Synthesis of Functional Ceramic Materials through Controlling Thermal Plasma Chemical Reactions

Plasma Processing Group

Nano Ceramics Center
National Institute for Materials Science

We are trying to utilize **chemical aspect** of thermal plasma, which has been used mostly for **high-temperature heat source**.

- ✓ New generation method; **time-domain control.**
- ✓ New chemical reaction field.

Characteristics of thermal plasma

1. High temperature; 10,000-15,000K.
2. Generation at relatively high pressure; ~1 atom.
   Equilibrated plasma; Te/Tg ~ 1.
   High concentration of chemically reactive species.
3. Very rapid cooling in the plasma tail, $10^{4\text{-}6}$ K/s.
4. Discharge without a electrode; oxidative, reductive, and reactive plasmas can be generated.

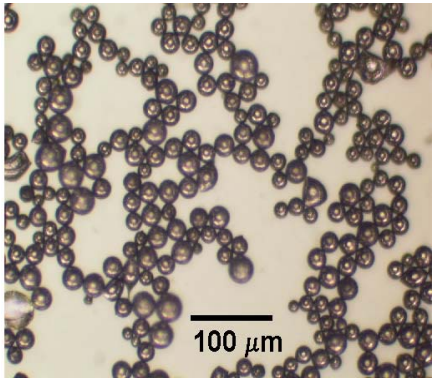
Generation of Induction Thermal Plasma

Thermal plasma gives unique reaction fields for materials processing.

High temperature heat source → **Chemical reaction fields**

Much heat transfer from plasma to particles.

Spheroidization in thermal plasma

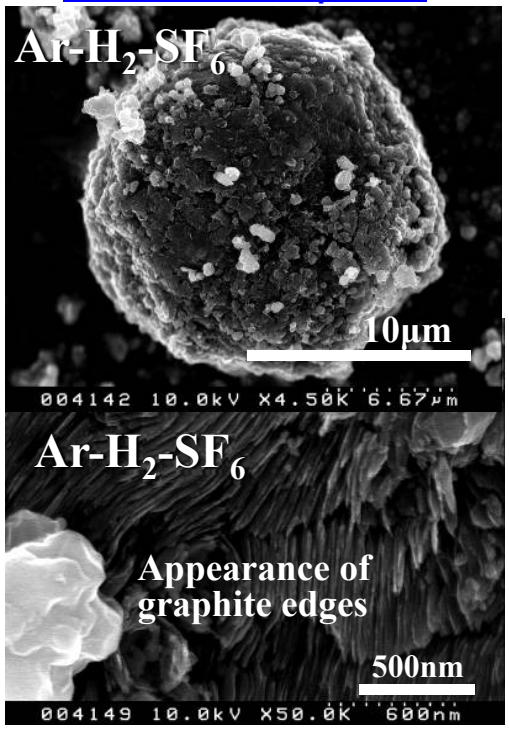


Refractory TiC particles were melted and spheroidized in thermal plasma.

[*J. Am. Ceram. Soc.*, 84, 1929(2001).]

For example, 30 kg/h (1 ton/week) of tungsten powders can be spheroidized.

Grahite powder treatment in reactive thermal plasma



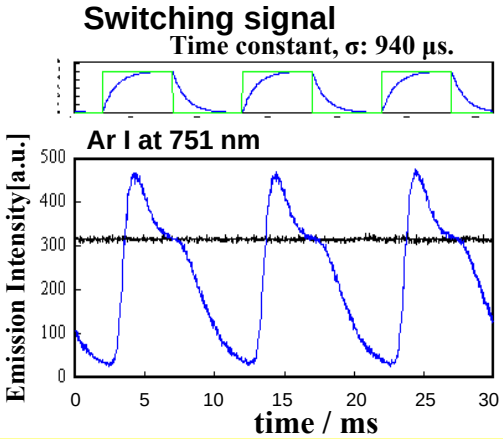
Disordering of graphite structure and the introduction of functional groups at surface.

Improvement of charge-discharge characteristics of lithium-ion rechargeable battery.

[*Carbon*, 42, 3229(2004) .]

