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# Size-Selective Treatment of Polypropylene Particles in a Plasma Cyclone Reactor

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## 1. Introduction

Surface modification with plasma is a favorable technique to improve surface properties of polymer substance without changing bulk properties. For the particles, however, there are some problems such as insufficient mixing of particles and contact with plasma, and difficulty in controlling the treatment time. In this study, a cyclone reactor combined with plasma generated by gliding arc discharge was developed. The cyclone reactor was expected to provide efficient contact between particles and plasma as well as size-selective treatment at the swirling particles region.

## 2. Experimental

The reactor consisted of an inner column connected to high voltage and an outer cylinder connected to ground as shown in Fig.1. An inlet tube was equipped tangentially at the top of the outer cylinder, and an outlet tube was combined with the inner column. Gliding arc discharge was generated between the two electrodes (columns) at the top of the reactor and moved downward while rotating because the inner column was tapered off to give downwardly widen gap of the electrodes. The particles carried with Argon gas were treated by passing through the plasma region. Polypropylene particles with mean diameter of 5  $\mu\text{m}$  were used as model particles. The behaviors of the gliding arc discharge was observed by a high speed camera. Wettability of the particles was analyzed by water contact angle measurement. The shape and size of the particles were evaluated by SEM.

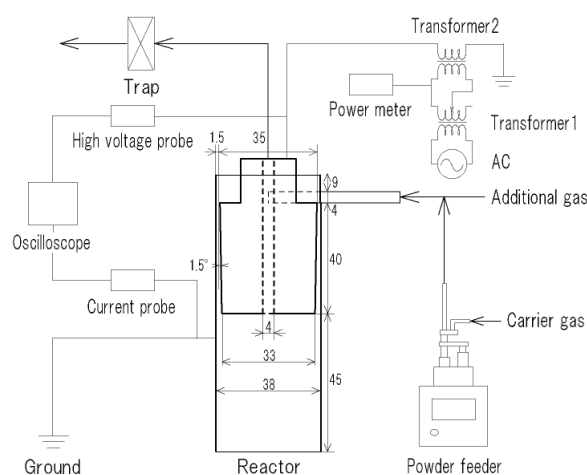


Fig.1 Experimental setup

## 3. Results and Discussion

Figure 2 shows the behaviors of gliding arc discharge generated in the reactor. The discharge moved downward with rotating between the inner and outer columns. The reactor indicated the size-separation characteristics that large particles remained inside the reactor, while small particles were entrained by the gas flow outside the reactor. The average diameters of the particles collected inside and outside the reactor were 5.2 and 4.1  $\mu\text{m}$ , respectively.



The separation characteristics was not affected by the plasma generation. Water contact angle of the particles captured inside and outside the reactor was also not changed by the plasma treatment. However a little of the particles collected only outside the reactor were converted to spherical shape as shown in Fig.3. By the observation of SEM, the ratio of particles having sphere shape was measured and indicated in Fig.4. The ratio was increased with increasing discharge voltage and gas flow rate, however, the ratio was about several percent under all conditions.

The spheroidization of the particles might be caused by heat from the plasma during their trajectory in the reactor. Thus the time required for the particles to melt by the plasma ( $t_m$ ) was estimated by the following equation:

$$t_m = \frac{\rho_p d_p C_{p,p}}{6h} \ln \frac{T_f - T_0}{T_f - T_m} + \frac{\rho_p d_p \lambda_{m,p}}{6h(T_f - T_m)}$$

where  $\rho_p$ ,  $d_p$ ,  $C_{p,p}$ ,  $\lambda_p$ , and  $h$  reveal particle density, diameter, heat capacity, and convection heat transfer coefficient respectively. The temperatures  $T_f$ ,  $T_0$ ,  $T_m$  mean fluid (plasma), initial and melting point of the particles. When the plasma temperature was assumed to be 438 to 973 K,  $t_m$  was calculated as 0.02 to 0.7 ms. The residence time of the particles in the reactor was estimated as about 40-70 ms, while the discharge maintained for about 10 ms. Therefore  $t_m$  was much smaller than these times, suggesting that the spherical particles were produced by melting immediately after the contact with the plasma. As mentioned above, sphere particles were only collected outside the reactor where smaller particles were collected. Those particles tended to be entrained by the flow similar to the discharge observed by a high speed camera as shown in Fig.2, hence the possibility of the contact between those particle and the plasma might be higher than that of larger particles. This might be why the reactor showed the size-selective treatment.

#### 4. Conclusion

The cyclone reactor combined with the plasma generated by gliding arc discharge was developed for the particle treatment. The results showed that only smaller particles were spheroidized, suggesting that the reactor had a potential for the size-selective treatment of particles.

#### Acknowledgement

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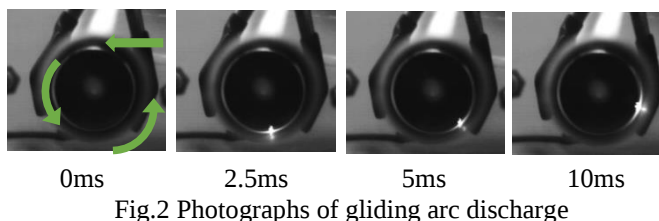


Fig.2 Photographs of gliding arc discharge

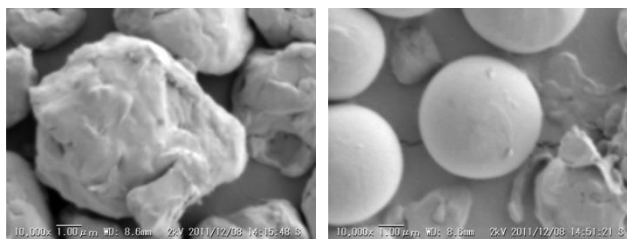


Fig.3 SEM images of plasma treated particles  
Inside of the reactor (Left), Outside of the reactor (Right)

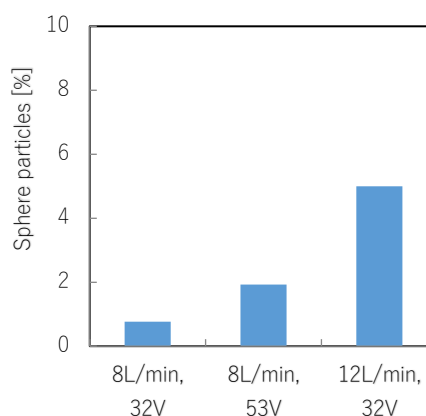


Fig.4 Fractions of the particles having sphere collected outside the reactor