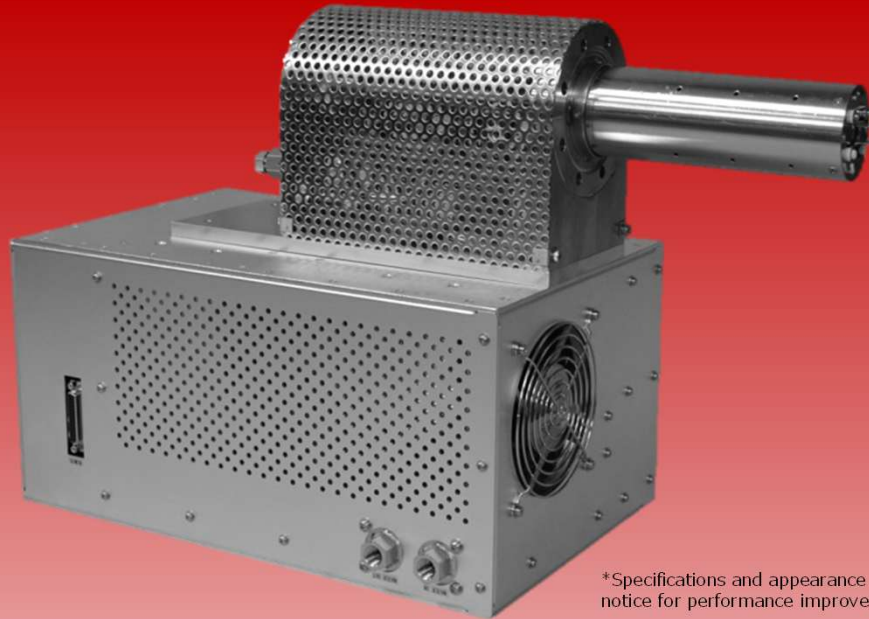


The only radical source that enables both high-speed and high-quality crystal growth

High Density Radical Source <HDRS>



*Specifications and appearance are subject to change without prior notice for performance improvement.

- High-flux atomic nitrogen radical supply that enables increased MBE growth rates
- Quantitative guarantee of absolute radical density (measured using a dedicated diagnostic system jointly developed with Nagoya University)
- Impurity-free design enabling high-quality and high-speed GaN growth
- Suitable for power-device and LED epitaxy
- Oxygen radical generation is available, enabling expansion to oxide materials

Key Features

- Ion- and electron-removal mechanisms
- High-density generation of H, N, and O radicals
- ICF114 flange mount
- Orifice for process chamber pressure adjustment

System Configuration

- Atomic radical generation source
- Integrated matching box (head-mounted type)
- Gas supply unit (optional)
- Feedback control (optional)

References

1. G. Herzberg, Spectra of Diatomic Molecules, 2nd ed. (Van Nostrand, New York, 1950).
2. O. Oda and M. Hori, Phys. Stat. Sol. A 218, 2000462 (2021).
3. S. Takashima et al., J. Vac. Sci. Technol. A 19, 599 (2001).
4. S. Chen et al., Jpn. J. Appl. Phys. 50, 01AE03 (2011).
5. F. Natali et al., J. Crystal Growth 311, 2029 (2009).
6. Y. Kawai et al., Phys. Status Solidi C 8, 2089 (2011).
7. T. Tabata et al., Phys. Status Solidi C 3-4, 646 (2012).
8. Y. Tsutsumi et al., ISPlasma2014/IC-PLANTS 2014, 06aP46 (2014).
9. Y. Cordier et al., J. Crystal Growth 433, 165 (2016).
10. C. Gerin et al., ACS Appl. Nano Mater. 720301 (2024).
11. Y. Horikoshi et al., Jpn. J. Appl. Phys. 25, L868 (1986).

