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Metal Plasma Formation in Duhocamis

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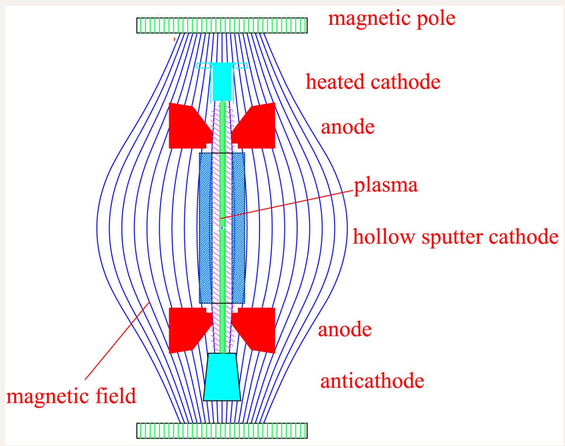
Abstract

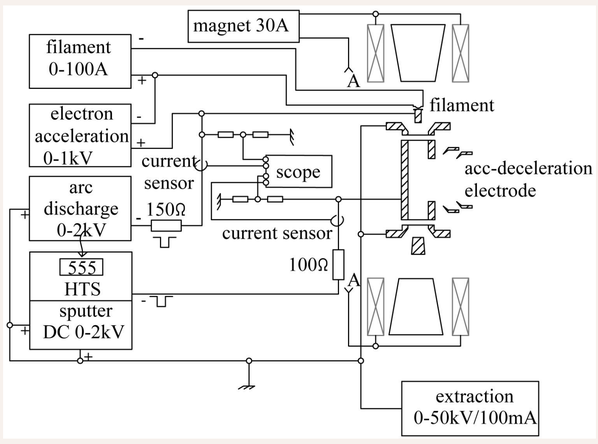
The dual hollow cathode ion source for metal ion beams (Duhocamis) was introduced in 2007. The Duhocamis is derived from the indirectly-heated cathode GSI-PIG ion source and more suitable for producing various metal ion beams. To further understand the discharge characteristics of Duhocamis, a series of arc discharge experiments have been performed on the test bench at Peking University. The transfer process from PIG discharge to dual hollow cathode discharge (DHCD) mode in the source was observed by changing the sputter voltage, and the metal ion ratio of > 90% for DHCD was measured.

Experimental setup and experimental conditions

Experimental condition: cathode heating power of about 900 W, constant Argon flow of 1 cc/min, a pulsed arc power supply with pulse width of 1 ms and repetition rate of 10 Hz. Half of the sputter cathode used in these experiments is aluminum and another half is copper. The extraction slit is on the copper electrode part. The ion source magnetic field was set at 0.26 T, around which field strength the discharge is not sensitive to the variance of magnetic field.



