Gliding Arc in Noble Gases Under Normal and Hypergravity Conditions

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***Abstract*—This paper describes the gliding arc operated in four different noble gases (helium, neon, argon, and krypton) under normal gravity and hypergravity conditions up to 18 *g*. We studied the influence of gas flow, gas properties, and gravity-dependent buoyancy on the gliding arc behavior.**

***Index Terms*—Atmospheric-pressure plasma, buoyancy, gas flow, gravity.**

GLIDING arc (GA) [1] has been studied for decades, as it is not only a scientifically compelling demonstration of dynamic plasma phenomena, but also a useful plasma source for many applications [2]. In these, the GA is typically operated in air at atmospheric pressure. However, less attention has been paid to the GAs in noble gases.

A typical feature of the GA is its movement along slanted electrodes. The discharge ignites at the shortest distance between the electrodes, then moves upward and finally at maximum elongation it extinguishes owing to insufficient power. The upward movement is due to two phenomena: 1) the GA can be dragged up with upstream gas flow and 2) a thermal buoyancy caused by the difference in mass density between the heated plasma column and the cold surrounding atmosphere is also directed upward. In case of a low or zero gas flow, the buoyancy can be the dominant force moving the GA. As the buoyancy is naturally related to the gas mass density, it increases with rising atomic mass of the used gas and the gravity level.

The effect of gravity on plasmas has been investigated before [3], but to our best knowledge, nobody has studied the GA in hypergravity which tends to emphasize the thermal buoyancy over the gas flow. We did so, using Large Diameter Centrifuge (LDC) [4] in ESA/ESTEC facility in the range of 1 *g*–18 *g*.

We used nearly quarter-elliptic copper electrodes with a minimum distance of 4.5 mm and an initial angle between them of 36° [5], [6]. These electrodes were connected to a current limiting high-voltage transformer supplying 0–10 kV at 50 Hz ac. The configuration was enclosed in a nonconductive discharge chamber with 2 dm^3 inner volume. Front and back walls were made of a heat-resistant glass allowing direct optical observation by digital cameras (Nikon D3100, Canon Power Shot A460). Four noble gases—He, Ne, Ar, and Kr—were selected to cover a wide range of gas mass densities. Their atomic masses are 4, 20, 40, and 84 a.m.u., respectively, giving the mass ratios 1:5:10:21.

Long exposure images of the GAs in four noble gases at 1 *g* are shown in Fig. 1. The gas flow and discharge voltage are slightly different for each gas to maintain stable gliding movement of the arc. Operating in ac, the arc filament periodically brightens and dims, which in combination with upward motion, forms a typical striped structure in the images. This allows a direct visualization of spatiotemporal GA evolution with 10 ms time intervals. The main difference in operation of the GA in different noble gases is, besides the apparent color due to dominant spectral lines, the minimum gas flow needed for the arc to glide (0.4 slm for He, 0.15 slm for Ne, and 0 slm for Ar and Kr). The maximum height achieved by the arc before extinguishing also differs. We did not find any conditions (gas flow 0–2.5 slm, discharge voltage 0–10 kV), for which the GA in helium and in neon would extend above the electrode region, whereas the GA in argon and in krypton often rose above the electrodes. This is caused by lower ionization potential of heavier gases which permits to sustain a longer channel at given maximum voltage.

The influence of hypergravity is demonstrated in Fig. 2 in which Kr is shown because the gravity-induced effects were the most significant for this heavy gas. When the gravity (and consequently the buoyancy) increased, the speed and frequency of gliding increased as well, whereas the maximum height reached by the filament decreased. We attribute the lower maximum height to the inhibiting effect of increased ion losses and discharge channel cooling by convective flow.

The experiments in the LDC have shown pronounced effects of gravity on the ac gliding discharge at atmospheric pressure. The effects were stronger for the heavier gases because of increased thermal buoyancy. The maximum extension of the filament before extinguishing, the gliding velocity, and the frequency of appearing of new filaments were the most affected parameters. In higher *g* levels, the plasma filaments moved quicker, tended to reach lower maximum height and the

