DETERMINATION OF GAS TEMPERATURE IN MICROWAVE DISCHARGES SUSTAINED IN ARGON-NEON MIXTURES BY USING PRESSURE BROADENED SPECTRAL LINES

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Use of the van der Waals Broadening of Atomic Argon Lines
to Measure the Gas Temperature in an
Atmospheric Pressure Ar-He Surface Wave Discharge
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Gas temperature is a key parameter to understand the processes that take place in a plasma because this temperature is related to the energy of the heavy plasmas particles which participate in the atomization of molecules and the formation of radicals from the substances introduced into the discharges. The method for the measurement of gas temperature in argon-helium plasma at atmospheric pressure, using the van der Waals broadening of spectral atomic lines, is adapted for the case of argon – neon mixtures. This method is useful especially when the use of OH radicals is difficult or the contribution of these radicals to the plasma pollution is to be avoided.

Though argon is the gas typically used to feed plasmas intended for chemical analysis, when a higher excitation/ionization efficiency is required, argon can be replaced or mixed with helium because its metastable and excited states have higher energies (≥ 19.8 eV) than those of argon (≥ 11.5 eV), thus improving the excitation of atoms and ions in the samples introduced into the plasma. But sustaining a helium SWDs at atmospheric pressure requires high microwave powers (> 1kW) and the use of a cooling system. The energy of neon metastable atoms (≥ 16.6 eV) lies between those of argon and helium, so that this gas can be considered as an alternative to helium. Moreover, SWDs sustained in neon require lower microwave powers (> 200 W) than those operated in helium or argon-helium mixtures. In this way, the use of argon-neon mixtures could be considered as an alternative to pure argon or helium plasmas and their mixtures.

The microwave power was coupled to the plasma by a surfaguide device, resulting in a plasma column that extended to both sides of the wave coupler, giving rise to a direct and an inverse column. The direct column is that where the gas flux and the propagation of the wave take place in the same sense, contrary to what happens in
the inverse

