Industrial Applications at the NSRRC (2024–2025)

Through advanced synchrotron capabilities, industry-dedicated infrastructure, expert scientific partnerships, and flexible industrial access models, the NSRRC continues to accelerate industrial innovation and strengthen Taiwan's global technological competitiveness.

Strategic Context & Vision

Taiwan's leadership in high-technology manufacturing depends on advanced analytical infrastructure to support rapid innovation. In this context, the NSRRC has strengthened its industrial engagement strategy over the past decade, positioning itself as a national R&D partner rather than solely an academic research facility. The establishment of the Industry Application Division marked a significant step toward integrating industrial applications within the NSRRC's mission.

By serving as a structured interface between synchrotron science and enterprise R&D teams, the NSRRC enables industry to access advanced characterization tools to address complex technical challenges. The focus includes semiconductors, energy storage, advanced materials, metallurgy, biomedical technologies, and precision devices—sectors central to Taiwan's economic development and global competitiveness.

In recognition of sustained efforts in strategic industrial engagement and innovation management, the NSRRC received the 2024 Technology Management Award (Academic and Research Team Category) from the Chinese Society for Management of Technology (中華民國科技管理獎). The award acknowledges the division's exceptional planning, promotion, and execution of the Industrial Application Service Platforms for Synchrotron Radiation Facility.

Industrial Access and Partnership Models

The NSRRC offers several engagement pathways tailored to industrial needs. Companies can access beamlines under proprietary arrangements that ensure confidentiality and intellectual property protection. Collaborative frameworks also enable beamline scientists and company engineers to jointly design experimental strategies and analytical methodologies.

Each major industrial sector is supported by dedicated project managers who cultivate long-term working relationships with corporate R&D divisions. This sector-specific approach enables the NSRRC to anticipate recurring technical challenges and provide targeted solutions efficiently. Beyond direct corporate engagement, the NSRRC collaborates with universities and analytical service providers to further expand industrial access to synchrotron capabilities.

Infrastructure Enabling Industrial Innovation

The NSRRC operates two synchrotron facilities, the Taiwan Light Source (TLS) and the Taiwan Photon Source (TPS), offering complementary high-brilliance X-ray capabilities. These facilities support advanced diffraction, scattering, spectroscopy, and imaging techniques essential for structural and chemical analysis across a wide range of materials systems.

The industrially dedicated **TLS 07A1** beamline has consistently addressed the majority (approximately 70%) of industrial analytical demands through integrated X-ray diffraction (XRD), X-ray scattering (XAS), and wide-angle X-ray scattering (WAXS) capabilities. As operational emphasis transitions toward TPS, a next-generation industrial beamline, **TPS 12A**, is being developed to incorporate advanced automation, high-throughput workflows, and AI-assisted data acquisition and analysis. This upgrade demonstrates the NSRRC's commitment to improving responsiveness, reproducibility, and operational efficiency for industrial users.

Accelerating Industrial Decision-Making

A key advantage of synchrotron-based analysis is its speed, sensitivity, and reliability. Compared with conventional laboratory instruments, synchrotron radiation enables rapid acquisition of statistically robust data, even for complex or low-signal systems.

This capability leads to shorter development cycles. Materials can be screened efficiently, structural transformations monitored in real time, and failure mechanisms identified at early stages. As a result, companies can make informed design and process decisions more quickly, reducing technical risk and optimizing resource allocation.

Key Industrial Domains and Impacts

1. Semiconductor Technologies

Taiwan's semiconductor ecosystem benefits significantly from its close geographic and technical integration with the NSRRC. Long-term collaborations have enabled semiconductor manufacturers to apply advanced techniques such as grazing-incidence diffraction and X-ray absorption spectroscopy to investigate nanoscale interfaces and ultra-thin dielectric layers.

Synchrotron-enabled diagnostics have clarified defect-related leakage mechanisms in high-k materials, contributing to performance optimization in advanced nano-scale chips. These sustained partnerships demonstrate how large-scale research infrastructure can be effectively embedded within industrial innovation pipelines.

In addition, synchrotron-based metrology has supported domestic development of extreme ultraviolet lithography-related materials and processes, providing benchmark characterization tools that reinforce Taiwan's leadership in advanced semiconductor manufacturing.

2. Energy Storage and Lithium-Ion Batteries

Energy storage is another area of ongoing industrial collaboration. *Operando* and *in situ* X-ray techniques have been used to monitor electrochemical processes in lithium-ion batteries, revealing phase transitions and interfacial evolution during charge–discharge cycling.

These structural insights have guided electrode material optimization, enhanced performance stability and supported patented technologies. Advanced battery systems informed by synchrotron analysis have been deployed in grid-scale energy storage and high-performance electric vehicles, demonstrating the practical impact of photon science on clean energy technologies.

3. Polymers and Carbon Fiber Materials

For polymer and fiber industries, small-angle X-ray scattering (SAXS) provides a critical understanding of mesoscale structural evolution. By analyzing crystallization kinetics and hierarchical organization, companies have enhanced the mechanical performance of recycled polymer-based materials, enabling entry into high-value international markets.

In carbon fiber development, micro-beam techniques have revealed structural heterogeneity within individual filaments, linking nanoscale architecture to macroscopic mechanical strength. These findings inform process optimization and support the scaling of production lines for aerospace-grade applications.

4. Sustainable Metallurgy

In response to carbon neutrality goals, the NSRRC participates in hydrogen-based metallurgy initiatives to reduce emissions in steel production. A high temperature (1800 °C), environmentally controlled experimental platform enables real-time *in situ* synchrotron radiation analysis using XRD, XAS, and X-ray imaging techniques to monitor the structural and chemical evolution during reduction reactions.

