Double Layers & Striations in Spherical Plasmas

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The observations of and research on double layers and striations in gas discharges has a long history. The study of plasma double layers underwent a resurgence of interest in the 1970s by, notably, Noah Hershkowitz and his collaborators. Most of the research over the decades has involved collisionless gases p << 1 mTorr in, typically, Ar or He. In 1997 the Russian group of Nerushev, *et al.* [1] began publishing a series of articles over a period of about 17 years on striations in collisional molecular gases in an anode centric divergent spherical geometry. The gases used were acetone and methanol in N_2 at pressures of p > 0.1 Torr. The most significant observation of theirs was the formation of spherically symmetric striations around the high voltage anode. They never reached a conclusive explanation of their existence and stability. Examples of such striations are shown in Figure 1. These are photographs of mine were taken of a gas discharge in H_2 containing a small mole fraction of N_2 (Childs, Clarage, and Anderson,

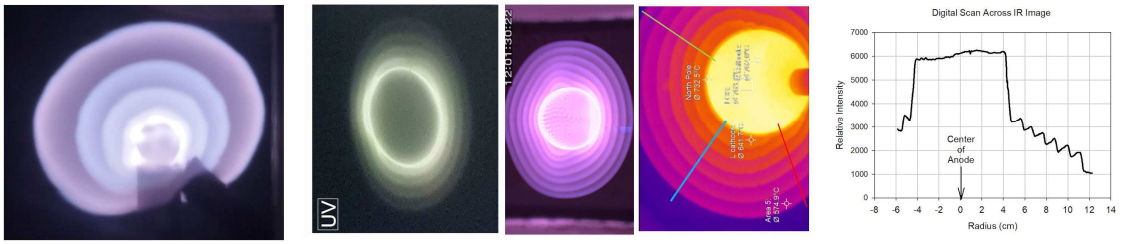

Figure 1: L to R: photo of H_2 plasma with 6mm anode; UV, Visible, IR images, the last showing an anode (diameter 8 cm) temperature of 763 C; a density scan across the IR image

unpublished). Performing Abel's transform on the scan shows that the emissivity of the bright regions is about three times that of the dark regions. These are double layers and more. The dark regions are potential minima where the electric field goes through zero and reverses. I proposed in 2015 [2] that the potential wells are due to negative ions. Indeed, even molecules used in the Russian experiments dissociate into more simple electronegative species such as CO and H_2. Measurements by others on very low pressure plasmas and my own modelling and simulation of this plasma show that dominant ions tend to be NH_3^+ and NH_4^+, the dominant neutral fragment is NH_3, and the negative ions are H^- and NH_2^-. The negative ions form at low E/N, *i.e.* in the dark regions.

My observations are that the plasma does not shift into the striated mode until there is a disturbance, such as a diffuse arc to ground or spikes in the applied DC voltage – I will show videos of this process. They tend to be preceded by anode spots. Once formed the striations are very stable and may persist for hours unless perturbed by voltage, current, or gas pressure and composition changes. The addition of a small amount of Ar, for example, destroys them.

Acknowledgement: The experiments were performed *sans* diagnostics by Childs, Clarage, and Anderson in Toronto. I took the photographs of computer monitors using a 24 MP Canon.

References

[1] OA Nerushev, *et al*., *JETP*, **66**, (1997), 711.
[2] WL Morgan and MW Childs, *Plas. Sour. Sci. Technol*.,**24**, (2015), 055022.