§13. Study on the Interaction between Metal Vapor and Plasma Using Stabilized High Current Arc

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Tungsten, which will be used as a divertor target in ITER D-T operational phase, has many advantages compared to CFC, such as low physical sputtering, low tritium retension, high thermal conductivity, high melting temperature(3695 K) and so on. The usage of tungsten, however, brings another problem different from CFC. The surface modification by hydrogen and/or helium plasma irradiation at elevated temperature has been studied extensively and it has been discussed what are benefits and drawbacks when tungsten is used as plasma-facing components[1].

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)[2] requires experimental approaches different from those in steady state and low heat flux experiments(<10 MW/m^2). Simulation experiments of material erosion in ITER using high power plasma guns have been intensively studied. 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. A scematic diagram of the cutting arc plasma and diagnostics is shown in Fig. 1. The arc current flowing between hafnium(Hf) cathode and anode made of copper is controlled by a DC current source(I_{arc}=10~150 A). This type of arc plasma torch enables us to generate very high heat flux plasmas with good reproducibility. The plasma heat flux onto the cathode surface is several hundreds MW/m^2 in steady state and several GW/m^2 in arc ignition and arc quenching phases[3]. These properties of high heat flux arc plasmas are very useful to study the transient behaviour of the divertor materials during ELMs and disruptions in fusion reactor complementally with other ELM/disruption experiments. In Fig. 2 the abrupt ejection of molten Hf from the hot cathode surface observed by high speed color camera is shown. The bright area in the figure is the hot molten cathode with T=3,500 K ~ 4,000 K. The cathode surface temperature is estimated from RGB intensities of the color camera image under black body approximation. Typical error of the present temperature measurement is estimated to be about 150~200 K. In the experiments disruptive ejection of the cathode molten materials, which may related to some fluid dynamic instabilities, is observed in the steady state arc in addition to the arc ignition phase with pulse ~GW/m^2 heat flux. When a new Hf cathode which has a flat cathode surface is used, a large Hf bubble grows up and then burst to release Hf vapor to the arc plasma column. The generation of the Hf bubble might come from the boiling of Hf molten pool. In near future we will test tungsten cathode with helium arc palsmas using this arc plasma torch.

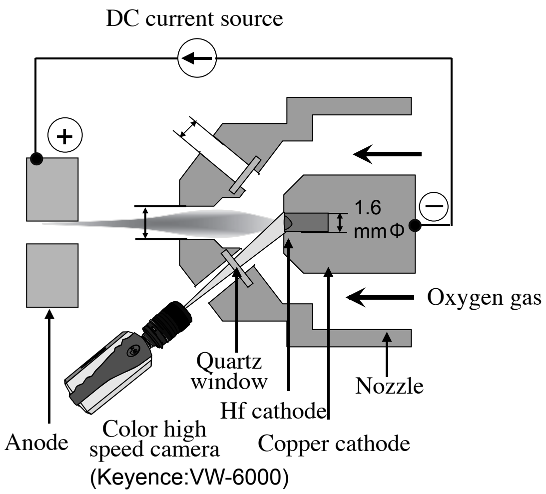

Fig. 1 Schematic diagram of the plasma cutting arc torch and observation of the cathode hot spot.

1) Brooks, J.N., Allain, J.P., Doerner, R.P. et al.:Nucl. Fusion **49**(2009)035007.
2) Hassanein, A., Belan, V., Konkashbaev, I. et al.:J. Nucl. Matter. **241-243** (1997)288.
3) Yamaguchi Y., Yoshida, K., Uesugi, Y., Tanaka, Y., et al.:Journal of The Japan Welding Society **29**(2011)010.

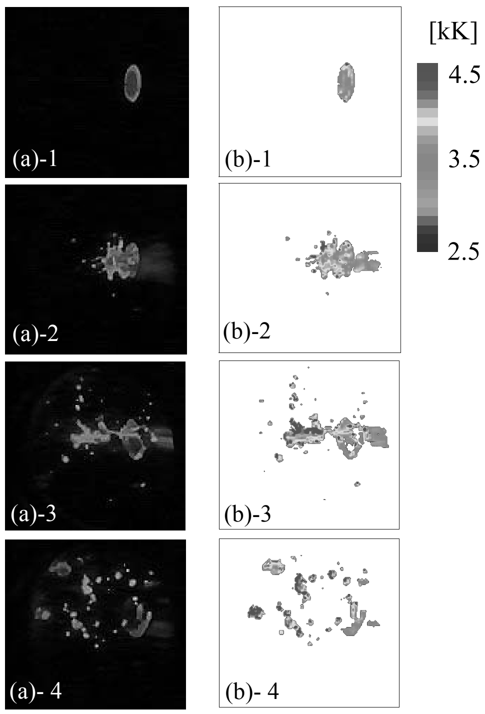

Fig. 2 Abrupt ejection of the Hf droplet from the molten Hf pool as a cathode spot(a-1~4) and the change of surface temperature during the cathode spot instability(b-1~4). Frame interval of each picture from the top to the bottom is 125 μs.