Chamber clearing

L. Bromberg

ARIES Meeting

Madison, WI

September 20, 2001

Motivation

- Aerosols are created in chamber due to large heating flux on surface of liquid
- Aerosols are charged, due to presence of plasma afterglow following the pulse
- Electric fields can be used to remove aerosol
    - Similar to electrostatic precipitators used commercially for removing particulate matter from industrial flows

Structure of talk

- Charge state of aerosols exposed to plasma conditions
- Motion of charged aerosols under the presence of an electric field
- Implications to IFE chamber clearing

Aerosol charging

- In the presence of a plasma, a particulate charge varies as

$$dq/dt = I_{\mathrm{i}}+I_{\mathrm{e}}$$

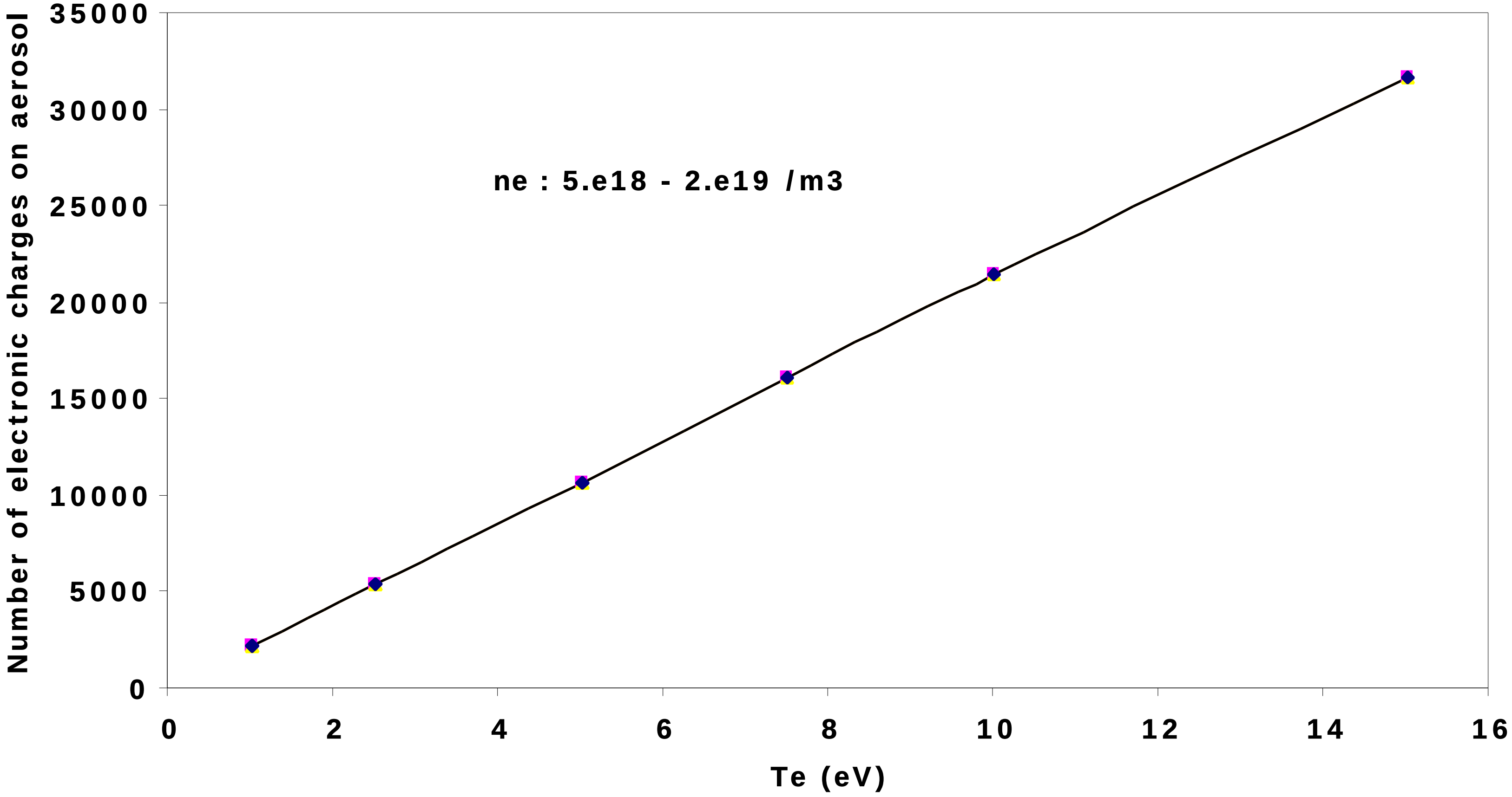
where

$$I_{\mathrm{e}} = - \pi\, a^2\, e\, v_e\, n_e \exp\left(-e^2 \,|\, Z \,|\, / \,\varepsilon_0\, a\, T_{\mathrm{e}}\right)$$

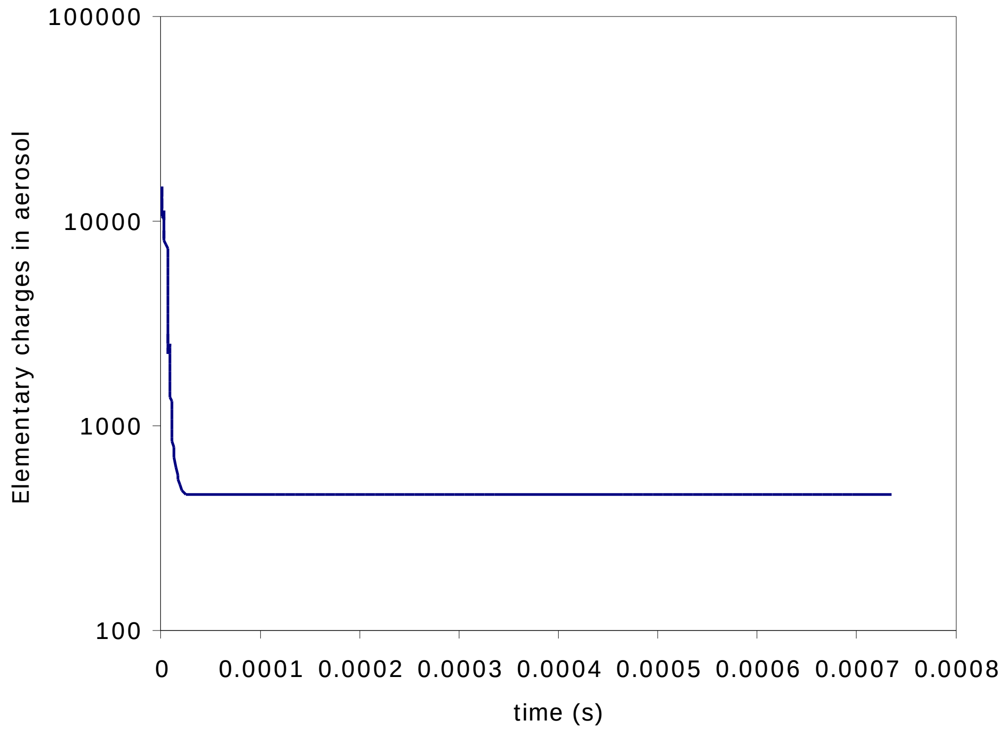
$$I_{\mathrm{i}} = \pi\, a^2\, e\, v_i\, n_i \left(1 + e^2 \,|\, Z \,|\, / \,\varepsilon_0\, a\, T_{\mathrm{i}}\right)$$

- Z is the average number of electronic charges in the particulate
- It is assumed that all radiation fields have decayed away
  - Good for times > 1 microsecond

