

CARBON SPARK EVAPORATION

The invention relates to a method for the cathodic spark evaporation of carbon targets or targets with a high carbon content for the production of carbon layers or layers that contain a high proportion of carbon.

In particular, the invention relates to the production of hard carbon layers that exhibit no or only a small hydrogen content and whose hardness can be varied over a wide range.

According to embodiments of the invention, a device is proposed that may enables the spark to be ignited at low voltages electrically, i.e. without mechanical ignition contact, and with the possibility of a correspondingly high repetition frequency.

This device may further enables the spark to be directed safely on a carbon target even of smaller surface and with a small or no magnetic field enhancement, in order to guarantee a reproducible coating under vacuum.

~~In a further aspect, according to the invention a~~ device and a method are also described that may enable the proportion of the multi-charged carbon ions to be controlled during coating and the coating rate to be modified.

The advantageous combination of method and device is used to strongly inhibit resp. to prevent splatters that are generated during spark evaporation from being integrated in the deposited layer.

Finally, embodiments of the invention relates to a hydrogen-free carbon layer produced with this method by using the disclosed device and whose hardness and surface roughness can be varied to a large extent and with which the tribological system consisting of coated body and the respective counter-body can be specifically optimized.

An important execution of the layer consists in doping with other elements, in particular with metals and gases, without however larger quantities of hydrogen being integrated.

The advantage of method B is the comparatively high voltage when igniting the spark (positive influence on the generation of multi-charged C-ions) and the possibility of adjusting the spark duration in such a manner that the spark (for example during ignition in the middle of the target) is interrupted before it reaches the target edge and jumps over onto other materials. The frequency of the pulses is limited mainly by the speed of the ignition mechanism. Most ignition methods, however, are unreliable and/or cause disproportionally high costs at high frequencies and over long process times, as already discussed above.

In view of the above, it would be desirable to have a method that operates with low or no DC current portion, yet at the same time has a high burning voltage in the pulse, with which it is additionally possible to work with high frequencies and wherein the pulse ignition is achieved reliably and efficiently.

The disadvantages of the different methods for igniting and operating a cathodic spark on a carbon target can be summarized as follows: the methods so far for spark evaporation are based either on a DC spark current overlaid with pulses or on intermittent sparks operated with additional ignition devices. The pulse superimposition of method A merely results in small overvoltage spikes of the spark discharge in the pulse rise and the associated comparatively lower generation of multi-charged ions. The necessary charge time of the capacitor furthermore limits the duty cycle of the pulse portion. The frequent ignition during pure pulse operation in method B reduces either the reliability of the coating process and/or can be achieved only by means of very expensive solutions.

Embodiments The aim of the invention seek is to propose a method for the cathodic spark evaporation of carbon, with which it is possible to achieve ignition sequences at very high frequencies and short pulse durations without the limitations of method A (permanent underlying direct current) and of method B (ignition at each pulse) being necessary.

Advantageously, it should be possible to combine this ignition method both with a "slow" initial ignition, as can be used with method A, and also with "fast" ignition methods of the

discontinuous pulse operation that do not rely on a mechanical contact as described by Anders et al.

Embodiments of the invention seek to~~should~~ enable a discontinuous pulse operation without an additional ignition mechanism from another source being required after the initial ignition.

Embodiments~~An essential aspect of the invention also seek to enable~~ is the possibility of adjusting the value of the discharge current for the pulses, in order to specifically influence the degree of ionization of the carbon vapor.

Embodiments~~Another aim of the invention also seek~~ is to propose a coating method for the production of carbon layers that may enables a variable pulse-pause ratio during spark coating in order thus to achieve an optimum coating rate setting on the substrate.

The inventive method may~~should~~ additionally constitute an improvement of method A by providing, in combination with multiple pulses consisting of a fast sequence of individual pulses with short pulse times, a possibility for considerably increasing the discharge voltage of the spark discharge as compared with the discharge voltage of conventional direct current spark discharge.

According to a first aspect of the present invention, there is provided a method for operating a pulsed discontinuous spark discharge that is achieved by means of the discharge of at least one capacitor and where the corresponding discharge current is controlled by periodical switching on and off of the capacitor, wherein when the capacitor is switched off during the switched-off time intervals, no current is supplied from the supply, characterized in that within the switched-on time intervals the discharge current is momentarily interrupted upon reaching a previously determined threshold, with the result that subpulses occur within the pulses.

According to a second aspect of the present invention, there is provided a method for operating a cathodic spark evaporation, characterized in that the spark evaporation is operated by means of a spark discharge as defined in the first aspect.

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According to a third aspect of the present invention, there is provided a method for coating substances that comprises the following steps: providing substrates, placing the substrates in a vacuum chamber, pumping out the vacuum chamber and performing a cathodic spark evaporation of the kind described above.

~~The aim is attained in that d~~During cathodic spark evaporation, the spark discharge is achieved by means of the discharge of at least one capacitor and the corresponding discharge current is controlled in a usual manner by the periodic switching on and off of the capacitor, wherein according to embodiments of the invention within the switched-on time intervals the discharge current is briefly interrupted when it reaches a predetermined value. This leads to further pulses occurring within the pulse, which will be referred to hereinafter as subpulses.

Surprisingly, to initiate the subpulses no direct current portion may be required, i.e. within the pulse the spark discharge can be readily restarted after the voltage has been switched off. An ignition triggered externally may ~~is not~~ be required. Maintaining the spark by means of a direct current portion may ~~is also not~~ be required also.

Even more surprising, however, is that due to the subpulses, after expiration of the pulse itself, after the capacitor has been switched off and at the end of the rest interval, switching on the capacitor will cause the spark discharge to start again, and this readily, i.e. without an ignition triggered externally being necessary. A base current between the pulses ~~is~~ therefore may ~~also not be~~ necessary. By contrast to the state of the art, the spark operation occurs according to embodiments of the invention with considerable interruptions.

This may ~~have~~ has the advantage, on the one hand, that thanks to the subpulses within the switched-on time intervals, the ionization of the evaporated particles may increases significantly. On the other hand, the possibility of reigniting the spark after the period of rest merely by switching on the discharge voltage may ~~have~~ has the advantage that the coating rate can be restricted without any problem and there is thus the possibility of achieving hard carbon layers with a high number of sp³.

There is as yet no complete explanation as to why the reigniting to subpulses as well as the renewed ignition after the rest interval is readily possible. The inventors however presume that the increased degree of ionization of the evaporated particles lowers the ignition threshold to such an extent that even a small voltage is sufficient for reigniting the spark. It is hypothesized that, possibly due to the inertia of the ionized particles, this applies in particular also after the end of the rest interval. It is important to note that the question as to how long the rest intervals between the pulses can be chosen depending on the pulse duration and the number of subpulses, will depend directly on the actual conditions of the spark evaporation facility used. It is however easy for the one skilled in the art to determine experimentally the duration of the rest interval at which the spark no longer ignites.

The invention will be described in detail on the basis of examples and with the aid of the figures, without this limiting in any way the general inventive idea.

The figures show:

Fig. 1: diagrammatic representation of method A (state of the art)