DETERMINATION OF THE CONCENTRATION OF SMALL IMPURITIES IN A rarefied HELIUM PLASMA [[1]](#footnote-1)\*)

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We study low-density (p~10-5 atm) electric discharge helium plasma near a tungsten wall on a copper base. For the density of the plasma-forming gas [He] ≈ 1013÷1014cm-3 and charged particles (n ≈ 1011÷1013 см-3) the main mechanism of spectral line broadening is the Doppler effect which is determined by the temperature of the emitting particles [1]. According to the “effective lifetime” model by Biberman L.M. [2], the intensity of a reabsorbed spectral line corresponding to m→k optical transition is determined by the effective transition probability *A*mk*\* = A*mk *∙ θ*mk, where *A*mk is the spontaneous transition probability of an optically thin line and *θ*mk is the escape probability for the considered point of plasma for the photon which corresponds to this transition.

For a Doppler line contour emitted from the center of a cylinder with radius R the photon escape probability is given by [2]: , (1)

with the absorption coefficient in the line center

(2)

being determined by the concentration of particles on the absorbing level and the half-width of the Doppler line .

Diagnostics of plasma parameters of our installation was carried out by registering optical emission spectra of the plasma using a three-channel AvaSpec-ULS2048 spectrometer in the wavelength range 200–1100 nm. For the low density plasma, only emission lines corresponding to transitions to the base state of the atoms can be reabsorbed. In He+Cu plasma, these are resonance lines Cu I 324.7 and 327.4 nm. We also observed the lines Cu I 510.5 and 578.2 nm, which have common high energy level with lines at 324.7 and 327.4 nm respectively. We shall determine an estimate for resonance line 327.4 nm photon escape probability using the measured intensity ratio of the lines with common (i.e. equal) population of their emitting energy level *N*4p:

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By solving this equation for the photon escape probability of resonance line at λ=327.4 nm, we can determine its numerical value *ϴ*4p-1s= 0.20. By solving equation (1), we determine the optical density of the plasma *k*0*R =*2.35and thus for *R =* 1.6 cm*,* obtain the value of absorption coefficient in the center of the line 327.4 nm: *k*0*=*1.5 cm-1. By estimating the Doppler half-width of the resonance line Cu I 327.4 nm for *T* =1200 K, we have for *μ= 63.5*4, *v*0= 0.92∙1015 s-1 this result: Δ*vD* =2.8∙10 9 s-1. Then we can use (2) to determine the concentration of absorbing copper atoms in the base state =5.7∙1011 cm-3. By performing a similar comparison of intensities of the second resonance line at 324.7 nm and line at 510.6 nm, we determine *θ* = 0.14, *k0R =3.0* and[Cu] = 4.8∙1011 cm-3. The average density value [Cu] =5.2∙1011 cm-3 corresponds to saturated copper vapour pressure above metal with temperature K [3]and this temperature is in good agreement with the atom temperature we used earlier to determine the Doppler width of the line.

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References

1. V.N. Ochkin. Spectroscopy of Low Temperature Plasma.Moscow: Physmatlit, 2006.
2. L.M. Biberman, V.S. Vorob’ev and I.T. Yakubov. Kinetics of Nonequilibrium Low-Temperature Plasmas. Berlin: Springer, 1987.
3. S. Dushman. Scientific Foundations of Vacuum Technique. N-Y, London, 1962.

1. \*) [abstracts of this report in Russian](http://www.fpl.gpi.ru/Zvenigorod/XLIX/Lt/ru/FC-Chinov.docx) [↑](#footnote-ref-1)