RESEARCH NEWS

Ceramics recycling

Energy-efficient and low in emissions — silicon carbide recycling with RECOSiC©

Silicon carbide is a popular industrial material for many applications. The extremely hard, heat-resistant material is used for refractory components and semiconductors, for instance. But its production is energy-intensive and emits a lot of carbon dioxide, as well as producing large amounts of by-products and waste products. Researchers at Fraunhofer Institute for Ceramic Technologies and Systems IKTS have developed RECOSiC©, an especially environmentally friendly recycling process that turns these by-products and waste products back into high-quality silicon carbide. This new process improves yields and also reduces the dependency on suppliers of raw materials.

Due to its tremendous hardness — nearly as hard as diamond — and heat resistance, the industrial material silicon carbide (chemical formula: SiC) is a sought-after commodity in the industry sector. SiC has applications in the chemical industry, as technical ceramics and for refractories, and is also used in semiconductors. It is produced using the Acheson process, in which quartz sand and petrol coke are heated in a cylindrical furnace to around 2,500 °C. The resulting carbothermic reduction produces silicon carbide as its end product. The process is not complicated but produces a great deal of CO_2: around 2.4 tons of the greenhouse gas are released for 1 ton of SiC from the carbothermic reduction alone. This is in addition to the enormous power consumption of 7.15 MWh/t, which is required to run the furnace for days. This releases another 1.8 tons of CO_2 for each ton of SiC.

"The Acheson process is nearly 130 years old and is one of the classic, dirty industrial processes that are no longer in step with our times," explains Jörg Adler, department head for non-oxide ceramics at Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden. His team and their industry partner ESK-SiC GmbH have now developed a method for recycling the resulting waste and by-products. RECOSiC© reduces industrial pollution and turns the recycled materials into high-quality silicon carbide. ESK-SiC GmbH, based in Frechen, near Cologne, has many years of experience in the treatment and refinement of raw materials.

High-tech furnace transforms waste and by-products into SiC

At the edges of the giant open-air Acheson furnaces, a significant portion of the primary raw materials — quartz sand and petrol coke, cannot react fully to form silicon

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carbide because the temperature is not high enough. Due to the sheer size of the furnaces and the enormous heat generated, installation in the factory building is hardly possible. Contamination from the air is an additional factor for open-air furnaces. Previously, the incompletely formed SiC, along with the waste and by-products, could only be used for inferior applications or had to be disposed of. This is where the patented RECOSiC© process comes in. "We heat these by-products in a high-tech furnace with an inert atmosphere to temperatures up to 2,400 °C. This produces more high-quality SiC. The energy input under RECOSiC© is 80 percent lower than in the Acheson process, which also reduces CO_2 emissions significantly," explains Adler.

In contrast to the Acheson process, the high-tech furnace produces very little waste and by-products. Impurities are separated or vaporized during the chemical reaction. Under high heat, metals such as iron form lumps, which can be removed mechanically. As a result, the yield is nearly 100 percent.

Another major advantage: RECOSiC© produces high-quality SiC with a purity grade of 99 percent or even more. Matthias Hausmann, managing director of ESK-SiC GmbH, explains this with an illustrative example: "It's as if you had a process that turned waste paper into new paper that's just as good as — or perhaps even better than — the original paper."

Specifications and purity of SiC become controllable

To achieve this high level of quality, the researchers at Fraunhofer IKTS do not stop at feeding the material into the furnace. The base material is initially analyzed, pretreated and stoichiometrically supplemented. In other words, the raw materials are mixed in the exact ratio needed to create the chemical compound with the required properties in the chemical process. When needed, the experts also add certain additives. Finally, the process parameters for the furnace are configured, including peak temperature, duration and control of temperature development over the entire process. This enables them to control the process and determine the properties of the final SiC product, such as particle size and purity grade, ahead of time. The team at Fraunhofer IKTS also benefits from its many years of experience and expertise in ceramic materials.

"As a technology service provider, we — together with our industry partner ESK-SiC — can now supply SiC as a raw material with the specifications needed for the customer's specific application," says Adler. "At the same time, we can develop custom-tailored raw materials and processes together with partners from the ceramics industry that make new product features possible, even including recyclability."

This innovative method does not only process by-products from the Acheson process, however. It is likely that defective or used ceramics-based components, such as diesel particle filters and wall tiles from waste incinerators, can also be recycled with it. In general, any material with a SiC portion of 50 percent or more is suitable for recycling into high-quality silicon carbide.

Reduced dependency on raw materials suppliers

Matthias Hausmann says: "With RECOSiC©, we are taking an industrial process that used to be very dirty and harmful to the environment and making it much cleaner, while conserving valuable resources at the same time. This is an important step towards a sustainable circular economy."

The improved utilization of primary raw materials also reduces dependency on foreign raw materials suppliers and increasingly fragile supply chains. Fraunhofer IKTS developed and tested RECOSiC© in a pilot-scale plant. ESK-SiC GmbH began running an industrial-scale prototype facility in the second quarter of 2023. Further capacity expansions are in planning. As a result, attractive, high-tech jobs for sustainable technologies in Germany are being created in the energy-intensive raw materials sector.

Fig. 1 RECOSiC© uses waste and by-products from the Acheson process and turns them into high-purity silicon carbide in an enclosed high-tech furnace. The product of the process is powdered SiC.

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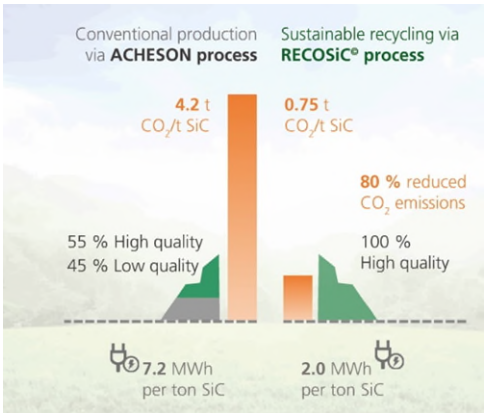

Fig. 2 The graphic depicts the advantages of RECOSiC© compared to the Acheson process: CO_2 emissions and power consumption are lowered significantly, while the yield of high-quality SiC is much higher.

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Fig. 3 The researchers are also working on using defective or used ceramics-based components as feed stock for producing high-quality SiC in future.

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