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Conjugate Heat Transfer Between a Solid and Rarefied Gas

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Modern technological developments inthe areas of photolithography and MEMS increasingly hinge on resolving microscopic phenomena such as the interaction between rarefied gases and solids. Therefore, the development of computational methods that are capable of resolving such phenomena is necessary for the technological development of photolithography machines and MEMS.

On the macroscopic level the thermal interaction between solids and fluids is studied extensively and well understood. However, rarefied dynamics are not accurately resolved by continuum models, such as the Navier-Stokes-Fourier equations, making traditional conjugate heat transfer inapplicable to small-scale applications. Such lack of resolution precludes accurate predictions of conjugate heat transfer in nex generation photolithography machines and MEMS which exhibit significant rarefied phenomena.

Typically, fluids on these length scales are described by the Boltzmann equation. Numerical approximations of the Boltzmann equation have been well studied since the later half of the 20th century, with e.g. direct simulation Monte Carlo [1] or the method of moments [2]. However, there is a gap in our knowledge to couple these methods to a solid model.

In this work we present conjugate heat transfer between a rarefied gas and solid by coupling the Boltzmann equation to the heat equation. The Boltzmann equation is discretized using the Discontinuous Galerkin Finite Element Moment method [3] and the heat equation with the finite element method. The coupling between the two solvers is done using coupling library preCICE [4].

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