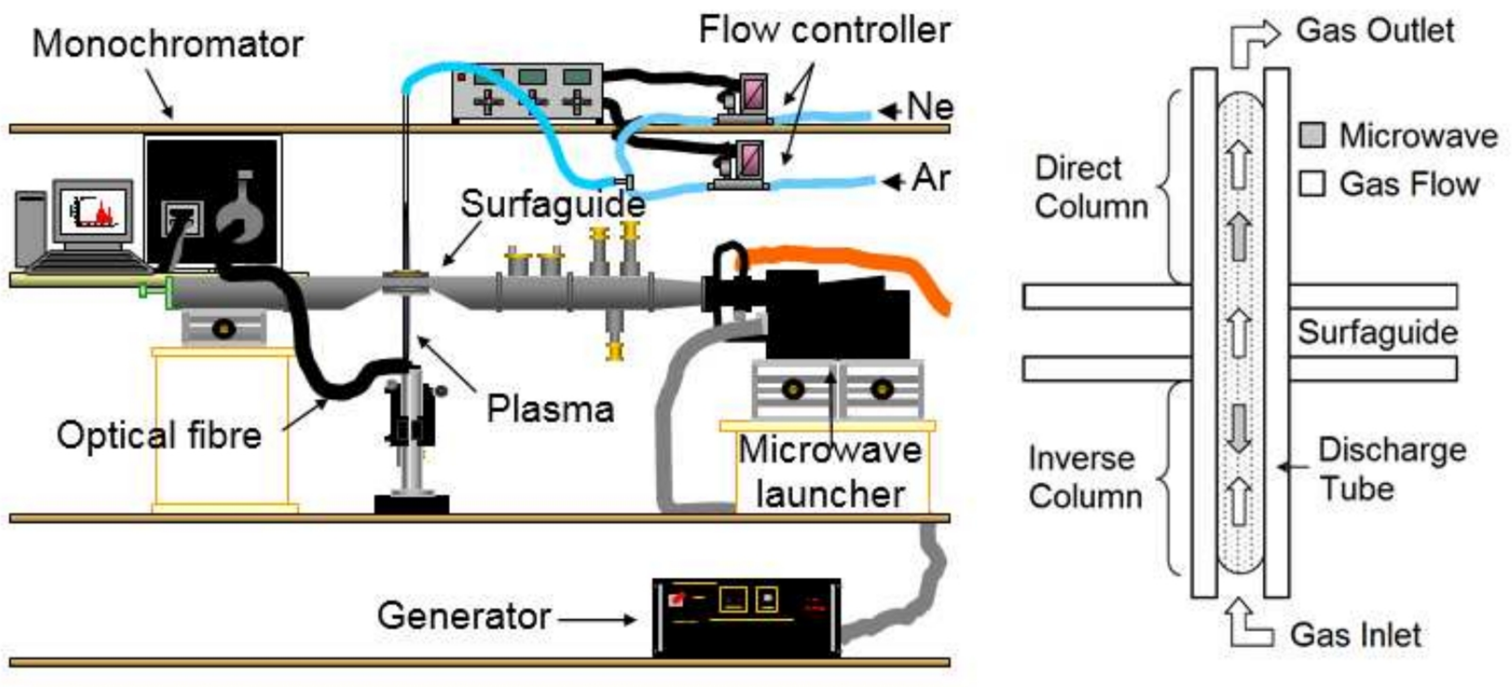
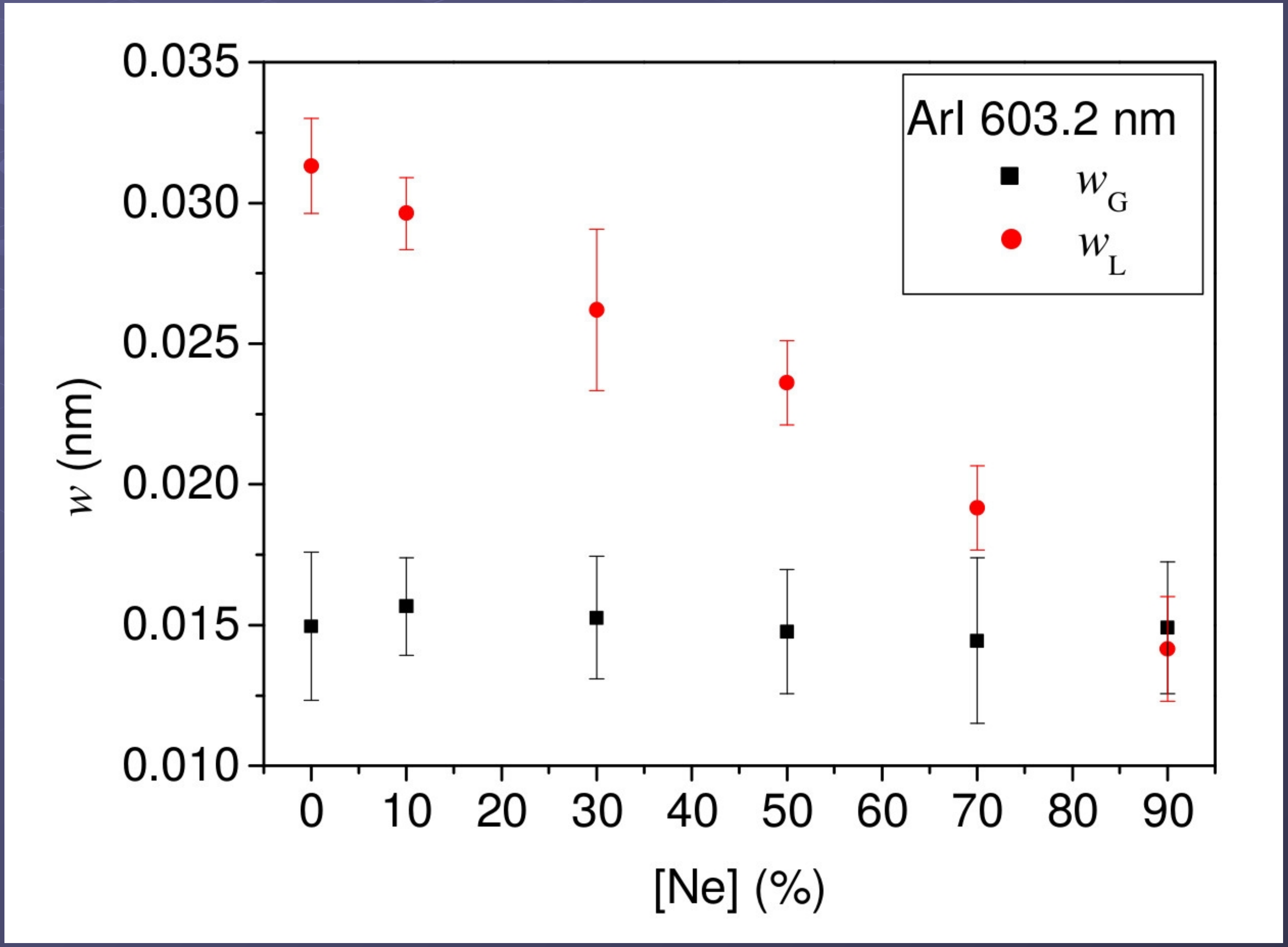


