Optimization of carbon heating tube rapid heating system by electric field analysis using finite element method

Takuma Uehara[1], Tomoyoshi Miyazaki[1,2], Go Kobayashi[3], Masahiko Hasumi[1], Takuji Arima[1], and Toshiyuki Sameshima[1]

[1]Tokyo University of Agriculture and Technology, Graduate School of Engineering, 2-24-16, Naka-cho, Koganei, Tokyo, 184-8588, Japan
[2] Techno Research., Ltd., 5-9-10 Shimozato, Higashikurume, Tokyo, 203-0043, Japan
[3]ORC MANUFACTURING CO.,LTD. 4896 Tamagawa, Chino, 391-0011 Japan
Email: tsameshim@cc.tuat.ac.jp

Introduction

We have proposed a heating system with a lamp of carbon heating tube(CHT) for rapid thermal heating [1]. The CHT consists a quatz tube filled with carbon particles and Ar gas. CHT absorbs microwaves efficiently. The absorption efficiency of the microwaves depends on the shape of the cavity and the conductivity of the CHT. In this paper, we report characterization of the electric field distribution in the cavity in the steady state during microwave irradiation analyzed by a numerical simulator constructed with the three-dimensional finite element moment meshod to determine the effective condition of microwace absorption by the CHT.

Experimental

The electric field distribution in the cavity in the steady state during microwave irradiation was numerically analyzed by a simulator constructed with the three-dimensional finite element moment method combined with the Cholesky decomposition. The cavity had a structure with a cylindrically upper part with a diameter of 300 mm and a spherically lower part to promote interferingly multiple reflection of the microwave in the cavity and to have the CHT effectively absorb the microwave. The microwave was set to a frequency of 2.45 GHz and a power of 200W. The grid system of the cavity and waveguide was formed with the equilateral triangle elements with the sides ranging from 1 to 4 mm for the numerical calculation. They were assumed as perfect electric conductor which reflects completely the microwave. The CHT was set as a cylinder 60 mm in length and 4 mm in radius. The CHT grid was formed with 1 mm side equilateral triangle elements. The electrical conductivity of carbon was widely changed from 0.1 to 10000 S/m to find an effective condition of microwave absorption by the CHT.

Results and Discussions

Figure 1 shows a cross-sectional distribution of the electric field in the cavity. The cavity surfaces and CHT surfaces out lines were traced by solid black curves and red curves respectively. Fig. 1 (a) shows the result for CHT with conductivity of 0.1 S/m is placed at the center of the cavity, the electric field intensity distributed from 25 to 175 kV/m for the most region. On the other hands, as shown in Fig. 1 (b) for the CHT conductivity of 10 S/m, the electric field is lower than 20 kV/m. Fig. 1 (c) shows the results for the conductivity of 100 S/m, where the electric field intensity is concentrated around the CHT and shows a value of 30 to 40 kV/m. From the results of Figure 1 shows the value and distribution of the electric field change depending on the conductivity of CHT. Figure 2 shows average electric field intensity in the cavity space as a function of the conductivity of the CHT. Although the average electric field intensity was very high of 1173 KV/m in the case of no CHT, it was decreased by installing CHTs, as shown in Fig. 2. The minimum average electric field intensity was 5 kV/m when the electrical conductivity ranged between 10 and 55 S/m. This means that the effective absorption of the microwave power by CHT reduced the electric field intensity in the cavity. The average electric field intensity gradually increased as the electrical conductivity further increased. The calculation supports experimental results of low microwave refection from the cavity and effective heating of the CHT.

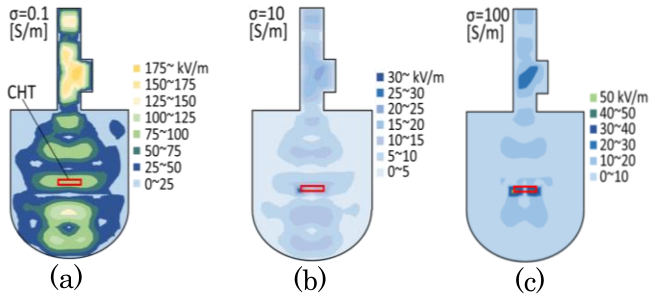

Fig. 1 Calculated cross-sectional electric field distributions in cavity (a) 0.1 S/m CHT , (b)10 S/m CHT (c) 100 S/m CHT when the microwave of 200W output.

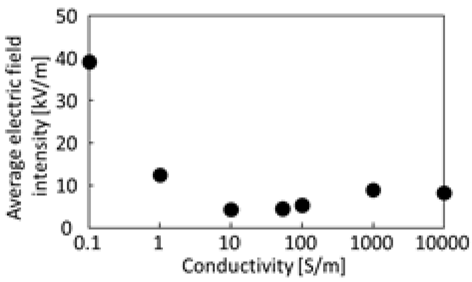

Fig. 2 Average electric field intensity in the cavity space as a function of the electrical conductivity of the CHT.

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References

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