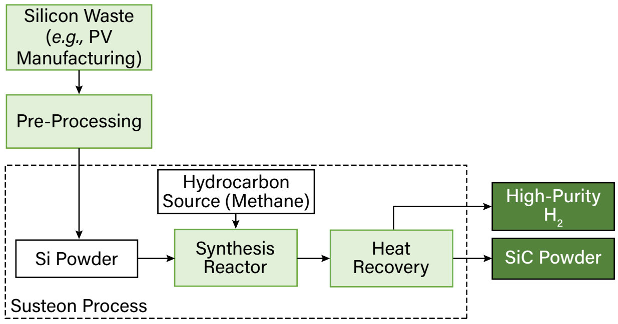
# A Novel, Low-Cost Sustainable Process to Produce Silicon Carbide

Silicon carbide (SiC) is a versatile non-oxide ceramic that has gained considerable interest for a range of applications. Its unique physical and chemical properties include relatively low thermal expansion, high force-to-weight ratio, high thermal conductivity, hardness, resistance to abrasion and corrosion, and most importantly, sustained elastic resistance at temperatures up to 1,650°C. These properties have led to its use as an advanced ceramic component for the defense, steel manufacturing, chemical, aerospace, and automotive industries. In addition, its electrical properties, in combination with its mechanical and thermal properties, make it an excellent semiconductor for high-voltage and high-temperature power electronic systems, such as electric vehicle powertrains and 5G power transmitters.

SiC is conventionally produced via the Acheson process, invented in 1893. The Acheson process reacts petroleum coke and high-purity crystalline silica (quartz $SiO_2$) in an open-atmosphere 30-kA electrical resistance furnace. This manufacturing process produces toxic gases (predominantly SOx, NOx, and CO) and releases heavy metal particles that present environmental and health risks. Further, the SiC ingot product requires additional processing, including chemical purification and grinding to a particle size of 1–10 µm; the processing and handling of these particles have been reported to cause respiratory damage and lung cancer.

Due to these emissions and safety risks, the U.S. produces only about 4% of the global demand for SiC. Yet SiC is a critical material for the production of components and devices used in U.S. national security, semiconductor, and clean energy technologies. With the U.S. SiC market expected to increase from $200 million in 2020 to over $600 million in 2030, developing an innovative and efficient SiC production process that reduces environmental emissions and safety risks and allows for domestic manufacturing is necessary to meet the growing demand for this critical material.

While working on producing hydrogen from methane pyrolysis, researchers at Susteon, a small business in North Carolina's Research Triangle, serendipitously discovered that Si powder works effectively as a catalyst to convert methane into high-purity hydrogen. Their initial hypothesis was that carbon released during the methane pyrolysis step is deposited on the Si particle and can be recovered by chemical/mechanical means. However, the analysis of solid particles found that the SiC phase forms by reaction of Si with carbon under the pyrolysis conditions. This discovery led to funding from the U.S. National Science Foundation (NSF) to develop a process to convert low-cost natural gas and industrial silicon waste powder into a high-purity SiC powder, while producing hydrogen ($H_2$) as a clean, salable byproduct.




▲ Susteon's silicon carbide synthesis process uses recycled silicon waste material to produce high-purity silicon carbide and hydrogen.

Compared to today's SiC production, Susteon's process has potential to reduce $CO_2$ emissions by 75% and eliminate the release of toxic SOx, NOx, and heavy metals at very low production cost. Once successfully developed, the process can produce a high-purity, microsized green SiC (*i.e.,* β-SiC polytype) for $10 to $20 per kg, less than half the cost of the current state-of-the-art technology. The use of recycled waste Si and fugitive methane or biogas can further reduce the cost and greenhouse gas emissions from SiC production.

Susteon has designed and built a bench-scale, proof-of-concept reactor to evaluate the feasibility of the process and generate key process design information, including the reactor operating conditions, to achieve the requisite SiC product purity. A key challenge is to provide controlled heating at scale. The company plans to use this information to design and build a pilot-scale prototype to produce up to 100 kg/day of SiC. Several industrial partners have expressed interest in the SiC produced from this process as it provides a new green pathway for cost-effective and domestic manufacturing of low-emissions SiC.

Rakesh Kapoor, currently a Principal at Materials Outovation and a former Director of Engineered Ceramics at Saint-Gobain, says, "I believe this synthesis route could provide high-purity SiC for high-end ceramics applications at much lower carbon footprint than the classical Acheson process and potentially at lower cost." CEP

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