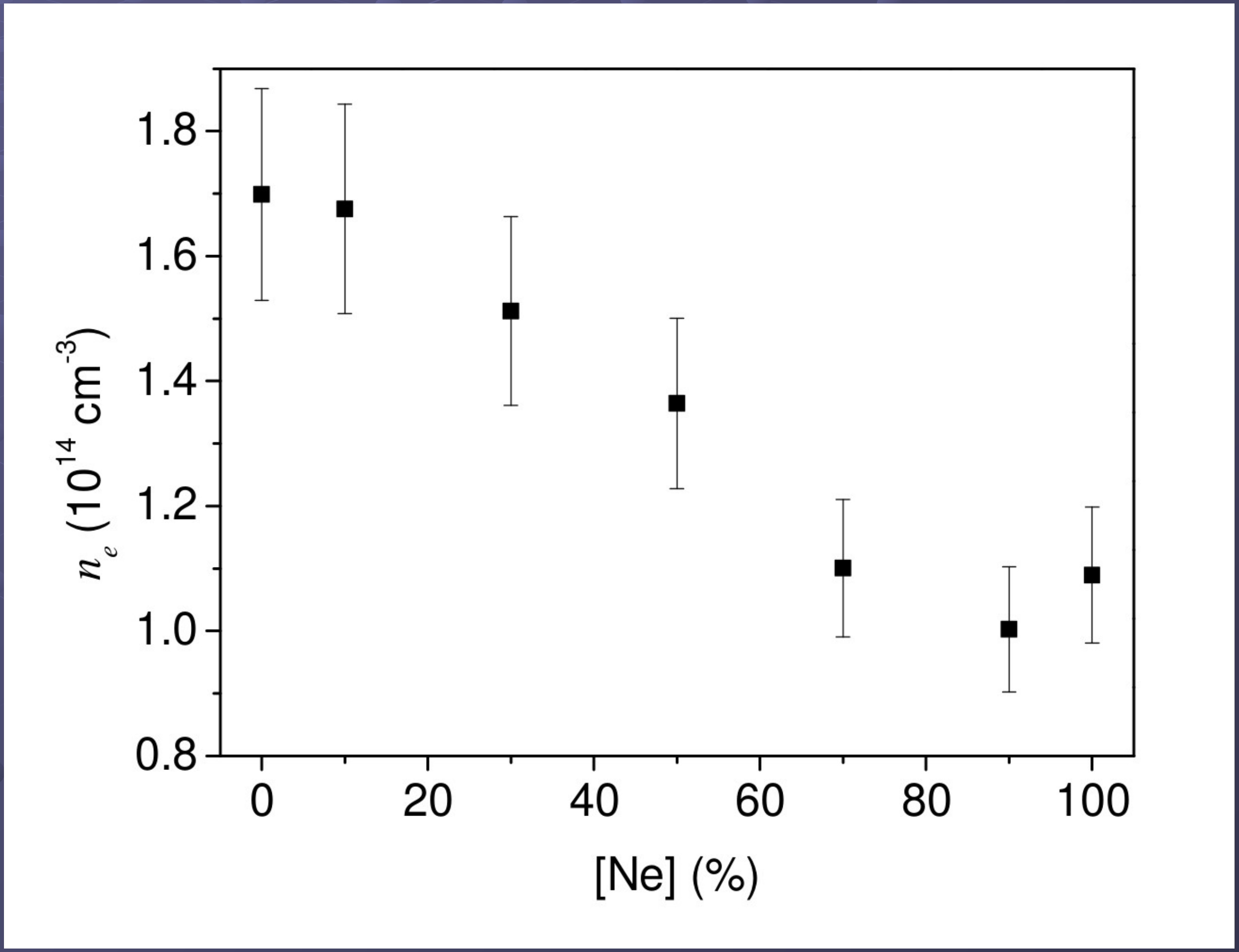
Figure 1. Experimental Setup.

