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Numerical Analysis for Low-Temperature and Dense Plasma Generation using Pulsed Power Discharge Devices
数値解析によるパルスパワー放電装置を用いた低温高密度プラズマ生成の検討

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To investigate properties of low-temperature and dense plasma for the inertial confinement fusion, the numerical simulation of time-dependent one-dimensional thermal diffusion is carried out in the compact pulsed power discharge device. The simulation result is useful to understand the thermodynamic phenomena during the discharge in comparison with the experimental result. Using an intense pulsed power generator "ETIGO-II", it is expected that the properties of dense plasma is investigated during the short time duration such as the implosion dynamics of inertial confinement fusion pellet.

1. Introduction

Property data of low-temperature and dense plasma are important to understand implosion dynamics in a fuel pellet of inertial confinement fusion (ICF) [1]. Because the phase of the fuel pellet changes from a solid to plasma due to irradiation of energy drivers.

In this study, we numerically investigate to generate the low-temperature and dense plasma by using pulsed power discharge devices to obtain the properties of low-temperature and dense plasmas.

2. Numerical Simulation for Foam/Plasma Generated by Compact Pulsed Power Discharge

Time-dependent one-dimensional thermal diffusion equation with cylindrical symmetry configuration is numerically solved to simulate the low-temperature and dense plasma generation in the compact pulsed power discharge experiment [2]. The computational box is shown in Fig.1. In this apparatus, a foamed copper is used as a sample, and is surrounded with a hollow sapphire capillary. Table I shows the material parameters for numerical simulation. The initial temperature is set as 300 K. The input energy is given by the corresponding experimental data [2]. The density of the foamed copper in the hollow capillary is 0.032 times the solid density. In this setup, the fluid dynamics of the sample plasma is limited by the capillary. For this reason, we only calculate the thermodynamics in the foam/plasma without the fluid phenomena of plasma.

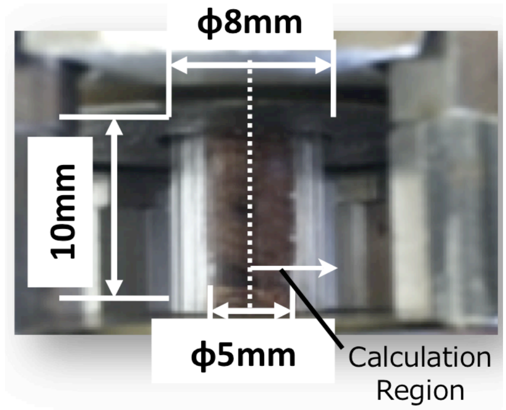

Fig.1. Computational box for time-dependent one-dimensional thermal diffusion equation with cylindrical symmetry configuration

Table I. Material parameters for calculation

Copper Region:	
Thermal Conductivity	κ(T) [3,4] W/m K
Specific Heat	C_v(T) [5,6] J/kg K
Solid Density	8920 kg/m^3
Sapphire Region:	
Thermal Conductivity	42 W/m K
Specific Heat	750 J/kg K
Solid Density	3970 kg/m^3

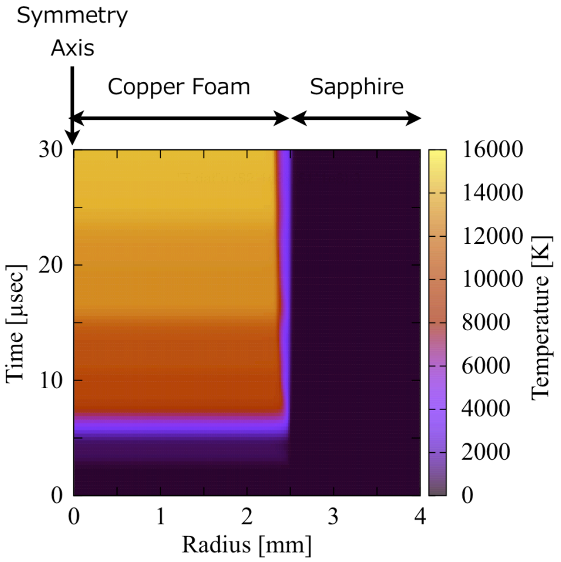

Fig.2. Calculation result of time-dependent one-dimensional thermal diffusion equation with cylindrical symmetry configuration in regions of foamed copper and sapphire capillary

The conventional thermal property data of copper in solid, liquid, and gas phases are given by Refs. [3-6]. Since the sample is a foamed material, we assumed that the skin effect can be ignored. As a result, the discharge current distribution is assumed as uniform in the copper region.

Figure 2 shows the numerical simulation result of time-dependent thermal diffusion in the copper foam and the sapphire capillary regions. The numerical simulation confirmed that the sample is achieved to the temperature generating plasma. The result indicates that the temperature at the interface between the copper foam and the sapphire capillary is diffused, and the temperature around the edge of copper region is reduced due to the difference of the heat capacities.

The result can be compared with the experimental result to understand the phenomena in the capillary during the discharge.

3. Dense Plasma Generation using Intense Pulsed Power Device

As mentioned in previous section, the compact pulsed power discharge device is useful tool to generate the low-temperature and dense plasma condition. Although typical implosion time for ICF is in several-10 ns [7], the discharge time driven by the compact pulsed power device is not suitable to observe the fast phenomena during the implosion.

The nominal parameters of the intense pulsed power generator "ETIGO-II" [8] (see Fig.3) are 1 MV- 1MA - 50 ns (FWHM) in the current condition. Using this intense pulsed power device, the volumetric dense plasma generation is expected, even in the short pulse duration. For example, it is estimated that the foamed copper of ϕ20 mm x 100 mm with 0.032 times the solid density can be ablated in the nominal parameter operation of the voltage and current.

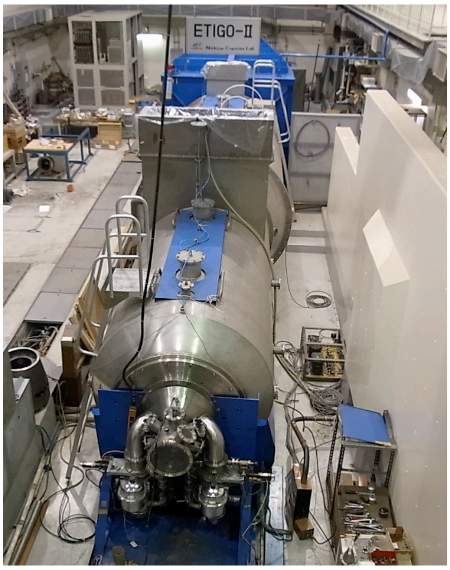

Fig.3. Intense pulsed power generator "ETIGO-II" at Extreme Energy-Density Research Institute in Nagaoka University of Technology

4. Conclusions

To investigate the low-temperature and dense plasma for the inertial fusion energy output, the numerical simulation of time-dependent thermal diffusion was carried out in the compact pulsed power discharge device. The simulation result is useful to understand the thermodynamics phenomena during the discharge. Using the intense pulsed power generator "ETIGO-II", we will investigate the properties of dense plasma during the short time duration in comparison with the implosion dynamics of ICF pellet.

References

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