High voltage pulses generation in the plasma-beam discharge

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The work considers an application of unstable regimes of the plasma-beam discharge for high-voltage pulses generation. Pulses of negative voltage could be obtained at beam collector electrode under constant negative bias of about 100-300 V. The discharge instability is caused by the presence of the thin dielectric film (5-10 nm) on the electrode surface. The negatively biased electrode will obtain the N-shaped CVC (Fig.1) with a portion of negative differential resistance if the secondary e-e emission coefficient for plasma hot electrons becomes large ($\sigma >> 1$ in presence of a thin dielectric film due to field emission) and if the overall current of supra-thermal electrons is rather large (could be in presence of the electron beam in plasma).

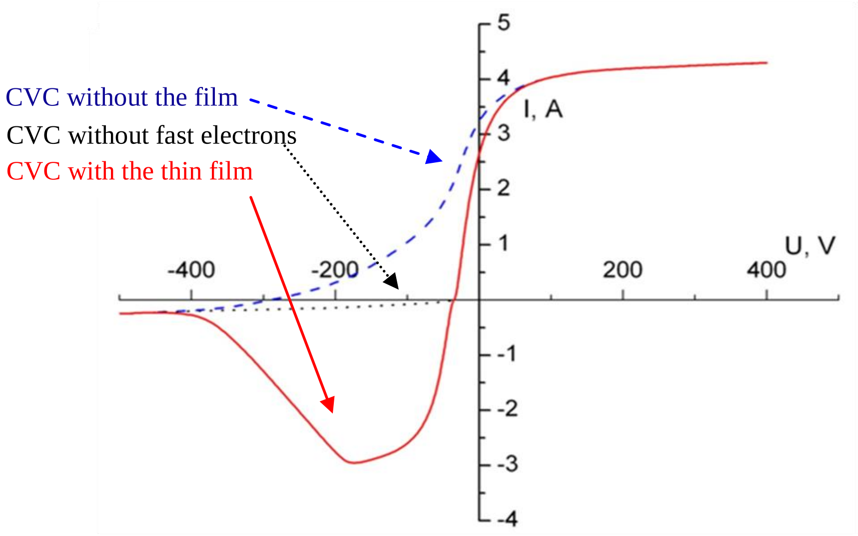

Fig.1. The role of a dielectric film and fast electrons in N-shaped CVC formation

Fusion reactor plasma facing materials – W and Be could have a dielectric oxide film on the surface suitable for N-shaped CVC formation, as it was observed in experiments with Al electrode (equivalent to Be) [1] and ITER-grade W electrode (Fig.2). With the working point in the region of negative resistance (achieved by the proper biasing) one could obtain the relaxation oscillations regime in the discharge circuit (bias source – external inductance – electrode – sheath capacitance – plasma – ground). The voltage pulse amplitude could be increased by the increasing the external inductance, but the maximum amplitude is limited at a value of about 10 kV by the secondary ion-electron emission current rising.

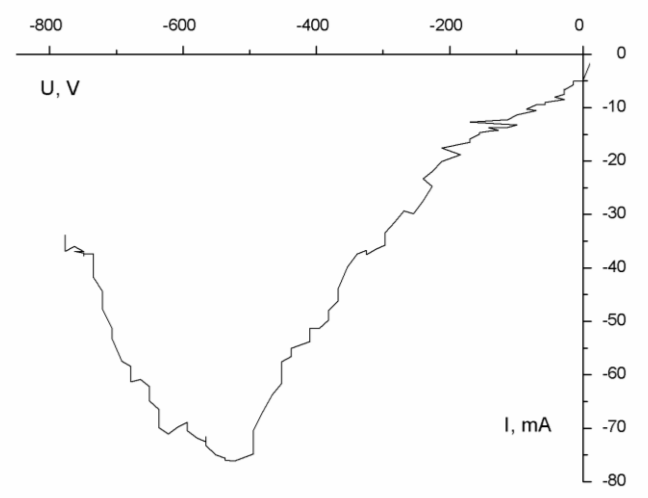

Fig.2. N-shaped CVC of the W electrode

Voltage pulses with amplitude up to 70 kV were achieved in regimes with the discharge current disruptions, when the energy stored in external inductance transfers to the capacity of the plasma-electrode contact (Fig.3).

