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Modelling for turbulent transport of nanoparticles growing around a thermal plasma jet

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Modelling works for expressing the simultaneous processes of growth and transport of nanoparticles around a turbulent-like thermal plasma jet are presented. From the physical aspect, extending the previous model, a simple-but-consistent model which requires less computational costs is developed to describe the nanoparticles' birth and collective growth through homogeneous nucleation, heterogeneous condensation, and coagulation among themselves as well as transports by convection, diffusion, and thermophoresis. From the mathematical aspect, an original simulation code with higher accuracy is developed to express thermal plasma turbulence and to capture steep gradients in the spatial distribution of nanoparticles. As a base case, an argon thermal plasma jet is ejected at 1.5 slm from the nozzle, and iron vapor is supplied at 0.1 g/min with the plasma jet. The computation shows that the high-temperature plasma jet entrains the surrounding non-ionized gas because of Kelvin-Helmholtz instability at their interface. The instability waves grow up and then the interface rolls up to eddies. As the jet goes downstream, the eddies break to smaller ones, which lead to turbulence transition. This feature has also been reported in the experimental study. The iron vapor is transported with the plasma flow and simultaneously diffuses across the plasma's fringe where the vapor experiences the temperature decrease. As a result, the vapor changes its phase to nanoparticles through nucleation and condensation. The nanoparticles are also transported by convection and diffusion. The regions of large diameters coincide with those of low number densities of nanoparticles, because the size of nanoparticles increases through coagulation among themselves decreasing their own numbers.