Profiles of 425.9 and 603.2 nm lines of ArI were considered in this study. These lines were chosen because the van der Waals broadening of these ones were utilized in the investigation that was carried out to measure the gas temperature in Ar-He for comparison. Besides, the spectra from OH radicals (306–312 nm) and the H β line from the Balmer series were registered for gas temperature and electron density determination, respectively. Both OH radicals and hydrogen atoms were present as impurities in the
plasma gas.

The dependence of the Gaussian and Lorentzian widths of the 603.2 nm ArI line on the neon gas concentration in the discharge. As can be seen, the Gaussian width of the profile remains almost constant (0.015 ± 0.003 nm) with the increase of the Ne gas concentration. Comparing this value with the one obtained for the instrumental broadening it can be said that the main contribution to the Gaussian part of the Voigt profile for the 603.2 nm line is the instrumental width. Similar results were obtained for the 425.9 nm line.



Ne was determined using its relation with the Stark broadening of the H β line of the Balmer Series. For this line, the Lorentzian width was ascribed to the Stark broadening. The tables given in the GC Model, including effects of ion dynamics on the spectral ine profiles, were used to calculate the electron density from the Stark broadening. In Fig. are Ne values obtained for a given axial position (z = 8 cm) using different Ar–Ne mixtures.



Gas Temperature from the van der Waals broadening of the atomic Ar lines

- While any spectral line could theoretically be used for the determination of the plasma gas temperature using its van der Waals broadening, only those exhibiting sufficiently large broadening values must be considered to minimize the indeterminacies. Moreover, considering that the intensity of some argon spectral lines undergoes a significant decrease when a second gas is added to the mixture], only the ArI lines 425.9 and 603.2 nm have been considered for the calculation of gas temperature from their van der Waals broadenings according to the results obtained in previous works concerning Ar–He mixed gas plasmas.
- The van der Waals broadening from Eq. (6) of the reference where the Ar-He case was considered can be rewritten for the case of Ar–Ne mixtures as

$$w_W = 8.18 \cdot 10^{-26} \lambda^2 < \overline{R}^2 >^{2/5} \frac{P}{kT_g^{0.7}} \left(\frac{\chi_{Ar} \alpha_{Ar}^{0.4}}{\mu_{Ar-Ne}^{0.3}} + \frac{\chi_{Ne} \alpha_{Ne}^{0.4}}{\mu_{Ar-Ne}^{0.3}} \right)$$

- with λ being the wavelength of the spectral line in nm, P the pressure in Pa, Tg the gas temperature in
- K, k the Boltzmann constant, χ the molar (volume) fraction of the gas, α the atomic polarizability of
- the neutral perturber (16.54×10 -25 and 4×10 -25 cm -3 for argon and neon, respectively), μ the reduced
- mass of the colliding atoms and <R^2> the difference of the mean square radius of the emitting atom in the upper and the lower levels of the transition.

$$w_W\left(425.9\ \text{nm}\right) = \chi_{Ar}\frac{1.479}{T_g^{0.7}} + \chi_{Ne}\frac{0.932}{T_g^{0.7}}$$

$$w_W\left(603.2\ \text{nm}\right) = \chi_{Ar}\frac{4.217}{T_g^{0.7}} + \chi_{Ne}\frac{2.683}{T_g^{0.7}}$$

Lorentzian widths and Stark broadenings ($\times 10^{-2}$ nm) of the Ar atomic lines considered in this work for several concentrations of neon (z = 8 cm).