This infrastructure supports the development of cleaner and more sustainable metallurgical technologies, aligning with

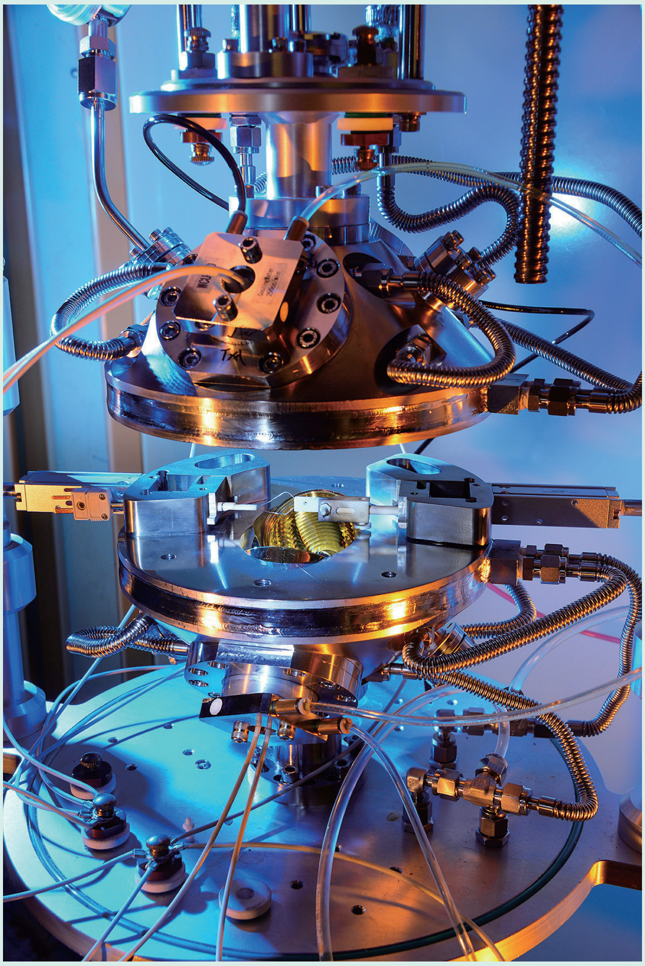

Fig. 1: A movable high-temperature (up to 1800 °C) *in situ* synchrotron platform adaptable to multiple beamlines, enabling real-time XRD, XAS, and X-ray imaging for hydrogen-based steelmaking research and low-carbon metallurgical technologies aligned with Taiwan's 2050 net-zero target.

Taiwan's national net-zero carbon target for 2050.

5. Biomedical and Micro-Device Innovation

In the biomedical sector, integrated analytical platforms that combine fractionation techniques, light scattering, and X-ray methods enable detailed structural characterization of nanoparticle-based drug delivery systems. These insights support optimization of formulations for vaccines and therapeutic carriers.

The number of pharmaceutical users increased significantly in 2024 and 2025, driven by the adaptation of the bio-SAXS beamline **TPS 13A** for studies on drug delivery and carrier systems.

Technology transfer has also extended to microfabrication. Deep X-ray lithography processes developed at the NSRRC have enabled the production of compact spectrometer chips for portable diagnostics. This spectrometer chip technology has received national innovation awards and demonstrates strong commercial scalability, highlighting how synchrotron-based fabrication can catalyze start-up growth and AI-enabled healthcare solutions.

6. Accelerator Technologies

The extensive experience accumulated by the NSRRC's accelerator divisions has enabled the provision of consultancy services to domestic hospitals and other synchrotron facilities in the design of high-quality magnet systems and vacuum infrastructure. In 2025, revenue from accelerator-related technologies contributed approximately 20% of total industrial income, reflecting the broader technological impact of the NSRRC beyond beamline applications.

Fig. 2: The mini-workshop on Analytical Advantages of Synchrotron Radiation Sources in Drug Delivery, held during the NSRRC 2025 User's Meeting. It attracted participants from academia and industry, highlighting NSRRC's bridging role.

Expertise as a Core Strength

Beyond advanced instrumentation, the NSRRC's scientific personnel are crucial to industrial success. Beamline scientists empower with experiment design, methodology development, and data interpretation, ensuring that analytical results become actionable industrial knowledge. This collaborative model builds trust, increases efficiency and supports long-term industrial partnerships.

Expanding Industrial Ecosystems

Industrial engagement has evolved from single-experiment interactions to programmatic, multi-year collaborations. The number of industrial commission cases increased from 39 in 2024 to 52 in 2025, reflecting rising annual revenue.

To further strengthen industry engagement and knowledge exchange, dedicated workshops were organized during the NSRRC 2025 User's Meeting, including the Extreme Ultraviolet Technology and Applications Workshop and a mini-workshop on the Analytical Advantages of Synchrotron Radiation Sources in Drug Delivery. In addition, "Propelled Toward Vega: Accelerating the Synthetic Fiber Industry's Next Step," presented at the Taipei Innotech Expo in October 2025, engaged approximately 100 visitors, including industry partners and the public. Together, these events attracted participants from industry, academia, and the public, reinforcing NSRRC's role as a bridge between scientific research and industrial implementation.

Outlook

The upcoming industrial beamline at the TPS, designed with integrated automation and AI-driven data workflows, marks the next milestone in enhancing industrial service capacity. Through ongoing infrastructure upgrades, strengthened collaborative networks, and expanded industry-focused support, the NSRRC is well positioned to deepen its impact on Taiwan's innovation ecosystem in the years ahead. (Reported by Mau-Tsu Tang)

Fig. 3: Presentation of "Propelled Toward Vega: Accelerating the Synthetic Fiber Industry's Next Step" at the October 2025 Taipei Innotech Expo. It attracted about 100 visitors, including industry partners and members of the public.