A Case Study of Research and Development in the Field of Semiconductor and Medical Device Components Enabled by Advanced Materials Processing in Gangwon

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Introduction

- **This work presents the outcomes of a project that leverages Gangwon's advanced materials and processing capabilities to localize key components for the semiconductor and medical device sectors.**
- **For semiconductors, we developed a novel chemical–mechanical polishing (CMP) pad conditioner using silicon nitride(Si_3N_4).**
- **The conditioner resulted from optimizing powder composition, milling methods, spray drying, cold isostatic pressing CIP), debinding, and sintering.**

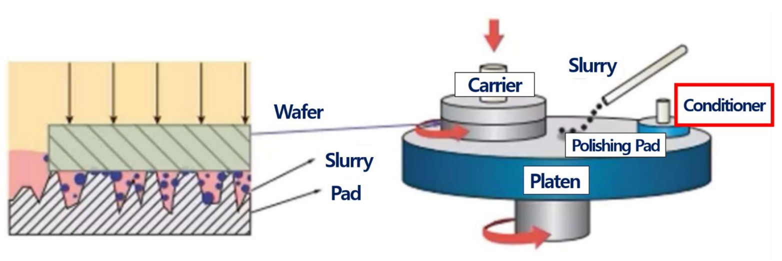

Fig. 1. Schematic diagram of CMP process and equipment.

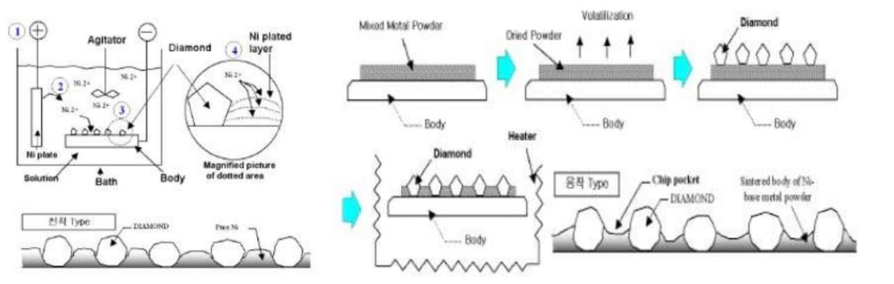

Fig. 2. Fabrication process of CMP pad conditioner: electroplating (left) and brazing Process (right).

- **For medical devices, we designed patient-specific radiotherapy shielding blocks from non-toxic, lead-free materials. Design parameters were optimized via Monte Carlo simulation, and prototypes were fabricated by CNC machining and 3D printing.**
- **These results demonstrate that Gangwon's advanced materials technologies are applicable to both semiconductors and medical devices, with strong potential for domestic localization.**

Fig. 3. Types of ancillary devices used in radiation therapy.

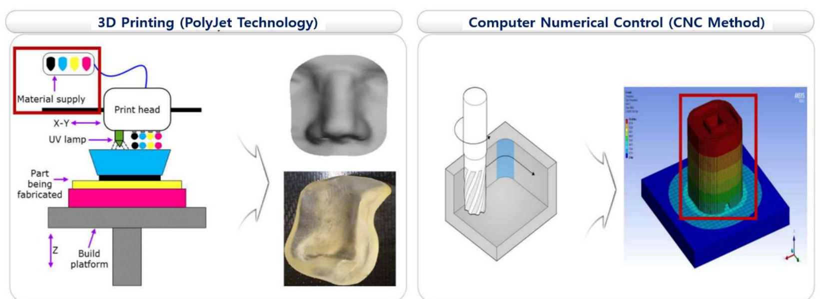

Fig. 4. Fabrication process and sample of radiation therapy ancillary devices using automated process.

Research Method

- **Project purpose: Rapid support for R&D projects that address regional science and technology needs.**
- **Support areas: Gangwon's core industries (bio-healthcare, semiconductors, future mobility, clean energy, food tech, defense industry, climate tech., etc.).**
- **Support scale: Approximately 10 projects; total budget of KRW 746 million; per project KRW 60–80 million.**
- **Project period: April–November (8 months).**
- **Eligibility: Research performers based in Gangwon.**
- **Project procedure**

Announcement and submission — early February	GISTEP
→ Project briefing — mid-February	GISTEP
→ On-site survey — late February	GISTEP
↓ Midterm review (August) and final evaluation (December)	GISTEP
← Project funding and execution — April–November	Research performers
← Selection evaluation — late March	GISTEP

Results and Discussion

Semiconductor manufacturing equipment

- **Si_3N_4-based CMP pad conditioner: We secured manufacturing technology for a Si_3N_4 CMP pad-conditioner material with a refined microstructure and enhanced density and strength, and we established mass-production standardization for molding, CIP, debinding, and sintering.**
- **Process optimization: Building on the composition identified in prior research, we quantified changes in sintered density as a function of dispersant and binder contents, and evaluated the effect of feed amount on raw-powder spheroidization to determine optimal conditions.**

