External magnetic field effects on the growth cycles of nano dusty plasma

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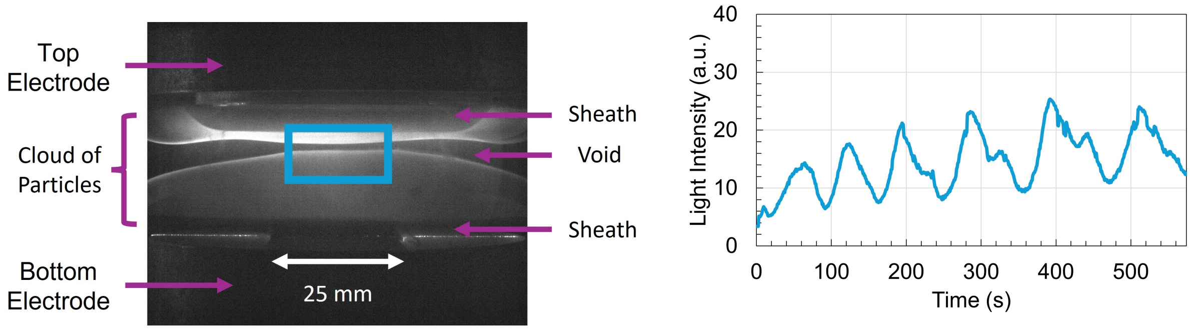
In low temperature plasmas chemical gases can polymerize into nanoparticles can grow via nucleation, coagulation, and agglomeration (also known as surface growth or accretion). This creates a dusty plasma, which is a system that contains all the plasma species and the synthesized solid nanoparticles (dust). The latter can range in radius from $\sim$ 1 - 500 nanometer (nm). Recent examples include the synthesis of titanium dioxide and carbonaceous nanoparticles from either titanium isopropoxide (TTIP) or acetylene, respectively [1, 2, 3].

In capacitively coupled plasma which are commonly used for these experiments, a cloud of dusty nanoparticles is formed in the bulk plasma between the electrodes. The cloud is usually visible via laser light scattering using a visible light laser that can become a stripe or sheet after passing through a cylindrical lens, for example, as seen in Figure 1a. This is truly one complex system where the plasma species and dust are coupled together via forces such as electric and drag. The nanoparticles grow in cycles and when one cycle ends, it is followed by the next generation of particle growth cycle. This can be measured experimentally by analyzing the temporal variation of intensity of pixels in camera images, for example as shown in Figure 1b, by selecting a region in the dust cloud, for example the blue region in Figure 1a.



(a) (b)

Figure 1: The growth cycles of nanoparticles: (a) A cloud of nanoparticles in the plasma, with the blue region indicating the area analyzed. Between the electrodes, the white region corresponds to the nanoparticle cloud, while the darker regions represent the plasma sheaths and the dust void. (b) Growth cycles obtained by measuring the light intensity in the blue region of panel (a) as a function of time, showing six consecutive nanoparticle growth cycles.

The plasma can be monitored using optical emission spectroscopy (OES). For example, if the plasma is ignited using argon, several peaks are shown in Figure 2.