[Ne] (%)	425.9 nm		603.2 nm	
	w_L	w_S	w_L	w_S
0	0.91	0.03	3.13	0.30
10	0.92	0.03	2.96	0.29
30	0.81	0.03	2.60	0.26
50	0.78	0.02	2.36	0.24
70	0.71	0.02	1.92	0.19
90	0.60	0.02	1.42	0.17

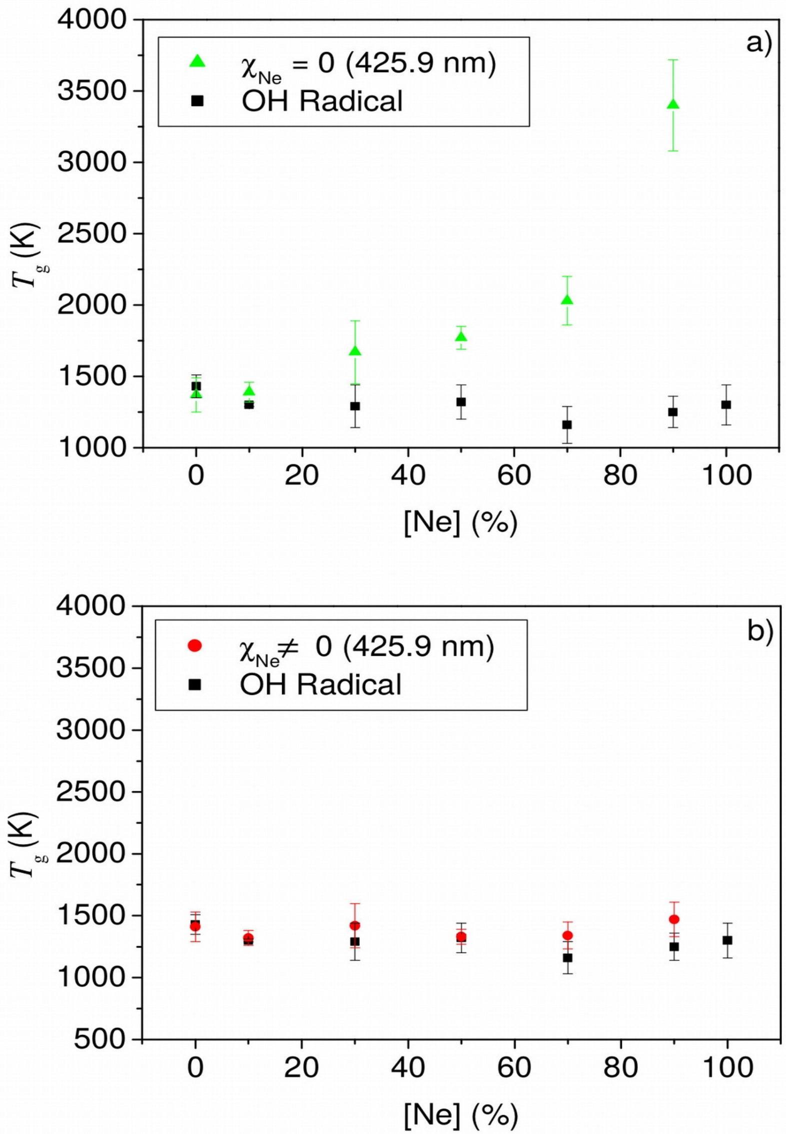


Figure 6 Gas temperature calculated from the van der Waals broadening of the 425.9 nm atomic argon line: a) Van der Waals broadening is considered only as Ar*–Ar interaction (χ_{Ar} =1, χ_{Ne}=0), b) Van der Waals broadening is calculated considering Ar*–Ar and Ar*–Ne interactions (z = 8 cm)