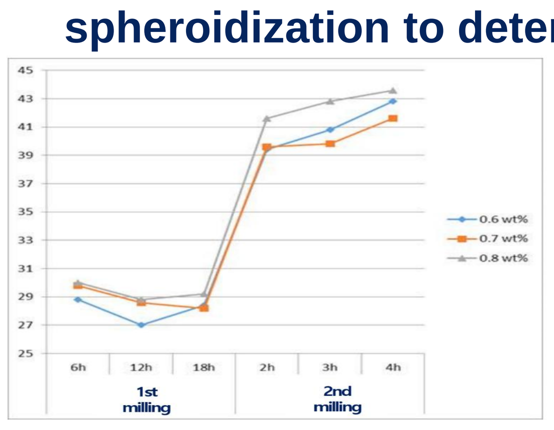

Fig. 5. Viscosity as a function of dispersant content and milling time (unit: cP).

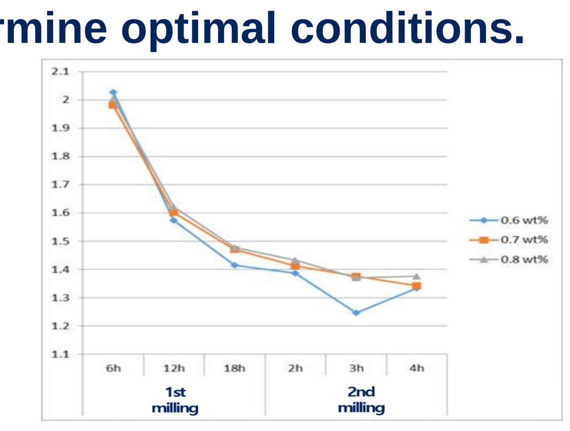

Fig. 6. Particle size as a function of dispersant content and milling time (unit: μm).

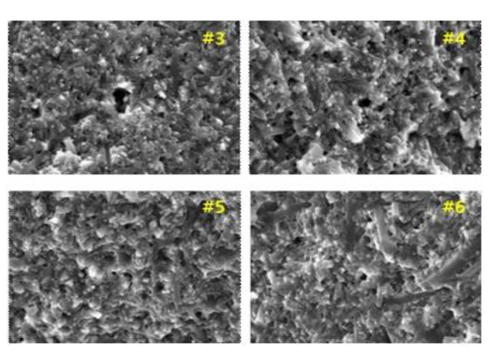

Fig. 7. Microstructure of fracture surfaces in sintered Si_3N_4 specimens with varying liquid-phase sintering additives

Results and Discussion

- **To achieve optimal sintering conditions for Si3N4 material with the goal of reducing porosity, an experiment determined that holding the temperature at 1,780°C for 240 minutes resulted in an optimal average density of 98.27%.**

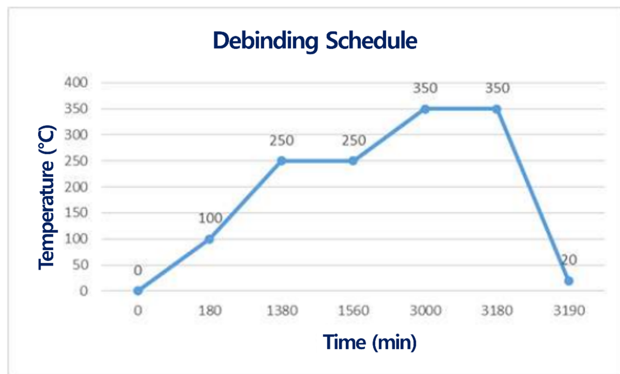

Fig. 8. Conventional debinding process schedule for Si_3N_4.

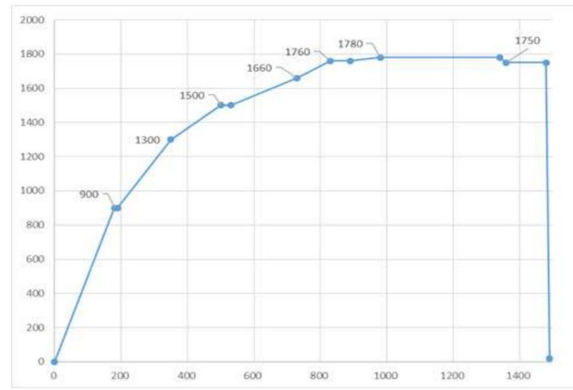

Fig. 9. Conventional sintering process schedule for Si_3N_4.

Fig. 10. Prototype of a debound body produced using the optimized debinding process for Si_3N_4.