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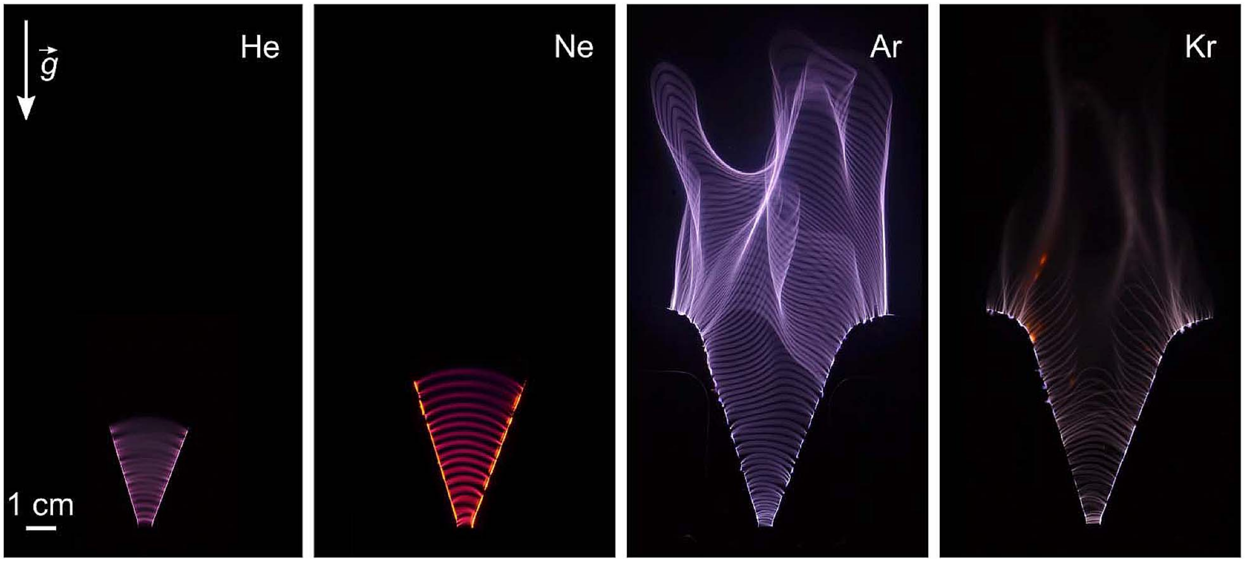

Fig. 1. Left to right: photographs of gliding arcs under normal gravity conditions, in helium (1 slm, 4 kV, 1 s exposure), neon (0.5 slm, 4 kV, 0.5 s exposure), argon (0.1 slm, 5.2 kV, 1 s exposure), and krypton (0.1 slm, 3.7 kV, 1 s exposure).

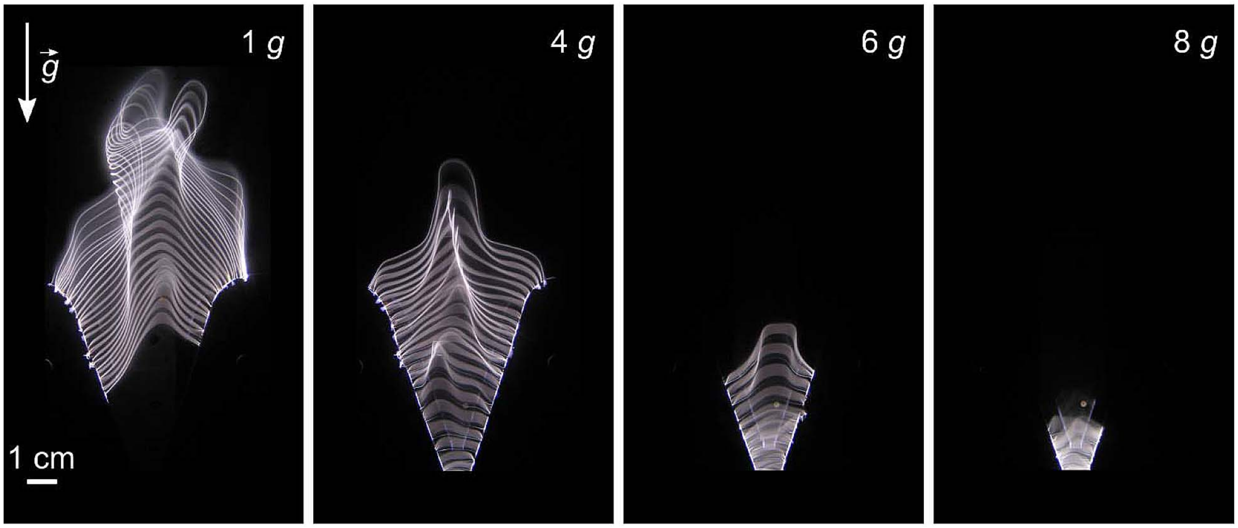

Fig. 2. Photographs of gliding arc in krypton (0.4 slm, 4 kV, 0.3 s exposure) under normal gravity and under hypergravity conditions. Left to right: apparent gravitational levels: 1 g, 4 g, 6 g, and 8 g. Appearance of the discharge for 10–18 g is essentially the same as in the 8 g image presented here.

whole lifecycle of one filament was shorter. Thus, the effect of increased gravity is quite similar to the one of increased gas flow.

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