proving that the Research Topic are more than just fleeting hype. The interest in the Research Topic can be expressed by the metrics of the Research Topic showing that since the start of the call and up to the date of this Editorial there are already more than eight thousand views and more than a thousand downloads of the research articles. The Guest editors warmly extend their gratitude to all contributing authors and welcome new future findings in the field.

Author contributions

DS: Writing – original draft. SL: Writing – review and editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Conflict of interest

Author DS was employed by Silicon Austria Labs GmbH.

The remaining author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript. AI was used to improve the connection among the papers of this Research Topic.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note