§34. Physics of High Energy Density Plasma driven by Fast Pulse Power Discharges

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Hot dense matters naturally observed in Jovian planets, white dwarfs and also in a fuel plasma of inertial confinement fusion, are of primary concern in this study. The plasma in a strongly coupled state is produced by a wire explosion driven by a fast pulse power generator composed of a water-filled test chamber, a low inductance discharge section and a cylindrically arranged capacitor bank. The electrical energy powered into the plasma is estimated by integration of voltage-current characteristics of the pulsed discharge. In order to estimate the plasma density, the boundary of the plasma evolution is observed with a fast framing photography. The cylindrical shock wave in water is measured by the schlieren method and the history of pressure evolution is evaluated by comparing the shock wave trajectory with numerical estimation based on a quotidian equation of state (QEOS)[1]. Evolutions of electrical conductivity, corresponding coupling parameters and the equation of state of the plasma are discussed.

In this study, thin wires are exploded in water by coaxially arranged low inductance capacitors [2]. The fast discharge is insulated and tamped by the surrounding water, and can make a dense symmetric plasma in the water filled test chamber. In contrast to previous experiment, our study is intended to make a semi-empirical scaling of the equation of state and transport coefficient. We observe the time history of the shock wave to estimate the temporal evolution of plasma pressure. The behavior of shock waves in the surrounding water is used as an indicator of the pressure history.

A schematic diagram of the experimental arrangement is shown in Fig.1. We use a capacitor bank consisted of cylindrically arranged $8 \times 0.4 \times 10^{-6}$F low inductance capacitors. To avoid the skin effect on the exploding plasma, thin wires made of Al or Cu are used. The electrical resisitivity is evaluated from values of the inductively corrected voltage and the discharge current using a voltage devider and a Rogowski coil. We also estimate the history of input power to the plasma with the discharge characteristics. The evolution of wire plasma is observed by a fast streak camera with microscopic attachment. The conductivity is evaluated directly from the electrical characteristics and effective diameter of the exploding-wire plasma. We measured the behavior and electric characteristics of plasma evolution at least three times. The results showed that the plasma is sufficiently reproducible to estimate parameters of the transient plasma.

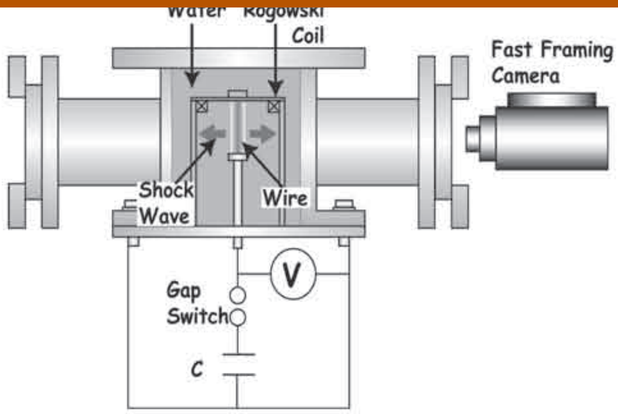

Fig.1 Schematic diagram of experimental arrangement for exploding wire experiments.

The experimentally estimated conductivity evolved from a value corresponding to a solid state with room temperature to a highly ionized state with intermediate stage. The regime which provides minimum conductivity is considered to be a phase transition region of the wires. In fact, we could observe visible image of wires only after around 500nsec from the start of discharge.

We have made a two-temperature 1D-MHD model coupled with a circuit model to calculate the behavior of wire explosion in water. Here, a quotidian equation of state (QEOS) [1] and the time history of experimentally obtained energy input to the plasma are used in the hydrodynamic simulation. Our goal is to make a semi-empirical modeling, using the numerical calculation and experimental values [3].

In order to study the physics of strongly-coupled, high-energy density plasma, a preliminary experiment and a numerical simulation were performed. The experimental results show that wire plasmas exploded in water are sufficiently reproducible to evaluate the evolutions of the plasma, especially the conductivity at phase transition regime. Results indicate that the evolution of the average electric conductivity of wire plasma after the phase transition region and the discrepancy of the numerical results from the experimental observation can be attributed to the conductivity model and the EOS model [4]. We are going to measure the trajectory of shock wave to estimate the time history of pressure and derive a more detailed semi-empirical modeling of the conductivity and the EOS for the strongly coupled plasma.

References

1). More,R.M., Warren,K.H., Younh,D.A, and Zimmerman,G.B., Phys. Fluid, **31**, 3059 (1988).
2). Desilva,A.W., and Katsouros,J.D., Phys. Rev., **57**, 5945 (1998)
3). Horioka,K., Nakajima,M., Sasaki,T., Mizoguchi,T., *Proc. 15th High Power Particle Beams*, Stpertersberg (2004)
4). Sasaki,T., Mizoguchi,T., Kikuchi,T., Nakajima,M., and Horioka,K., Proc. Jap. Soc. Fusion Sci., Sendai, (2004)