Schematic drawing for discharge body



Power supply system for Duhocamis

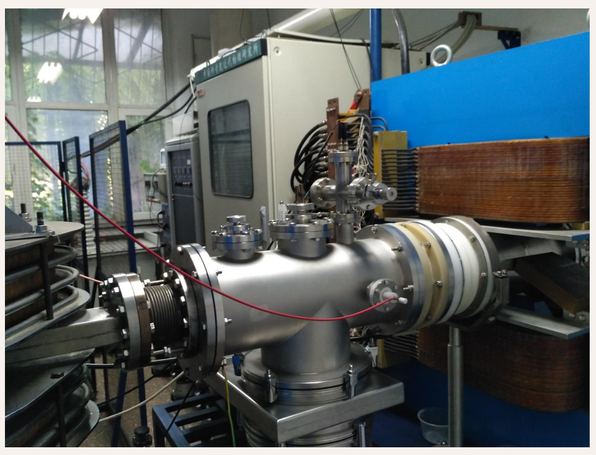


Photo of Duhocamis

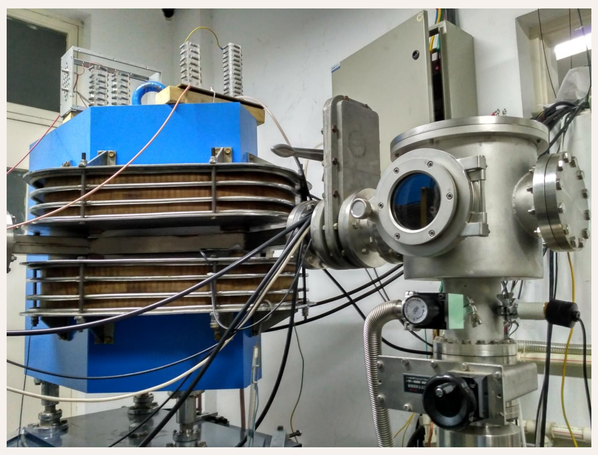
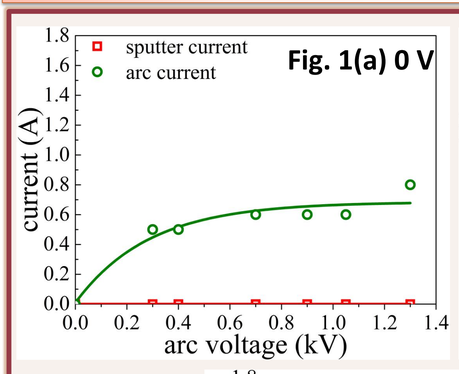
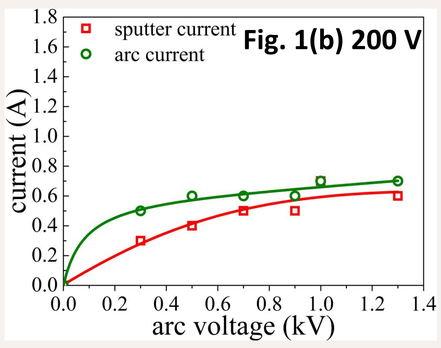
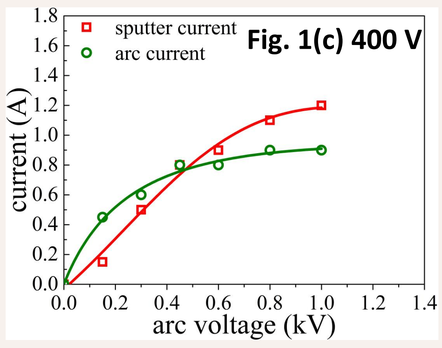


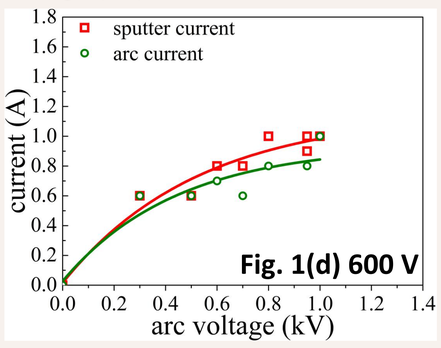
Photo of analysis magnet and target chamber

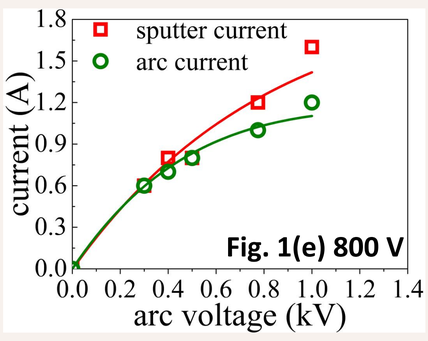
Experiment 1 - Effect of arc voltage on sputter current