Average electronic charge number vs T_e for several densities



Average electronic charge number vs time



- Aerosol charge equilibrates very fast with background
- Aerosol charge not very dependent on initial state
  - Initial aerosol charge depends on radiation field and fast electron/ion bombardment

Aerosol motion in the presence of an electric field

- The motion of a particulate in a gas under the effect of an applied field is given by:

$$v = Z_p E$$

E is the applied electric field and Z_p is the particulate mobility:

$$Z_p = q_p C_c / 3 \pi \mu a$$

where

q_p is the particulate charge
C_c is the Cunningham correction factor
μ is the gas viscosity
a is the particulate radius

$$C_c = 1 + \mathrm{Kn} (1.25 + 0.40 \exp(-1.1/ \mathrm{Kn}))$$

$\mathrm{Kn} = 2 \lambda / a$, λ being the mean free path of the a gas molecule

For Xe at 0.1 Torr, $\lambda = 2.62 \times 10^{-4}$ m

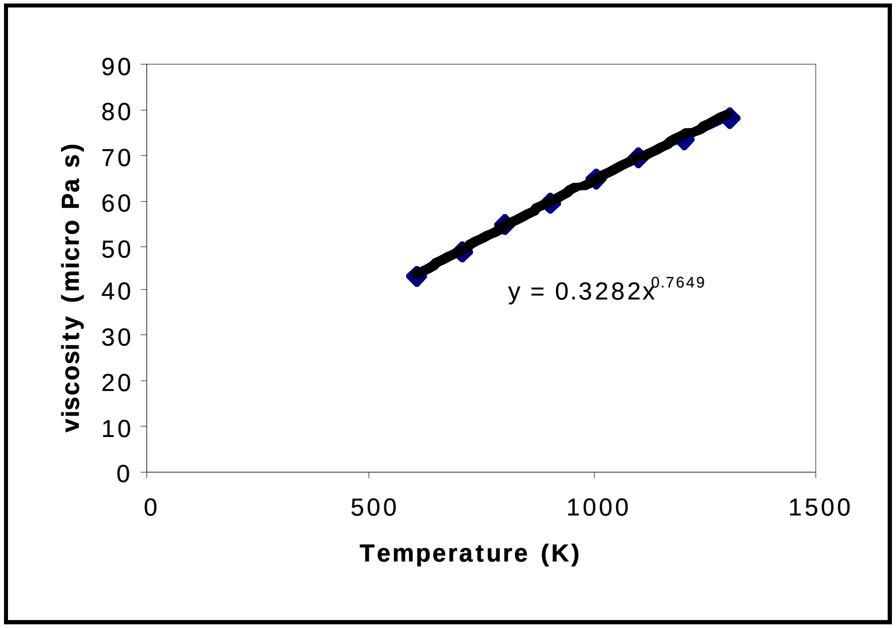
Gas viscosity

- Using the kinetic theory of transport gases (assuming hard sphere collisions):
- $\mu = \mu_0 \, (T / T_0)^{1/2}$

(independent of density!!!)

