SAFL Seminar Series

Wednesday, December 7, 2011, 3:30pm

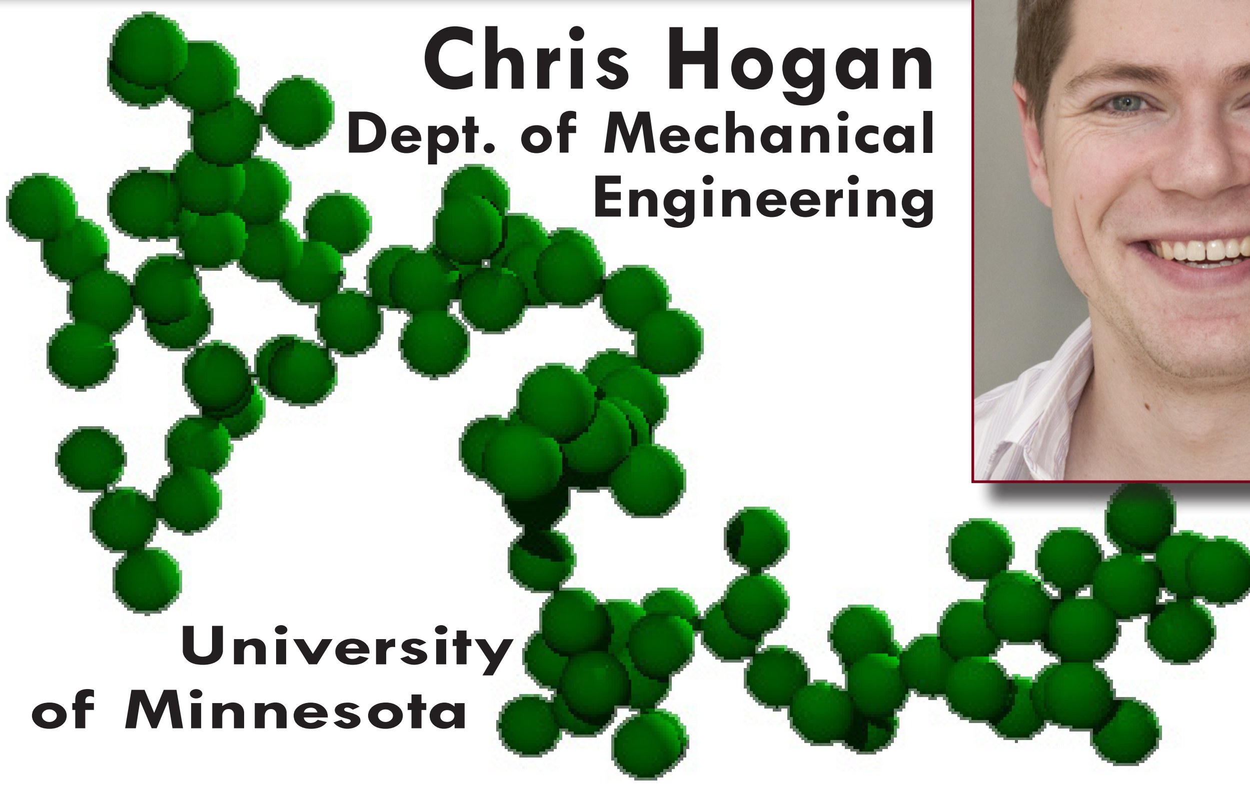
St. Anthony Falls Laboratory Auditorium

Mass and Momentum Transfer in Nanoparticle Aerosol Systems

Chris Hogan

Dept. of Mechanical Engineering

University of Minnesota



Abstract:

Aerosol nanoparticles are found ubiquitously in the earth's atmosphere, though for most of human history, the inhalation of these particles has had a negligible influence on human mortality. Recent technological advances, however, have led to (1) an increase in the number of nanoparticles an individual inhales over his/her lifetime, and (2) changes in the physical and chemical properties of inhaled particles. There is therefore concern over the presence of aerosol nanoparticles in the environment, and there is a need to better understand aerosol particle growth rates and transport. This talk focuses on recent developments in understanding the growth of aerosol nanoparticles by mass transfer, i.e. the rate of uptake of vapor by particles and the growth of particles via particle-particle collisions, momentum transfer from gas molecules to nanoparticles (drag), and the ionization of aerosol particles via collisions with atmospheric ions. These three processes play critical roles in controlling particle concentrations in the environment, the design of collection and filtration systems to remove particles from air streams, and the design of instrumentation to detect and analyze aerosol nanoparticles.

Our approach to examine mass and momentum transport to aerosol particles combines traditional engineering dimensional analysis with mean first passage time and direct simulation monte carlo (DSMC) calculations. There are two main challenges in these analyses. First, at atmospheric pressure, the hard-sphere mean free paths of gas molecules in air and the mean persistence distances of moving entities in an aerosol are on the order of tens to hundreds of nanometers, similar in size to atmospheric aerosol particles. For this reason, neither classical continuum approaches nor free molecular mechanics can be used to evaluate mass and momentum transfer rates in aerosol systems; at atmospheric pressure aerosol nanoparticles exist in mass and momentum transfer transition regimes. Second, aerosol particles produced in high temperature (combustion) processes are rarely spherical, and are more appropriately described as quasifractal agglomerates composed of primary spherules. A complete theory describing mass and momentum transfer in aerosol systems must account for the morphological diversity of real particles. Through dimensional analysis and mean first passage time calculations we are able to infer a mass transfer rate (collision rate) for vapor molecules to particles as well as between particles, for particles of both arbitrary size and shape. We are further able to develop an expression for the low Reynolds number momentum transfer rate (friction factor) of arbitrarily sized and shaped aerosol nanoparticles.