Synthesis of Aluminum Nitride Nano-particles by Arc Plasma

Background

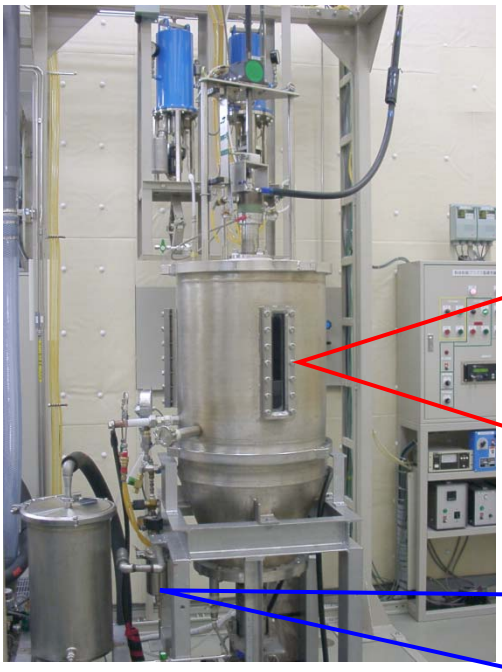
CRIEPI is now investigating all-solid insulating substation which is beneficial from environmental and disasters-preventing viewpoints. In order to develop solid insulating materials, the addition of large quantities of aluminum nitride (AlN) particles with high thermal conductivity to organic insulating materials was considered. Mixing nano-particles with large particles (a few microns particles) is a good way to achieve high ceramic particle content. However, the low production capacity of nano-particles makes it extremely expensive. Methods that utilize arc plasma have potential to raise the production rate because they allow plasma power to be upgraded with ease.

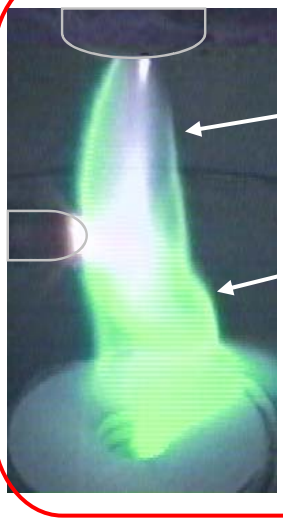
Principal results

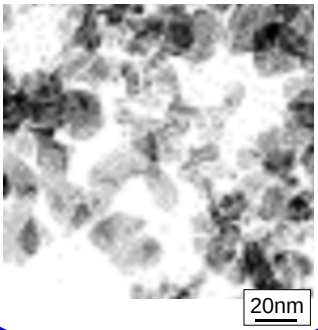
Purified AlN nano-particles of 30nm in diameter were synthesized by injecting Al particles (20 μ m) into an arc plasma (Photos 1-3). For the purpose of raising the synthesizing rate of AlN nano-particles, the proper conditions of injecting Al particles (position, angle, gas velocity) were clarified, in which the Al particles were wholly evaporated.

Future Developments

The mass production technology of AlN nano particles will be developed. Furthermore, high-dispersed AlN nano particles will be synthesized so that the nano particles don't agglomerate in the organic insulating material.







Experimental setup (Photo 1)

Long arc plasma (max. 300mm) can be generated, therefore the raw particles injected into the arc plasma can be wholly evaporated. The kinds of reacting/quenching gas can be changed. Hence, nano-particles other than AlN can be synthesized in principle.

State during experiment (Photo 2)

Al particles are evaporated in the arc plasma, and the Al vapor reacts with and is quenched by ammonia (NH_3) gas that is blown downstream from the arc plasma. As a result, AlN nano particles are synthesized. The AlN content increases (>99%) by passing the synthesized nano-particles through ethanol.

Synthesized nano particles (Photo 3)

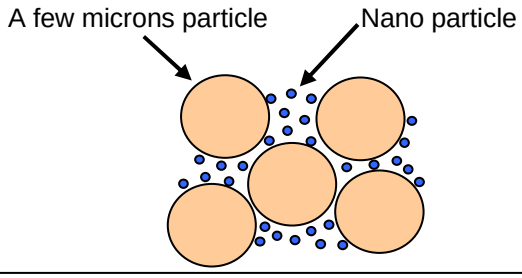
The AlN nano-particles of 20-30nm in diameter are synthesized. The AlN content is more than 99%.

