Two-dimensional estimation of number density distribution of precursor molecules during TiO2 nanopowder synthesis using induction thermal plasmas

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Résumé

The induction thermal plasma (ICTP) has been frequently used for nanopowder synthesis with solid feedstock powder injection.
It is thus important to clarify where the feedstock is evaporated and how the precursor vapor is generated and distributed in the ICTP torch to investigate nucleation and particle growth processes during this nanopowder synthesis. For this purpose, the authors developed a two-dimensional (2D) measurement method of temperature and Ti vapor admixture ratio in the pure Ar ICTP with Ti feedstock for Ti nanopowder synthesis. In addition, we also successfully estimated the number density distributions of Ti atoms and electrons under the local thermodynamic equilibrium (LTE) assumption using the estimated temperature and Ti vapor admixture ratio in the pure Ar ICTP with Ti feedstock.
The present paper describes estimated results on 2D distributions of temperature and number densities of TiO and TiO2, i.e. precursors for TiO2 nanoparticles, in a Ar-O2 ICTP with Ti feedstock. Experimental conditions were set as follows. Input power was fixed at 20 kW. The gas mixture of Ar and O2 was used as sheath gas with flow rates of 90 L/min Ar and 10 L/min O2. The pressure was controlled to be 300 torr. The Ti feedstock powder was continuously injected into the ICTP torch with a feeding rate of 2 g/min. The Ar gas was used as feedstock carrier gas with a flow rate of 2 L/min. The 2D-OES was carried out for the thermal plasma torch during TiO2 nanopowder synthesis processing. The observation region was set at 52×52 mm^2 region below the coil-end. Two Ti I atomic lines at wavelengths 453.32 nm and 521.04 nm were observed as well as O I atomic line at 777.54 nm. The following assumptions were adopted to estimate temperature and particle number densities: (a) LTE, (b) constant pressure, and (c) Ar and O2 gases were uniformly mixed. The Ti excitation temperature was estimated using the two-line method for observed two Ti I atomic lines. The Ti vapor admixture ratio in the experiment was determined by comparison between the measured intensity ratio and the calculated emission coefficient ratio of Ti I at 521.04 nm and O I at 777.54 nm at the estimated temperature. As results, the estimated Ti excitation temperature was found about 3.0 kK around on-axis region while it was between 4.0-5.0 kK in off-axis region. The main reason of this temperature difference is that the temperature increases due to joule heating in the off-axis region whereas it decreases due to

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energy consumption by feedstock evaporation at the on-axis region. It is also found that the downstream temperature was slightly lower than the upstream temperature. In addition, the estimated TiO density was 10^{14} m^{-3} below the coil-end region, and TiO density became more than 10^{16} m^{-3} at downstream region. In addition, TiO2 number density was also found to be much higher at downstream region. These results indicate that relatively high number density of precursor TiO and TiO2 molecules can be formed at downstream region in the ICTP torch during TiO2 nanopowder synthesis.