【Grant-in-Aid for Scientific Research (S)】

Broad Section C

Title of Project : Realization of completely distortion-free processing by plasma nano-manufacturing process and exploration of its theory

YAMAMURA Kazuya
(Osaka University, Graduate School of Engineering, Professor)

Research Project Number : 21H05005 Researcher Number : 60240074
Term of Project : FY2021-2025 Budget Allocation : 144,900 Thousand Yen
Keyword : Plasma, Ultraprecision machining, Widegap semiconductor, Difficult-to-machine materials, Slurryless polishing

【Purpose and Background of the Research】

Wide-gap semiconductor materials such as SiC, GaN, and diamond are promising materials for high-performance energy-saving power devices to realize a low-carbon society. In addition, fine ceramic materials such as aluminum nitride (AlN) substrates and sintered SiC are indispensable materials for epitaxial growth of GaN and molds for high-precision glass lenses. However, since all of them are highly hard, brittle, and chemically inert difficult-to-machine materials, the processing efficiency is low by conventional chemical mechanical polishing (CMP). In addition, since CMP uses a polishing solution called a slurry, which is a mixture of abrasive grains and a chemical solution, it has the disadvantages of high environmental load and high cost. On the other hand, if the removal efficiency is improved by a mechanical method, the microscopic shape and material properties deteriorate due to scratches, shedding, and an increase in the damaged layer, which deteriorate the electronic and mechanical characteristics of materials. Therefore, in the field of advanced materials, it is desired to develop a new processing method capable of obtaining a completely strain-free surface.

In this research, we will construct a "plasma nanomanufacturing process" consisting of shape creation by precision high-speed dry etching and high-efficiency strain-free polishing using surface modification by plasma irradiation. In addition, we will realize an innovative high-efficiency, completely strain-free manufacturing process that does not use slurry for hard and brittle functional materials, and explore its theory.

【Research Methods】

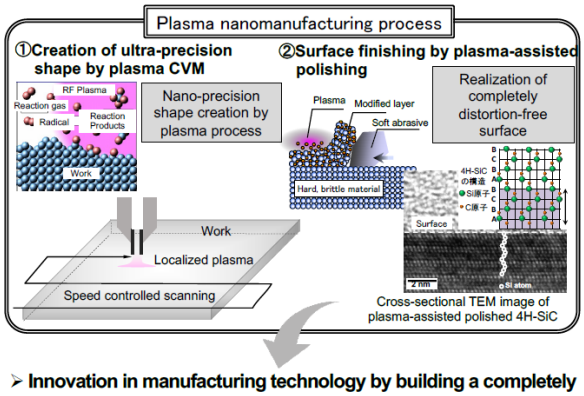
In this research, in order to create a new academic system of manufacturing based on "plasma nanomanufacturing process" and to achieve the purpose of providing it for industrial application, "nano-precision shape creation process by numerically controlled scanning of local plasma" and "slurry-less completely distortion-free polishing process by assisting plasma irradiation" will be developed. Specifically, the following items are executed.

- Development and performance evaluation of numerically controlled plasma processing equipment for free-form surfaces.
- Algorithm optimization in numerically controlled machining simulation.
- Development of plasma-assisted polishing equipment installed with a hybrid processing head that combines a plasma generation electrode and a polishing grinding stone.
- Development of continuous polishing process applying plasma dress in plasma-assisted polishing.
- Elucidation of smoothing mechanism and optimization of process parameters in plasma-assisted polishing.

Through the above development, we will build a completely strain-free manufacturing system based on the plasma process, which innovates conventional machining technology.

【Expected Research Achievements and Scientific Significance】

We will newly construct a "plasma nano-manufacturing process" that combines plasma CVM (Chemical Vaporization Machining) that enables nano-precision shape creation and plasma-assisted polishing (PAP) that can obtain smooth surfaces on an atomic order. Therefore, it is expected to establish an innovative high-efficiency damage-free manufacturing process that breaks the limits of the machining process that follows the conventional copying principle.



- **Innovation in manufacturing technology by building a completely distortion-free processing system**
- **Creation of a new academic field named "Plasma Nano Manufacturing Science"**

Fig. 1 Construction of plasma nano-manufacturing

【Publications Relevant to the Project】

- R. Sun, X. Yang, K. Arima, K. Kawai, K. Yamamura, High-quality plasma-assisted polishing of aluminum nitride ceramic, CIRP Annals, 69, 301-304 (2020).
- R. Sun, X. Yang, Y. Ohkubo, K. Endo, K. Yamamura, Optimization of gas composition used in plasma chemical vaporization machining for figuring of reaction-sintered silicon carbide with low surface roughness, Scientific Reports, 8, 2376 (2018).

【Homepage Address and Other Contact Information】

http://www-nms.prec.eng.osaka-u.ac.jp/en/