Thermal conductivity of insulating material

Material	Organic	Inorganic		
	Epoxy	SiO_2	Al_2O_3	AlN
Thermal conductivity [W/m/K]	0.2	1～5	5～10	100～200

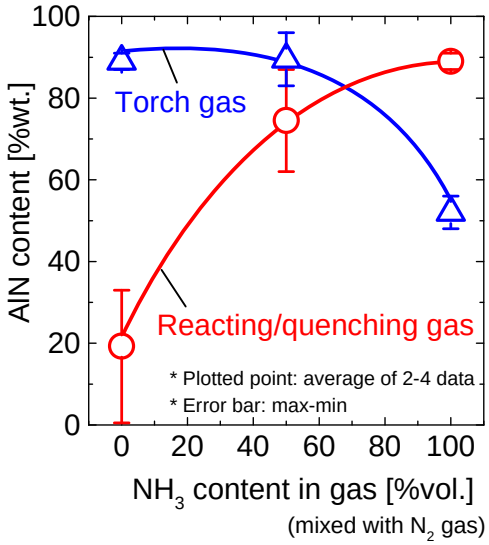
At present, epoxy resin mixed with SiO_2 (silica) or Al_2O_3 (alumina) is usually used as solid insulating material for electrical equipment that requires high thermal conductivity. The power of electrical equipment for all-solid substation that CRIEPI investigates is so high that the solid insulating material requires higher thermal conductivity. Therefore, CRIEPI investigates using AlN particles as fillers of epoxy resin.

Image of high particle content



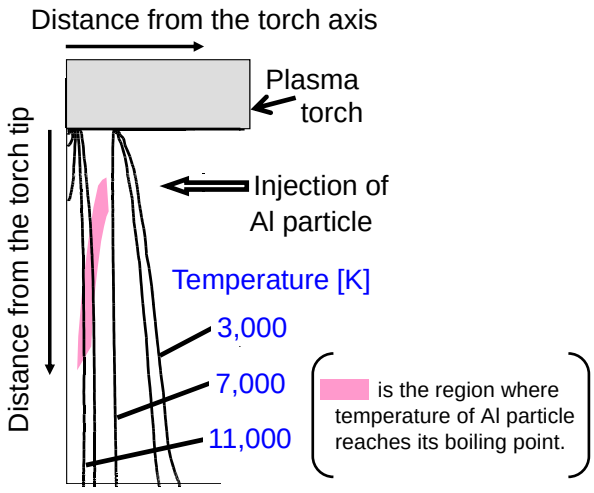
In order to develop solid insulating material with high thermal conductivity, it is necessary to add large quantities of AlN particles to epoxy resin. Mixing a small-grained particle with a large-grained particle is considered to be a good way of achieving a high particle content. Commercially available AlN particle has a size of a few microns, therefore AlN nano particle is required as a small-grained particle.

Conditions of synthesizing purified AlN nano particles



Chemical equilibrium composition calculations and experiments were carried out, in which the kinds of gases of “Torch gas” (for generating arc plasma) and “Reacting/quenching gas” (for blowing into Al vapor downstream from the arc plasma) were changed. As a result, when N_2 was used as the “Torch gas” and NH_3 was used as the “Reacting/quenching gas”, nano particles of 90% in AlN content was synthesized (non-reacted Al content in the synthesized particles was 10%). The AlN content in the synthesized particles increased (>99%) when the synthesized particles passed thorough ethanol because the Al nano particles reacted with the ethanol and were trapped.

Results of numerical analysis on evaporation behavior of Al particle under chosen conditions



Numerical analysis clarified temperature and velocity in the arc plasma and evaporation behavior of Al particle in the arc plasma. Proper conditions of injecting Al particles (position, angle, gas velocity) were chosen from the viewpoints of evaporation behavior of Al particles and thermal damage of injection port due to high temperature of the arc plasma. The numerical analysis was considered appropriate because the evaporation region of Al particle in an experiment agreed with the calculation results approximately.