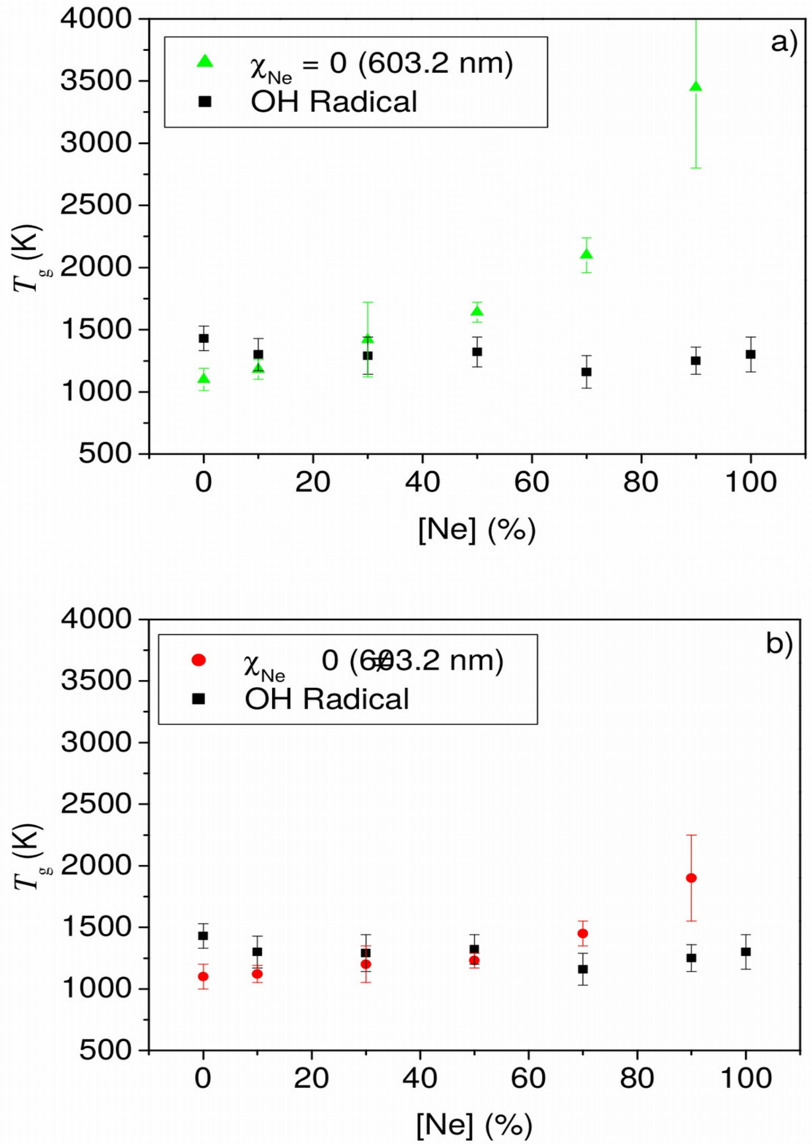


Figure 7 Gas temperature calculated from the van der Waals broadening of the 603.2 nm atomic argon line: a) Van der Waals broadening is considered only as Ar*–Ar interaction (χ_{Ar} =1, χ_{Ne}=0), b) Van der Waals broadening is calculated considering Ar*–Ar and Ar*–Ne interactions (*z* = 8 cm)

Conclusions

- We have adapted the method for the measurement of gas temperature of a microwave plasma at atmospheric pressure, using the van der Waals broadening of spectral atomic lines, for the case of argon – neon mixtures. The 425.9 nm and 603.2 nm Ar I lines have been determined as suitable for its application, and the method was tested experimentally. Our results show that gas temperatures obtained using 425.9 nm line are in good agreement with measurements from OH radical. So, we could recommend this line when the use of OH radicals is difficult or is desirable to be avoided due to pollution. In the case of 603.2 nm line, discrepancies with OH radical measurements appear for Ne proportions above 50 – 70%, but for lower ones the both methods give similar results. When we compare our experimental width for the ArI 603.2 nm line using the coefficient 2.683, we obtain overestimated T g values. Then, for the further sophistication of the method the more accurate Ar* Ne potentials are needed.

Thank you for attention!