§13. Interaction between Metal Vapor and High Heat Flux Plasmas using High Current Stabilized Arc Plasmas

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Study of the dynamic response of tungsten surface to the transient and extremely high plasma heat load in type-I ELM's and disruptions (>100MW/m^2) requires experimental approaches different from those in steady state and low heat flux experiments(<10MW/m^2). In the present experiments, high current stabilized arc plasmas with ~GA/m^2 is used as a high heat flux pulse and steady state plasma source. The plasma heat flux onto the cathode surface is several hundreds MW/m^2 in the steady state and is several GW/m^2 in the arc ignition phase. These properties of high heat flux arc plasmas are very useful to study the transient behavior of the divertor materials during ELMs and disruptions in fusion reactor complementally with other ELM/disruption experiments. On the other hand, arc plasmas are used in various devices, such as light sources, plasma arc cutting, electric circuit breakers and ignition plugs, etc. It is very important to understand the physical and chemical interactions of the high heat flux arc plasmas with the refractory metal cathode for improvement of these industrial devices. In the present experiments dynamic interactions of high current density arc plasmas with hot metal cathode are studied using a plasma arc cutting device, which can generate stable arc plasmas in a small fixed volume[1)]. Images of the cathode hot spot obtained form a fast color camera show that the rotation of local hot cathode spot heats the Hf cathode surface gradually and forms the larger cathode spot on the center of Hf electrode at t ~100 ms after ignition. The cathode spot area spreads over gradually from the fixed local cathode spot to the whole cathode area. And the cathode emission area becomes larger with increasing the arc current. The temperature distribution estimated from the RGB signals of the color images of the cathode shows that the cathode surface temperature is between 3,700 K and 4,300 K. This temperature is higher than Hf melting temperature(2,503 K) and lower than Hf boiling temperature(4,547 K)[2)]. Thermionic electron emission current density J is calculated from the estimated cathode temperature, supposing that whole cathode surface is solid Hf or solid HfO_2. Thermionic electron emission current IHf and IHfO2 are estimated to be ~160 A and 40 A, respectively when the preset arc current is Iarc=135 A, where IHf/ Iarc=1.2 and IHfO2/Iarc=0.3. To estimate the themionic current J in detail, physical properties of Hf and HfO2 as hot liquid materials are needed[2)] but unfortunately not available at the moment.

Unstable phenomena of the molten cathode pool, such as small droplet ejection acompanying wavy motion of the molten cathode and large dropelet ejection from the cathode, are often observed when a new cathode with a flat cathode surface is used at the first time as shown in Fig. 1. The bubble appears from the molten pool and grows within ~0.2 ms, then evaporates intensively due to the arc plasma heat flux, leading the bubble explosion. After the bubble explosion, cathode spot goes back to the quiet phase. These intensive and dynamic cathode phenomena can not seen in the arc voltage and current measurement. In addtion to the large scale droplet ejection from the cthode during arc plasma generation, fine droplets are ejected just after arc plasma termination as shown in Fig. 2. So far we have used the Hf cathode, which is normally used in arc plasma cutting device. Now we have modifyed it to use tungsten as a cathode in spite of Hf. In near future the interactions of tungsten cathode with the high curret arc plasma of hydrogen or helium will be shown elsewhere.

1) Y. Yamaguchi, et al., Journal of the Japan Welding Society **29**(2011)010 in Japanese.
2) S.Izumi, Data book of metal, Maruzen Company (1984).

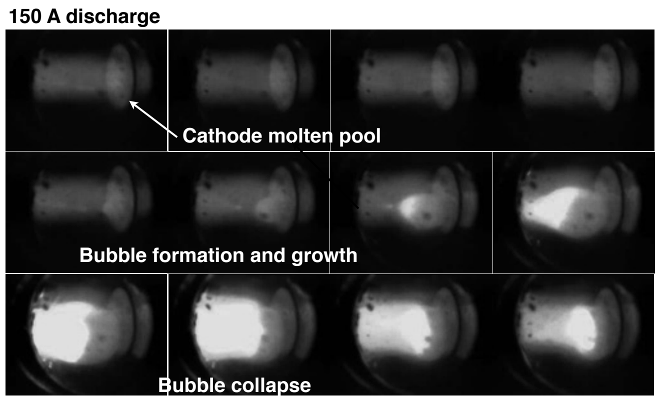

Fig. 1 Frame by frame pictures of abrupt cathode material ejection the from the molten cathode pool after bubble formation and growth. Frame rate is 23000 fps.

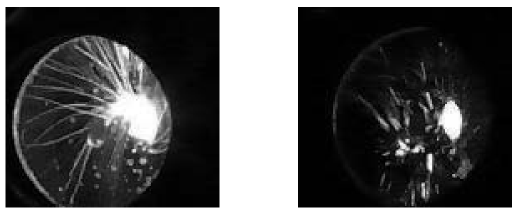

Fig. 2 Fine droplets ejection from the molten cathode pool just after arc termination. Exposre time is 1/8,000 s(left) amd 1/10,000 s(right).