- For Xenon,
- $\mu \sim 44$ μPa s at 600K

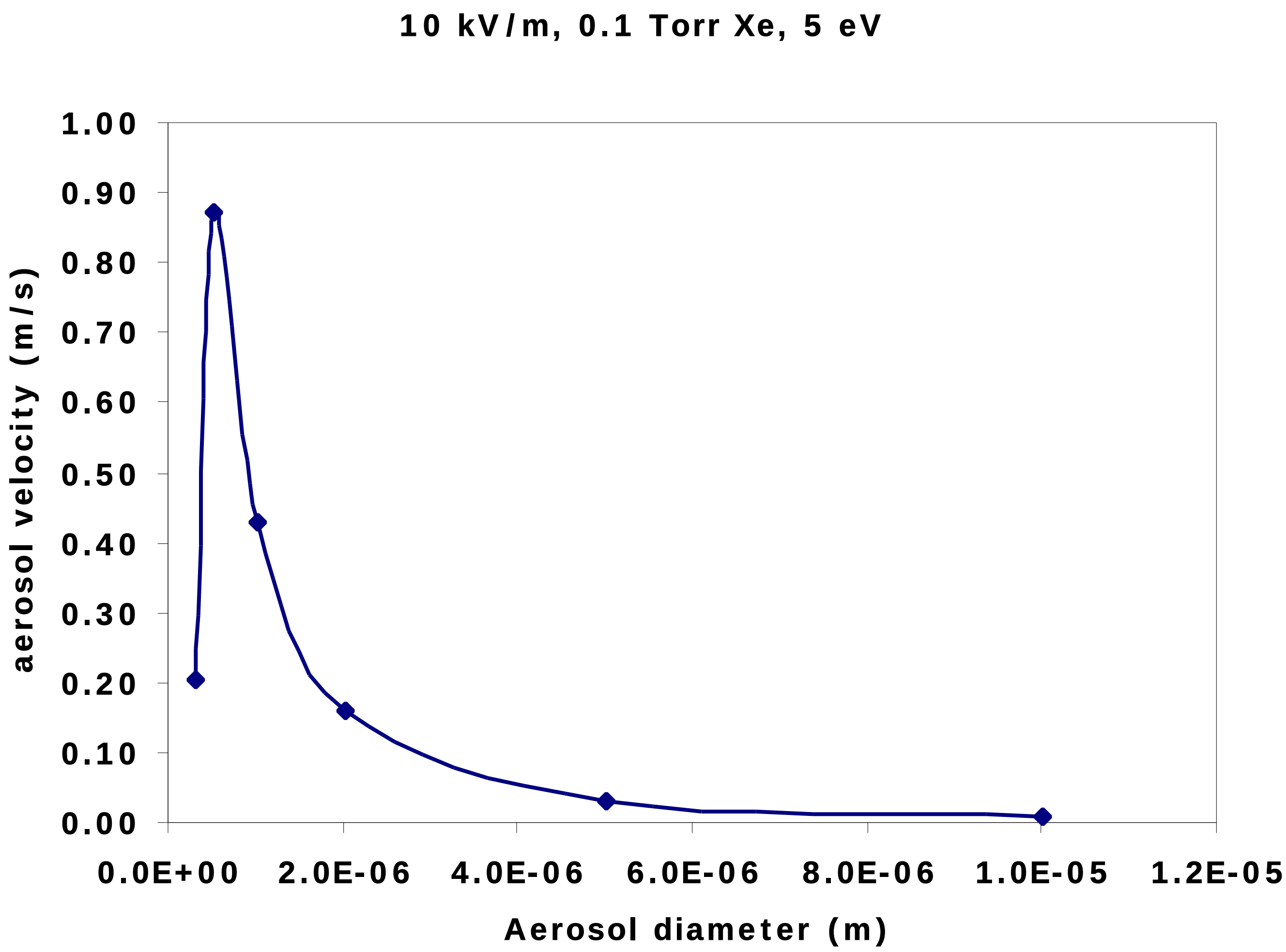
At 2000 K, $\mu \sim 110$ μPa s



Aerosol cleaning

pressure (STP)	Torr	0.1
Electron temperature	eV	5
Viscosity, Xe	Pa s	1.10E-04
Mean Free path	m	2.62E-04
Aerosol diameter	m	3.00E-07
Knudsen number		1747
Cunningham factor		2883
Elementary charges		1.39E+01
Mobility		2.07E-05
Applied electric field	V/m	1.00E+04
Aerosol velocity	m/s	2.07E-01

Velocity of aerosols



Aerosol clearing with electric fields

- Velocity of aerosols is small, compared with the chamber size
  - < 1 m/s

- For a rep-rate of 10 Hz, the maximum distance that the aerosols will be able to move is 0.1 m!

- Unlikely that this approach would work for chamber clearing between pulse.

- Could be used to prevent aerosols from depositing in optics.