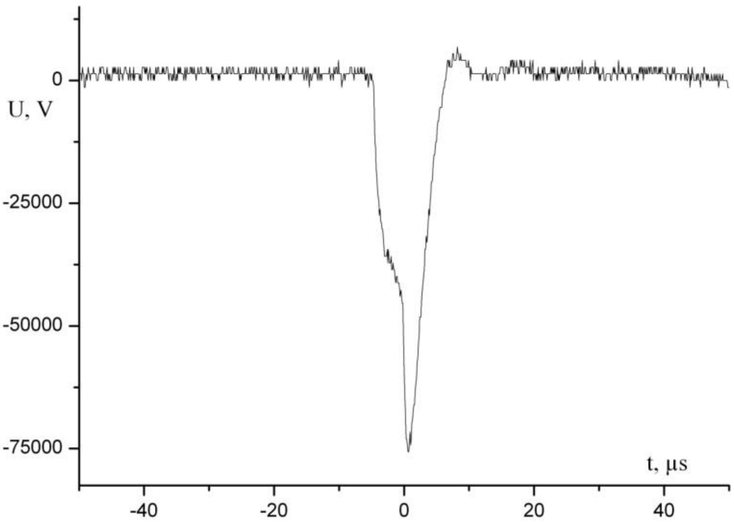

Fig.3. High-voltage pulse due to current disruption from the stable state

The current disruption occurs when the thin dielectric film becomes conductive due to the excitation of its electron system under intensive ion and electron radiation. So the secondary e-e emission coefficient becomes small (no field enhancement), electrode CVC becomes smooth (instead of N-shaped) and current through the plasma-electrode contact reduces to the standard level.

Such switching of the film to the conducting state could be achieved only in high density plasma with a high discharge current – in our experiments it was the auto-oscillating helicon discharge or the vacuum arc discharge regimes of the plasma-beam discharge (Fig.4). In the first regime the high voltage pulse was preceded by oscillations at eigenfrequency of plasma filled resonator, in the second one the pulse follows the stable state. The pulse amplitude is limited by leakage currents and parasitic discharges. Dielectric properties of the film are restored within a few microseconds, so the period between pulses is governed by the rising time of the discharge current.

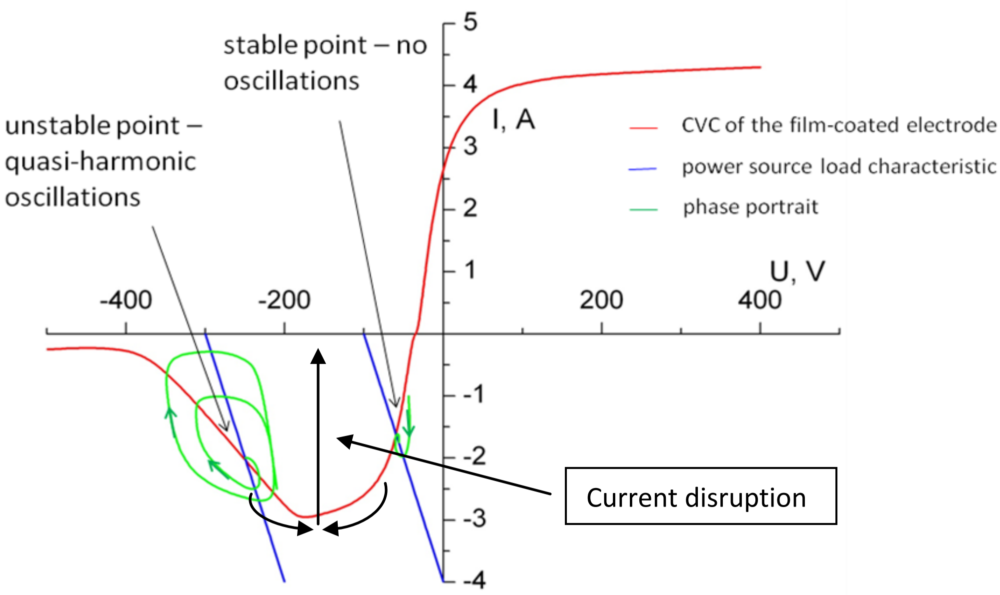

Fig.4. Two ways of current disruption

Such high voltage pulses could be used for the ion accelerating, and with the deuterium discharge this system will be the d-d neutron generator. The main advantages of the method are – no need of high voltage supply, high ion current, refilling of the target with deuterium during low voltage implantation period between high-voltage pulses.

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References

[1] K.M. Gutorov, I.V. Vizgalov, E.A. Markina, V.A. Kurnaev, Bulletin of the Russian Academy of Sciences: Physics, 2010, Vol. 74, No. 2, pp. 188–191.