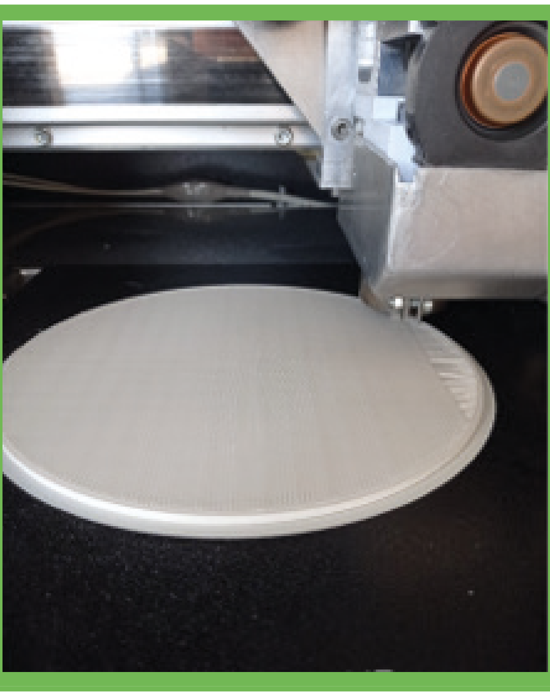
Advanced Manufacturing of next generation of Multi-material Ceramic Components for semiconductor industry

Abstract:

Today's semiconductor industry uses ceramic materials such as Al□O□, AIN, Si□N□, and SiC for wafer-processing components, including Electrostatic Chucks (ESCs). These ceramics are typically produced by hot pressing or sintering. Plasma etching applications require materials that combine high plasma resistance with excellent electrical performance. This project develops next-generation ESC ceramics using advanced shaping and rapid densification. Controlled grain growth improves plasma resistance. The goal is an end-to-end process for 8-inch and 12-inch Al□O□, AIN, and SiC ESCs with enhanced cooling and durability.



Countries involved

Application sectors
Industrial components, Semiconductor

Research and innovation domains
Advanced manufacturing processes, Smart & adaptative manufacturing systems, Sustainable manufacturing, Customer-based manufacturing

Total cost in M€ (millions)
1.8 M€

Starting date
01/09/2021

Duration (in months)
36 months

Project leader
RHP Technology GmbH

Project participans
Temnest

RATIONALE OF THE PROJECT

Electrostatic chucks (ESCs) are critical components in semiconductor manufacturing, used for adsorbing and thermally controlling wafers in plasma and vacuum processes. Modern ESCs must ensure wafer planarity, high reliability, reduced particle contamination, and effective cooling, while withstanding harsh chamber conditions caused by higher RF power and smaller feature sizes. Current ceramic, polymer, and coated ESCs face limitations in erosion resistance (40 μm today), electrical resistivity (Al□O□ ~40 kV/mm, SiC ~10^6 Ω·cm), thermal conductivity (<140 W/m·K for AIN), and manufacturing tolerances, particularly for multilayer structures below 2 mm thickness where electrode position accuracy <0.05 mm is required. The MMCC project addresses these challenges by developing ESCs with high-purity materials (>99.99%), controlled grain size (<1 μm), and improved properties: erosion resistance <20 μm, hardness 20 GPa, AIN thermal conductivity >200 W/m·K, and SiC resistivity >10^{10} Ω·cm. Key innovations include advanced 3D shaping and multi-material printing for precise green body formation, rapid hot pressing for densification in <4–6 hours, and integration of high-performance composites with 2–3× higher thermal conductivity than aluminum. This approach enables more uniform etching, reduced processing steps, and more cost-effective manufacturing, strengthening European ESC production for future high-power, small-pitch semiconductor devices.

TECHNOLOGICAL INNOVATION, ACHIEVEMENTS AND RESULTS

The MMCC project achieved significant technological innovation through the development of advanced 12-inch Al_2O_3 and 8-inch AlN electrostatic chucks (ESCs) using advanced shaping, 3D printing, and hot-pressing techniques. Key achievements include the optimization of electrical resistivity in both conductive and non-conductive layers (used for charge application) and the non-conductive layer (acting as a dielectric) on the ESC surface making the ESCs more suitable for high-precision and long-lasting use in the semiconductor industry. Additionally, the upscaling of 8-inch Al-SiC cooling plates to Ø400mm demonstrated high relative density (up to 99.1%), homogeneous microstructure, and excellent thermal conductivity (>230 W/m·K), with superior pressure resistance on bonding area (30 bar). Collectively, these innovations highlight advancements in material precision, scalability, and operational reliability for semiconductor applications.

MARKET POTENTIAL

The global electrostatic chuck (ESC) market was valued at $225 million in 2020, with a projected CAGR of 5.4% to 2025, led by Asia-Pacific (39%), the US (27%), and Europe (16%). Major players, primarily in Japan, include Shinko, NGK, Kyocera, Coorstek, and Sumitomo-Osaka, often supplying toolmakers such as LAM, AMAT, and TEL. The growing demand for 8” and 12” wafer fabs from TSMC, Samsung, Hynix, Intel, and Infineon drives the need for high-performance ESCs with precise electrical, thermal, and mechanical properties. TEMNEST’s 20-year experience in ESC design, manufacturing, and refurbishing provides direct market access for early deployment of 8” ESCs in Asian and US fabs, with 12” ESCs integrated into refurbishment services and new tool applications. RHP complement this by supplying 8” ESCs in Europe.

IMPACT POTENTIAL

The project strengthens Europe’s position in ESC manufacturing, a market currently dominated by non-European companies. By combining RHP’s expertise in advanced material processing with TEMNEST’s know-how in ESC integration and market access. Advanced techniques, including 3D shaping and Rapid Hot Pressing, enhance yield, durability, and efficiency, enabling the production of next-generation semiconductor devices. This approach directly supports the SMART goals of innovative, high-performance, and “SMART Manufacturing.

AlN (ESC)8 inch

Al_2O_3 (ESC) 8 inch

Al-SiC composite as Advanced Cooling solutions for ESC