- **By optimizing raw-material composition, enhancing formability, and adopting atmospheric sintering, we achieved mass-production feasibility and cost competitiveness, enabling the fabrication of a wide range of ceramic components for semiconductor manufacturing equipment.**

Medical Device

- **Using Monte Carlo simulations, we precisely reproduced the irradiation conditions of a medical linear accelerator(Varian Clinac iX), achieving a mean error of <1% relative to measurements and thereby ensuring the reliability of the computational model.**
- **Patient-specific thermoplastic boluses(PLA, TPU) fabricated via 3D printing showed a mean dose deviation within 2–3% compared with commercial gel-type boluses, supporting clinical applicability.**
- **For metallic shielding blocks, non-toxic materials—stainless steel, brass, and copper—achieved attenuation ≥95%, comparable to or better than conventional lead alloys.**
- **The research outcomes established both the technical and translational foundations for patient-customized radiotherapy accessories, as evidenced by publications in SCI-indexed journals, patent applications, and conference presentations.**

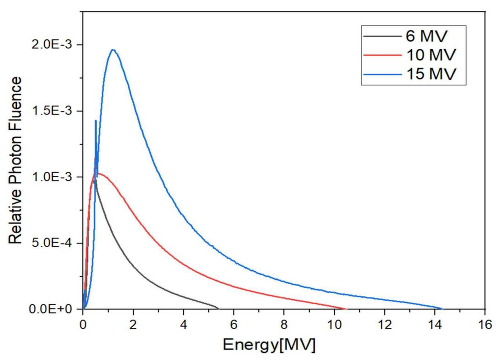

Fig. 11. Energy fluence spectra for photon beam energies.

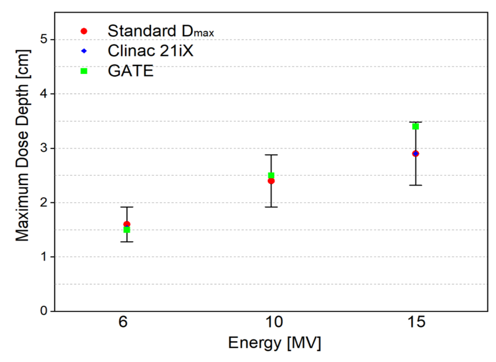

Fig. 12. Errors at depth of maximum dose(d_{max}) relative to Clinac iX specifications.

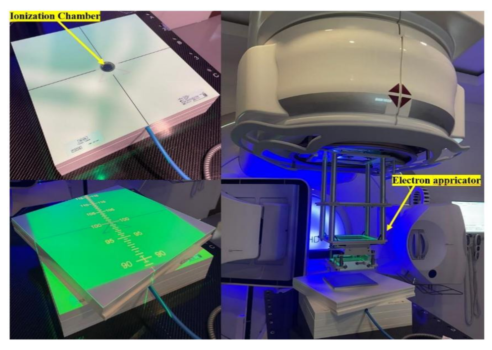

Fig. 13. Experimental setup for measuring radiation shielding ratios.

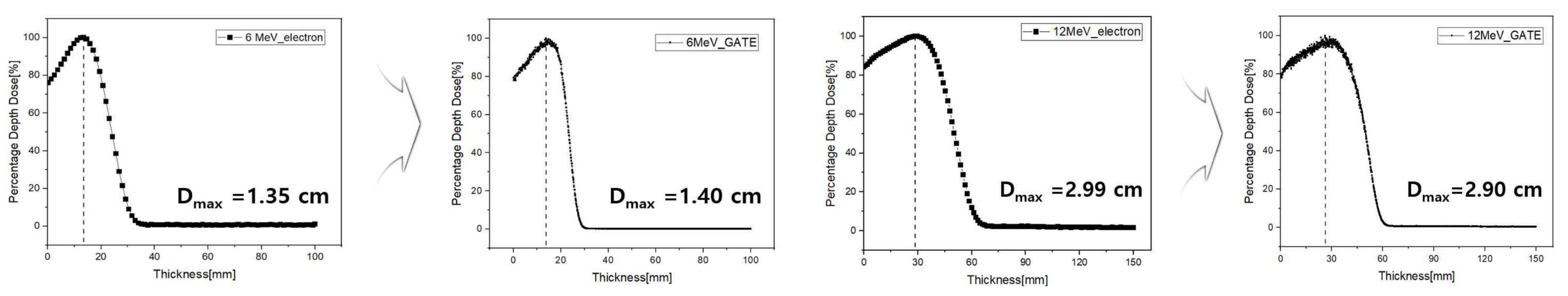

Fig. 14. Percentage depth-dose(PDD) curves for 6- and 12-MeV electron beams in a solid-water.

Conclusion

Semiconductor manufacturing equipment

- **The Si_3N_4-based CMP pad-conditioner technology enables expansion into large-format silicon-nitride ceramic components, opening new industrial market opportunities.**
- **In particular, atmospheric-pressure sintering facilitates scalable mass production with minimal shape constraints; as density and strength continue to improve under atmospheric conditions, the range of applications will further broaden.**

Medical Device

- **The work is expected to invigorate the relatively small domestic market for radiotherapy accessories and deliver R&D outcomes competitive with foreign technologies.**
- **The results provide foundational data across key variables for future studies and offer a pathway to extend into cutting-edge modalities such as proton and heavy-ion therapy.**

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