Silicon nitride (Si₃N₄) ceramics have been used in automotive, electronic, medical and aerospace industries, due to the unique combination of mechanical and thermomechanical properties. Significant improvements have been made in the processing routes of these ceramics. However, the strong covalent bonding and low self-diffusivity make the synthesis and processing of silicon nitride ceramics challenging.

The present research work aims at the fabrication of silicon nitride ceramics using a conventional sintering method via a liquid phase sintering mechanism. The process of densification and phase transformation for silicon nitride in liquid phase sintering requires sintering additives. The concentration of these sintering additives and their composition affect the mechanical, tribological, dielectric and thermomechanical properties like toughness, wear resistance, creep, thermal conductivity and strength at room as well as elevated temperatures during liquid phase sintering. Different types of nanosized sintering additives have been utilized in the present study for fabricating the silicon nitride ceramics. The effect of additives compositions, additives concentration and sintering temperature on the densification, phase transformation, microstructure and mechanical properties of sintered Si₃N₄ has been investigated.

The relative densities of sintered specimens doped with metal oxide nanosized sintering additives (MgO-A₂O₃) were found to be more than 93 %. The sintered samples doped with 4MgO-4Al₂O₃ exhibited the highest relative density (~ 97 %). The rare earth oxides (RE₂O₃) were found ineffective in improving the density of the sintered samples. The densities of sintered samples with 4MgO-4Al₂O₃-5RE₂O₃ was more than 93 % of the theoretical density. The process of α→β phase transformation was found to be dependent on the sintering temperature, additives types and composition. The microstructure of the samples sintered at 1600 °C with 4MgO-4Al₂O₃-5RE₂O₃ showed homogeneous distribution α-Si₃N₄ and β-Si₃N₄ grains in the ceramic matrix. The samples sintered at 1700 °C exhibited only elongated β-Si₃N₄ grains and produced a specific interlocking microstructure which enhanced the fracture toughness of the sintered ceramics. The mechanical properties of sintered ceramics changed with the RE₂O₃ compositions. The sintered samples doped with 4MgO-4Al₂O₃-5Y₂O₃ showed highest hardness, whereas samples doped with 4MgO-4Al₂O₃-5La₂O₃ exhibited highest fracture toughness. The increasing amount of Y₂O₃ in 4MgO-4Al₂O₃-5(Y₂O₃/La₂O₃) increased the hardness of sintered ceramics whereas reduced the fracture toughness. The overall fracture toughness and hardness of the sintered samples doped with compound mixture of Y₂O₃ and La₂O₃ were better than the sole RE₂O₃ doped samples.

The advancement of fabrication technologies enable production of ceramic components close to the final one, but in order to obtain the desired tolerances, dimensional accuracy and required surface finish, some machining process is required. Among all the machining processes, diamond grinding is the most suitable and most versatile process for achieving high precision and quality ceramic products. However, high hardness, strength and poor thermal conductivity of these ceramics make the grinding process extremely difficult. Also, the cracks generated during the grinding process have detrimental effect on the properties of the ground component. The widespread utilization of Si₃N₄ ceramics requires a cost-effective finishing operation without compromising any degradation in their properties. Hence this study also focusses on the grindability aspect of silicon nitride using resin bonded diamond wheel under different
cutting environments including flood and minimum quantity lubrication (MQL) with deionized water (DI-water) and nanofluids. Before evaluating the grindability aspect under different environments, preliminary experiments have been conducted under dry condition to understand material removal behaviour.

The present work explores the application of oxide-based (Al₂O₃, ZnO), carbide-based (B₄C) and lamellar structure-based (graphite, MoS₂, h-BN and WS₂) nanoparticles dispersed in DI-water under MQL mode grinding of silicon nitride ceramics. The grinding characteristics have been studied in terms of grinding forces, surface roughness and ground surface morphology, chip morphology and sub-surface damages. The lamellar structure-based nanoparticles based nanofluids outperformed oxide and carbide nanoparticles-based nanofluids during grinding of Si₃N₄ ceramics. Based on satisfactory grinding performance by the mono nanoparticles based nanofluids, the hybrid nanofluids have been prepared, and their grinding performance has been evaluated. The MoS₂ and WS₂ nanoparticles-based hybrid nanofluid has been found to be an effective cutting fluid for enhancing the grinding performance of Si₃N₄ ceramics. The optimized parameters have been determined using the desirability function approach for the grinding of Si₃N₄ under MoS₂-WS₂ hybrid nanofluid with surface roughness and chipping layer depth as the constraints. In the end, the confirmation test results have been validated by conducting the experiments.

Keywords: Silicon nitride, pressureless sintering, grinding, hybrid nanofluids, chipping layer.