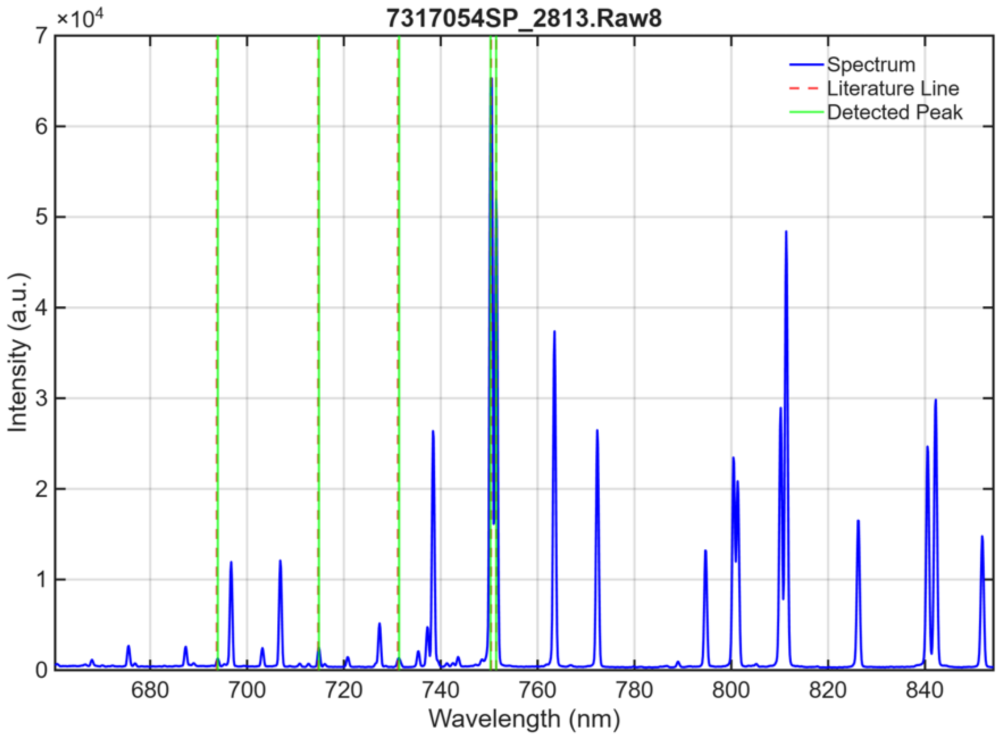


Figure 2: Survey optical emission spectrum of (OES) of the background argon plasma during nanoparticle synthesis showing several argon spectral lines. We have defined "literature lines" as peaks (751.56 nm, 714.70 nm, 750.38nm, 693.76, and 731.17 nm) which are used and described in [4]. We have also highlighted our detected peak close the literature lines.

Various studies in the last two decades have consistently shown the cycle time to decrease with the presence of an external magnetic field during particle growth [5, 6, 7, 8, 9]. Recently, we have attempted to calculate the electron temperature in-situ during the particles' synthesis, using a modified boltzmann plot as presented by F. J. Gordillo-Vázquez et. al. (2006) [4]. We carefully followed equation 8 of their paper, their defined their parameters for example a and b, and extracted line intensities from our OES spectra (figure 2). Our results are shown in Figure 3. We particulary observe: (1) the electron temperature increases with an increasing magnetic field and (2) the cycle time decreases with an increasing magnetic field.

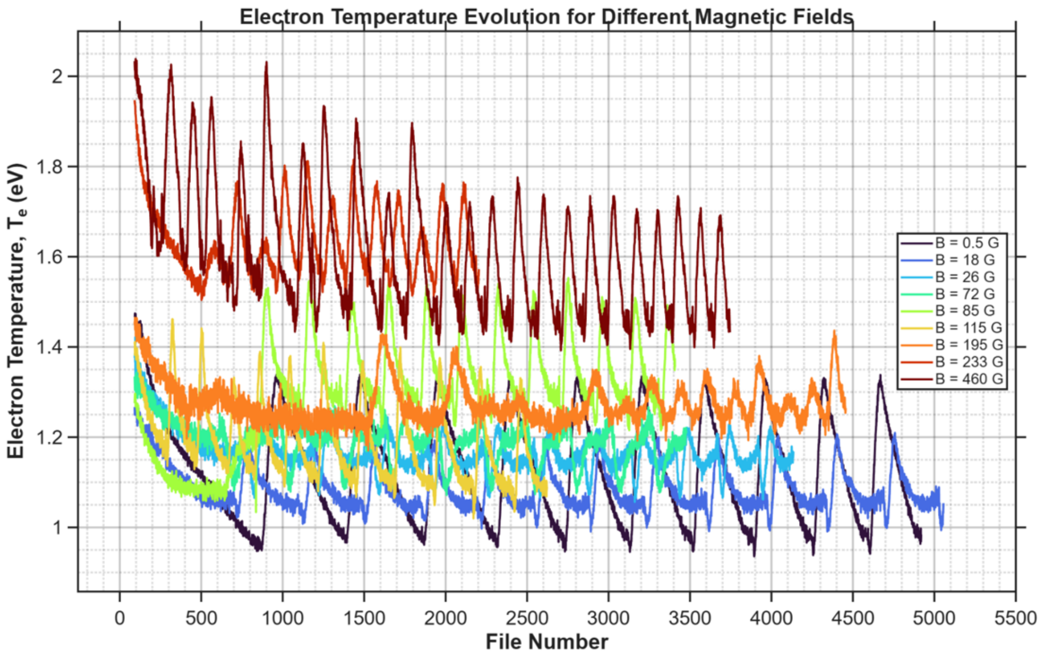


Figure 3: Temporal variation of the electron temperature of the background plasma when exposed to various magnetic fields during nanoparticle synthesis. Each file number represents data collected at an interval of approximately 0.2 seconds.

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