

§51. Evaluation of Electrical Conductivity in DLC Plasma toward Efficient Energy Coupling in Fast Ignition

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Critical to fast ignition¹⁾ is the transport of the laser-generated fast electrons and their associated heating of compressed DT fuel. The coupling efficiency of laser energy to these fast electrons and the energy deposited in the fuel should be improved the cone materials. Improving coupling efficiency, we should consider the behaviors of unstoppable, un-ejected, and diverging fast electrons. From the numerical results, the low-Z cone is expected to be the improvement of coupling efficiency, because the fast electrons are scattered by the large Coulomb potential of highly charged ions in high-Z cone wall²⁾. On the other hand, the transport of fast electrons in the cone depends on the electrical conductivity in warm dense matter (WDM) state³⁾.

From above evaluations, the diamond-like-carbon (DLC)⁴⁾ cone, which is one of the low-Z cone, is promised to increase the coupling efficiency due to the reduction of stopping power in cone compared to the high-Z cone. The properties of DLC respects the diamond and the graphite, however, materials in WDM state are in a complex area. The DLC is also made by the plasma-enhanced chemical vapor deposition on the substrate. Therefore, the properties of vapor DLC is difficult to obtain the conventional method.

To evaluate the electrical conductivity in DLC WDM, we propose a concept to investigate the WDM properties of insulator by using pulsed-power discharges. The concept of the evaluation of electrical conductivity for DLC WDM is a shock compression driven by an exploding wire discharge with confined by a rigid capillary. The qualitative evaluation of the electrical conductivity for the DLC WDM requires a small electrical conductivity of the exploding wire. To analyze the electrical conductivity of exploding wire, we have demonstrated an exploding wire discharge in water for gold.

The WDM generation by using pulsed-power discharge is qualitative evaluation of the electrical conductivity and the other plasma parameters. However, the pulsed-power discharge is difficult to make the WDM for insulator. To evaluate the electrical conductivity for DLC WDM, the shock compression driven by an exploding wire discharge with confined by a rigid capillary is considered. The exploding wire has a huge ablation pressure approximately a few GPa. Thus, the pressure of exploding wire drives the shock heating for the insulator as the DLC membrane which is coated on the wire. The heated DLC membrane state is observed by the ruby fluorescence for the pressure and the emission spectrum

for the temperature. The DLC membrane coated on the wire for gold was fabricated using RF plasma CVD.

The electrical conductivity is measured by the time evolution of voltage-current waveforms. Therefore, the electrical conductivity for the exploding wire should be small compared to that for DLC WDM. The electrical conductivity with the heated diamond at solid density have been reported to be over 10^4 S/m with 1 eV of temperature³⁾. It means that the exploding wire should be less than 10^4 S/m. To confirm the electrical conductivity of the exploding wire, we have evaluated the electrical conductivity of WDM.

We measured time evolutions of the voltage-current waveform, the input energy, the temperature, the resistance, and the hydrodynamic behavior for gold wire with 100 μm in diameter and 18 mm in length^{5, 6)}. The wire/plasma boundary and its temperature strongly depend on the input energy history. The resistance of wire/plasma respected by the voltage-current waveforms is estimated to be $10^3 \Omega$ from the beginning of discharge to 20 μs . It means that the resistance of wire/plasma constitutes the resistance of water. The density of wire/plasma is proportional to the wire/plasma radius. Thus, the exploding wire of gold in dense regime has a highly resistance.

To evaluate the electrical conductivity for low-Z materials as a DLC, we have proposed a concept to investigate the properties of WDM by using pulsed-power discharges. The concept of the evaluation of DLC for WDM is a shock compression driven by an exploding wire discharge with confined by a rigid capillary. The qualitative evaluation of the electrical conductivity for the DLC WDM requires a small electrical conductivity of the exploding wire. To analyze the electrical conductivity of exploding wire, we have demonstrated an exploding wire discharge in water for gold. The results indicated that the electrical conductivity of WDM gold for 5000 K of temperature has an insulator regime. It means that the shock compression driven by the exploding wire discharge with confined by the rigid capillary is applied for the evaluation of electrical conductivity for DLC WDM.

- 1) R. Kodama, *et. al.*, *Nature*, **412**, 798 (2001).
- 2) T. Johzaki, *et. al.*, *Nuclear Fusion*, **51**, 073022 (2011).
- 3) P. McKenna, *et. al.*, *Physical Review Letters*, **106**, 185004 (2011)
- 4) S. Fujioka, *et. al.*, *Plasma Physics and Controlled Fusion*, **54**, 124042 (2012).
- 5) T. Sasaki, *et. al.*, *Laser and Particle Beams*, **24**, 371 (2006).
- 6) T. Sasaki, *et. al.*, *Physics of Plasmas*, **17**, 084501 (2010).