New plasma generation method

- Pulse-Modulated RF Induction Plasma -



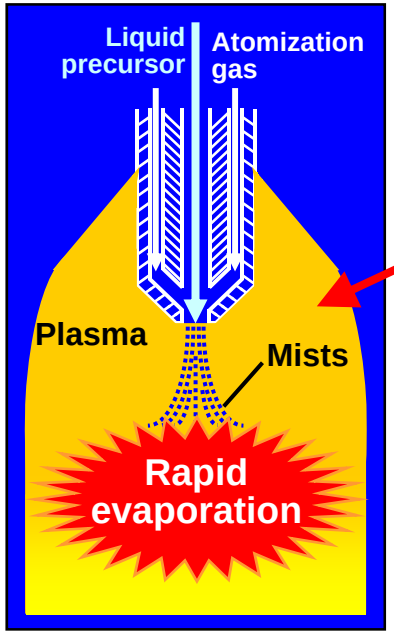
Response of plasma emission to the switching signal.

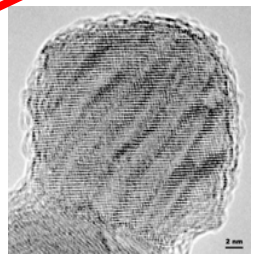
Improvement of UV emission of ZnO by hydrogen doping.

[*Appl. Phys. Lett.*, 71, 3787(1997); *ibid.*, 80, 2869(2002).]

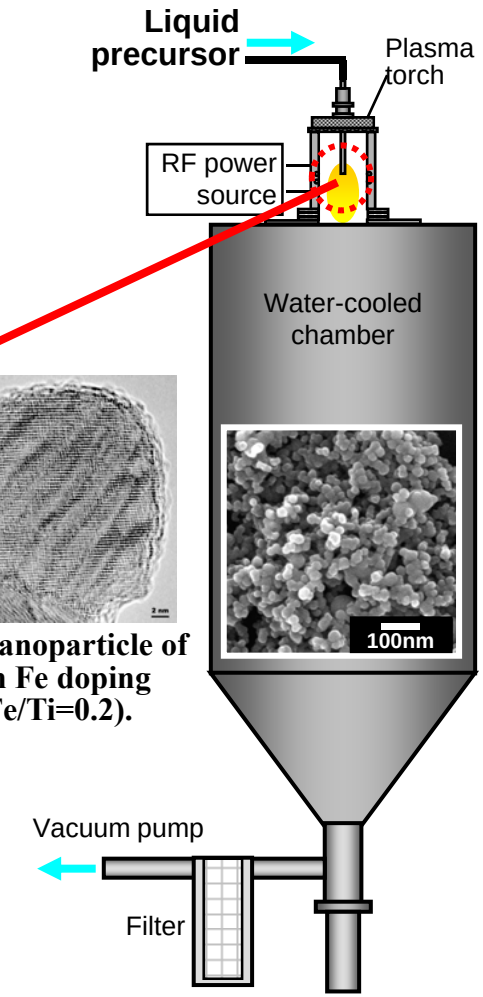
Synthesis of functional ceramic nanoparticles through controlled reactive thermal plasma processing

Synthesis of nanoparticles by plasma oxidation of liquid precursor mists





TiO_2 nanoparticle of high Fe doping (Fe/Ti=0.2).



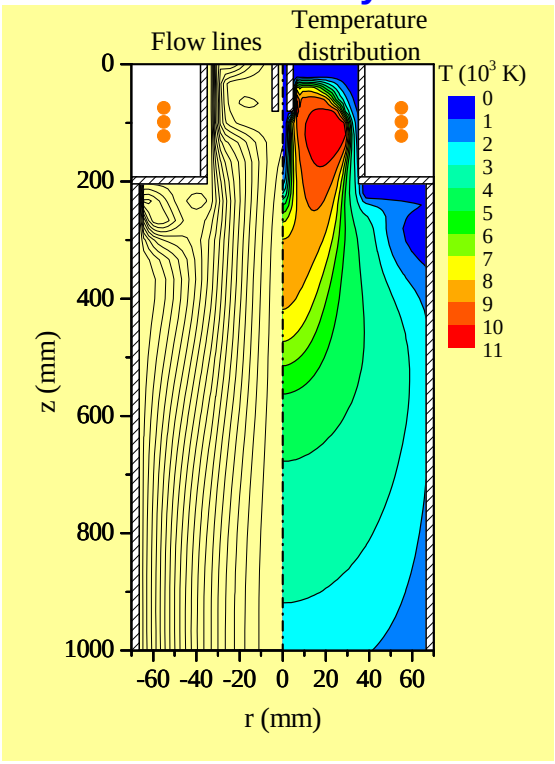
Advanteges

// High degree of super-saturation in a vapor phase.

// Precise control of chemical composition.

// Non-equilibrium conditions.

Optimization of reactor design and process parameters by numerical analysis



// Rapid quenching condition, and the flat radial distributions of flow and temperature.

// Particle size control, and sharp size distribution.