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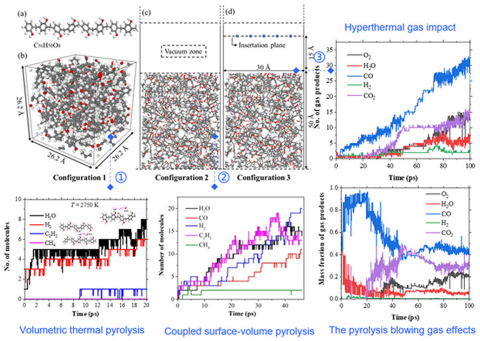
The process degrades materials and creates a blowing gas effect, both of which must be considered in microscopic models.



During re-entry to the atmosphere, air- and spacecraft are subjected to severe heating from friction, and often reach surface temperatures above 1000 degrees Celsius. Thermal protection systems are essential for negating this effect and allowing safe and reliable flight.

Carbon fiber-reinforced phenolic resin (PR) composites are an important matrix candidate for ablative materials required in thermal protection systems. However, PR deteriorates sharply under thermal pyrolysis, necessitating a microscopic and realistic understanding of that degradation.

Cui and Ye et al. simulated the pyrolysis mechanism of PR in the presence of hyperthermal gases under non-equilibrium conditions. Other studies focused on the interior thermal pyrolysis and neglected the influence of the external gas environment.

“Thermal pyrolysis gases vented out of the solid introduce a ‘blowing gas effect’ into the hyperthermal boundary layer, which could produce an insulation effect or promote further reactions at the interface,” said author Dongsheng Wen. “Pyrolysis should be a two-way communication, which cannot be captured by the typical volumetric pyrolysis approach.”

The team developed a gas-solid interaction model to establish surface-volume coupling and investigated the pyrolysis under the influence of multiple external gases. Including the coupling generated different pyrolysis products than the simpler volumetric approach. Additionally, the blowing gas rate was highly dependent on the external gas environment and the pyrolysis gas production rate.

“We are going to extend this work by translating the microscopic revelations from this reactive molecular dynamics study into macroscopic computational fluid dynamics modeling of complex hypersonic boundary layers,” said author Jin Zhao.

Source: “Coupled surface-volume pyrolysis effects of carbon-phenolic resin composites under hyperthermal non-equilibrium flows,” by Zhiliang Cui, Zhifan Ye, Jin Zhao, Xiangchun Sun, Guice Yao, and Dongsheng Wen, *Physics of Fluids* (2022). The article can be accessed at https://doi.org/10.1063/5.0098325.