Dynamics of a nanosecond diffuse pin-to-plane discharge – Effects of pin material at high overvoltage

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The dynamics and propagation speed of a pin-to-plane discharge generated in atmospheric air under high nanosecond overvoltage is analyzed and discussed for different pin materials. Pulses of 85kV with 2ns rise time are applied to a conical pin electrode made of different materials: aluminum, titanium, stainless steel, copper, molybdenum and tungsten. Discharge propagation speed is derived from sub-nanosecond time resolved imaging of the discharge front location with an accuracy of 0.3 mm/ns. Results clearly show the slowdown of the discharge with the tungsten electrode and, to a lesser extent, with aluminum. For these two materials, the average speed is decreased respectively by 20 and 10 % compared to the case of copper electrode.

1. Introduction

Pin-to-plane discharges generated under very high overvoltage (> 500%) nanosecond pulses, showing a large and diffuse pattern in atmospheric air, are not extensively studied and fully understood [1]. At such high voltages, the very intense electric field at the pin might induce non local mechanisms and specific behaviour (runaway electrons, X-ray emission). Some previous studies, in similar configurations, seem to show X-rays emission from the electrodes [2], which should depend on their material type since X-rays would arise from high energy electrons impact on the electrodes. Within this scope and considering that possible X-rays could influence the dynamics of discharges by photo-ionization effects, our study focuses on the only effect of the pin electrode material on the propagation speed, all the other experimental parameters remaining unchanged.

2. Experimental

The diffuse discharge starts to develop from a pin electrode with a well calibrated conical shape and a tip radius of about 30 µm. It extends and propagates towards a plane at 25 mm from the pin. A very high electric field (> 5000 Td at the pin, down to 20 Td at the plane) is generated by a +85 kV peak voltage nanosecond pulse (2 ns rise time and 5 ns width) at 5 Hz. Experiments are carried out with synthetic air (1l/min) at atmospheric pressure. Light emission from the discharge (mainly N_2(C-B) spectrum) is recorded with an intensified 4-Picos Stanford Camera (200 ps time gate) through a UV-visible lens (F/2.8). Propagation speed is derived from time resolved sequences of the discharge front location. Taking into account the jitter of the camera (100 ps) and the reproducibility of the discharge for given conditions, uncertainty on measurements is estimated to ± 0.3 mm/ns. **Figure 1** shows the results for six different materials classified, on x-axis, according to the energy of their characteristic X emission line (K_α). Electronic impacts can produce X-rays of respectively 1.5, 8 and 59 keV with aluminum, copper and tungsten.

3. Results

Discharge propagation is clearly slower with tungsten pin (speed 20 % less than with copper) and speed reaches lower maxima for decreasing K_α line energy between copper and aluminum. Pin material can have significant effects on discharge dynamics at very high electric field.

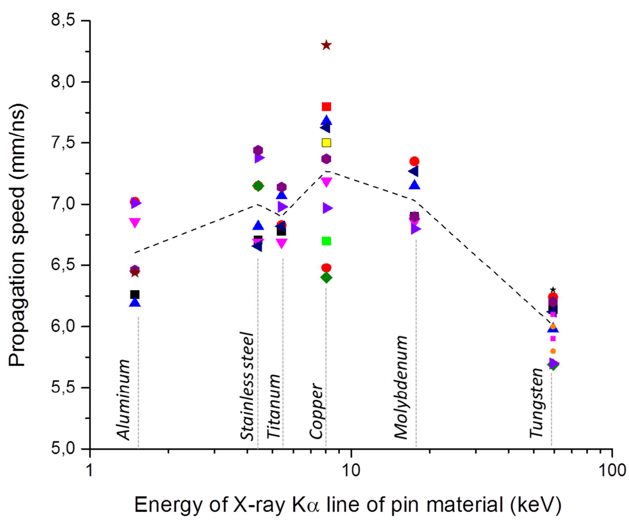

Figure 1. Discharge speed for six different pin anode materials according to the energy of X- ray K_α line

3. References

[1] P Tardiveau *et al* 2016 *Plasma Sources Sci. Technol.* **25** 054005

[2] C V Nguyen *et al* 2010 *J. Phys. D: Appl. Phys.* **43** 025202