Patents

Japan: JP-5673924, JP-5669084, JP-5896384, JP-5938809, JP-6519027

International: EP.2610895.B1 (DE,GB,FR), EP.3113583.B1 (DE,GB,FR), US9447518B2, US10577719B2, US10312054B2

Generation Process from Nitrogen Molecules to Atomic Radicals

Nitrogen molecules are excited to high-energy states through collisions with electrons, resulting in molecular bond dissociation and the formation of atomic nitrogen radicals. The generated atomic radicals subsequently relax to their ground state. Throughout this sequence of processes, the electron energy distribution plays a dominant role in determining the efficiency of radical generation.

Point ①

An electron energy of approximately 14 eV is required to excite and dissociate nitrogen molecules (Ref. 1).

Optimized Radical Generation Principles Based on Plasma Science

In conventional inductively coupled plasma (ICP) sources, the peak electron density is located in the low-electron-temperature region (approximately 2 eV). In contrast, in the high-energy region required for nitrogen molecule dissociation (approximately 14 eV), the electron population is extremely limited.

In capacitively coupled plasma (CCP) sources, electrons are present even around 14 eV, exhibiting an electron energy distribution distinct from that for ICP (Ref. 2).

Point ②

As a result, conventional ICP sources suffer from a shortage of electrons in the energy range required for nitrogen molecule dissociation (Ref. 2).

Hybrid Plasma Source Based on Plasma Science

A unique hybrid plasma source has been developed by integrating the respective advantages of ICP and CCP.

Point ③

This plasma source is novel in that it combines the advantages of both ICP and CCP, representing a new approach beyond conventional plasma generation technology.

Quantitative Evaluation of Radical Generation

The ability of the newly developed hybrid plasma source to generate atomic radicals was quantitatively evaluated and compared with that of conventional plasma sources. Because radicals are neutral species and difficult to measure, quantitative values are generally not provided in standard product specifications. In this evaluation, the density of atomic nitrogen radicals was quantitatively measured using a dedicated diagnostic system based on absorption spectroscopy (Refs. 3, 4).

Absorption spectroscopy: A technique for determining atomic density by measuring absorption at species-specific wavelengths.

Point ④

This is the first plasma source in which atomic radicals critical for thin-film growth have been quantitatively measured.

Verification of Plasma Source Characteristics Based on Measured Radical Density

Through direct measurements of the radical density, the characteristics of different plasma sources were compared.

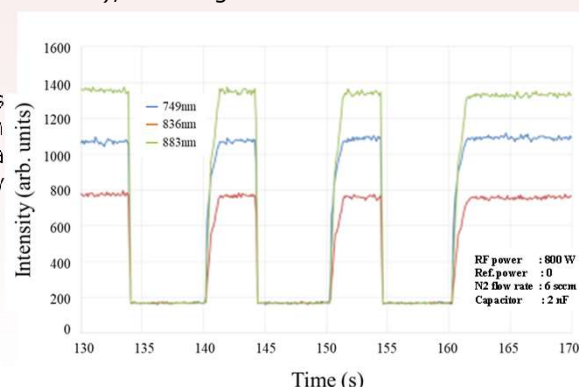
- HDRS: Stable discharge even under high-pressure conditions
- CCP characteristics: Electrons are generated under high-pressure conditions
- Conventional ICP sources: At increased nitrogen flow rates (greater than ~ 2 sccm), discharge and measurement become difficult in ICP systems

Point ⑤

On the basis of direct measurements, the nitrogen radical density was confirmed to be substantially higher than that for conventional ICP sources. In addition, users have reported that the GaN growth rate increased by nearly a factor of two when this radical source was used, with better crystal quality obtained (Refs. 5-10).

Point ⑥

Because plasma stabilization occurs almost instantaneously, the supply and termination of radicals can be controlled with high temporal precision. This capability is expected to enable the realization of migration-enhanced epitaxy (MEE) (Ref. 11), which has been proposed as an effective approach to suppress crystalline mismatch.



Time-dependence of plasma intensity in HDRS

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