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Modelling and Simulation of Turbulent Thermal Plasma Flows for Nanoparticle Mass Fabrication

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Simulation of a turbulent thermal plasma jet fabricating a great number of nanoparticles [1] is demonstrated using a theoretical model which simply and effectively describes collective particle growth through simultaneous processes of homogeneous nucleation, heterogeneous condensation, and interparticle coagulation [1, 2, 3]. For long and robust computation, the importance of numerical methods to solve the governing equations to capture steep gradients of nanoparticle concentration and plasma temperature and 3D dynamic motions of multi-scale vortices which are turbulent features of thermal plasma flows with low Mach numbers is discussed [4].

A non-transferred argon thermal plasma jet ejected from a circular nozzle with the diameter of 8.0 mm is simulated. At the nozzle exit, the plasma jet has steady profiles of temperature with the maximum 12000 K and velocity with the maximum 400 m/s. Silicon vapor is supplied at 0.1 g/min with the plasma jet.

Figures 1 and 2 show the snapshots of the instantaneous temperature and velocity fields and vortex structures obtained by the conventional and advanced methods [4], respectively. It is apparent that the advanced method simulates a complex flow field with widely spreading multi-scale vortices extracted from the velocity data by *Q*-criterion. Many vortices are generated even far from the plasma jet cores. Large vortices have higher temperatures whereas small vortices have lower temperatures as predicted on the basis of Kolmogorov theory [5]. Flowing downstream, the high-temperature thicker vortex rings deform largely whereas the low-temperature thinner vortex rings break up into smaller vortices. Compared with the advanced method, the conventional method does not simulate the turbulent features as shown in Fig. 1.

Figures 3 and 4 show the snapshots of the instantaneous number density and mean diameter distributions of silicon nanoparticles. The larger size regions coincide with smaller number density regions. This result indicates that simultaneous coagulation decreasing particle number plays an important role for collective nanoparticle growth as well.

References

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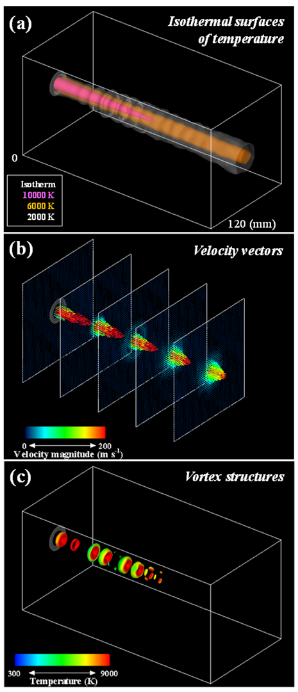

Figure 1 Thermofluid field by a conventional method

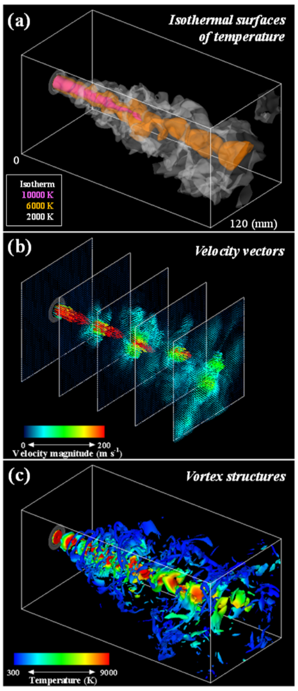

Figure 2 Thermofluid field by an advanced method

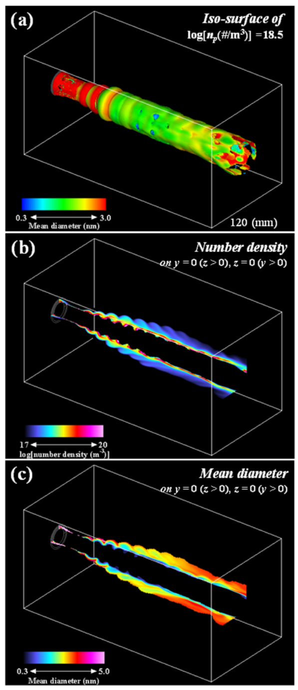

Figure 3 Nanoparticles by a conventional method

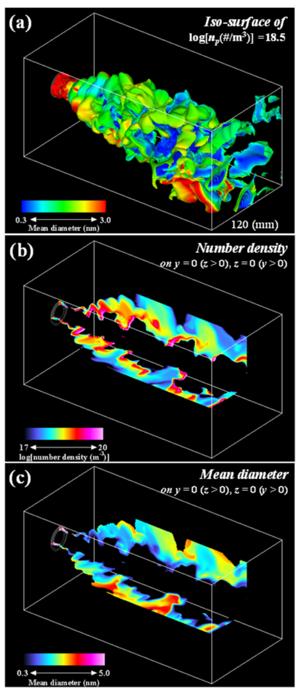

Figure 4 Nanoparticles by an advanced method