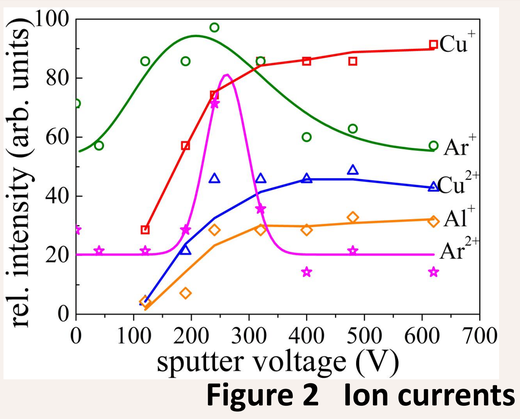






The arc current is higher than the sputter current when the hollow cathode power supply voltages are at 0 V and 200 V. When the hollow cathode power supply voltages are higher than 400 V, the arc current can be lower than sputter current. Those current variance is corresponding to the following plasma formation process. The arc discharge produces heated-cathode plasma, which is primordial plasma and mainly consists of Ar ions. Then the heated-cathode plasma will move to the hollow sputter cathode tube under the force of the sputter electric field and magnetic field, thus the hollow cathode plasma can be initiated. Hollow cathode plasma can be stronger than the heated-cathode plasma when the hollow cathode power supply voltage is > 400 V. In this condition, the Ar ions acquire enough energy and sputter out metal atoms and secondary electrons from the hollow cathode. Therefore, part of sputtered metal atoms are ionized. The hollow cathode plasma are strengthened further by ionized metal ions and significantly decrease the content of gas ions, which is related to the higher sputter current.

Experiment 2 - Effect of hollow cathode discharge on metal ion current



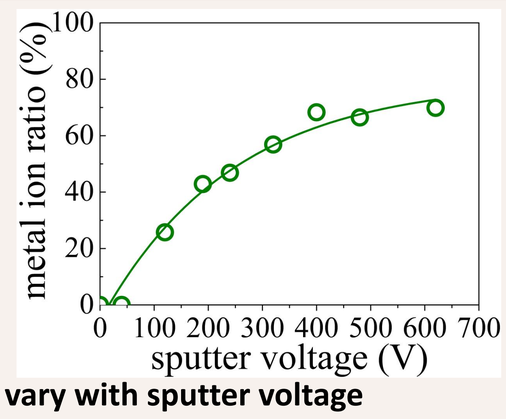


Figure 2 Ion currents vary with sputter voltage

With increased sputter voltage, the ion currents of Ar^{+} and Ar^{2+} first increase, reach their maximum at sputter voltages of about 200 V and 250 V, respectively, and then decrease. The currents of metal ions (Cu^{+}, Cu^{2+} and Al^{+}) increase fast from zero to their respective steady values, when the sputter voltage increases from 0 to ~ 400 V. The metal ion ratio is about 50% at the sputter voltage of about 250 V. It shows that the hollow cathode plasma is initiated by PIG discharge and then the discharge enters new discharge mode — the dual hollow cathode discharge with a sputter voltage of more than 250 V, in which the hollow cathode plasma mainly consists of metal ions of Al and Cu.

The metal ion ratio increases rapidly with the sputter current from 0.8 A to 1.2 A. The metal ion ratio can reach to about 90% when the sputter current rises up to 1.6 A. It is nearly pure metal ion plasma.

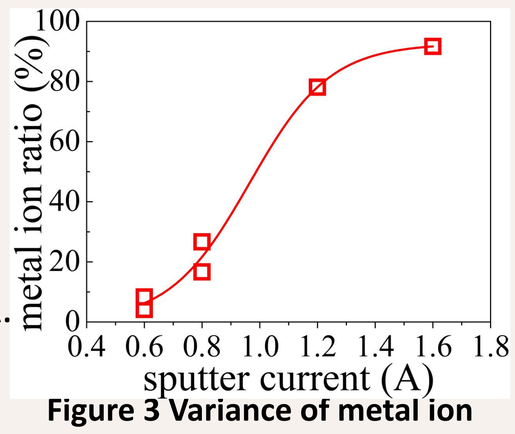


Figure 3 Variance of metal ion ratio with sputter current

Conclusion

In Duhocamis, discharge mode transition happens at the sputter voltage of ~ 250 V, if we define DHCD mode is the case that the metal ions ratio is larger than 50%. The metal plasma formed in the tubular-hollow sputter cathode is mainly controlled by the sputter voltage. It is possible to obtain nearly pure metal plasma (about 90% of metal ions) at high sputter current together with high arc current.