UV radiation in narrow DISCHARGE tubes at different supply regimes

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Describe discharge characteristics in narrow and super narrow tubes P_{fg}(133-800 Pa), discharge current I(0,05-1A) of AC, DC discharges (50 Hz-100 kHz) with sinusoidal and pulse shape for different time interval between pulses C(C=2÷10), where $C=T/t_p$, T, t_p - are the pulse length and pulse time.

Using mathematical modelling the comparative studies have been carried out to determine the radiation power input F_{e185} and F_{e254}, radiation efficiency for Hg resonance lines η_{185} and η_{254}, electric field E, electron temperature T_e, volume losses via elastic collisions P_v and wall losses P_w for Hg-Ar-Kr mixtures discharge.

Independent variables are the discharge tube radius R(0,3÷1,8 cm), mercury vapour pressure P_{hg} and rare gas filling P_{fg}(133÷800 Pa), discharge current I(0,05÷1,0 A). Radiation efficiency of AC and DC discharges (50 Hz ÷ 100 kHz) was compared with sinusoidal and pulse shape for different time interval between pulses C (C=2÷10), where $C=T/t_p$, T, t_p - are the pulse length and pulse time, respectively.

Discharge characteristics were defined by solving the closed system of differential equations. The detailed description of the model is given in [1,2]. The calculations as in [4] have been done with account for the deviation of Maxwellian electron energy distribution from electron power input $f_e(\varepsilon)$ approximated as in [3]. Direct and stepwise ionization of Hg atoms and fill gas as Hg atoms ionization from the resonance levels of the fill gas have been considered.

The calculated and experimental data shown in the table are well in agreement among themselves and with data given in [4] as to 254 nm.

Table

Calculated and measured results for three types of AC discharges 50 Hz, P_{Hg}=0,93 Pa.

	Calc:meas	Calc:meas	Calc:meas
R, cm	1,8	1,2	1,2
I, A	0,4	0,4	0,4
rare gas	Ar	Ar	75%Kr+25%Ar
P_{fg}, Pa	400	400	200
η_{254},%	60,1 61,2	59,8 59,1	68,4 67,4
η_{185},%	9,8 10,2	11,4 11,2	13,5 13,0

As experiments have shown at HF discharge supply for sinusoidal and pulse current (C=2÷10) operation frequency within the range ≥ 20÷30kHz to 100kHz the value $\eta_{254}(\eta_w)$ reach saturation. In both cases of supply, the value η_{254} is close to η_{254} at DC, and is 2%-3% higher than η_{254} for 50 Hz at equal P_c for R>0,8 cm. For R=0,3-0,7 cm HF influence on η_{254} growth decreases at HF pulse operation η_{254} becomes lower than at f=50 Hz and DC, while this difference increases with an increase in C. At HF the value of η_{185} slightly decreases as compared with the 50 Hz operation. A very strong influence of C on the column characteristics is necessary to note. Thus, in similar discharge conditions the changes in C from 2 to 10 decrease E by 2 times. η_{254} =f (C) showed maximum and η_{185} =f (C) - minimum at the same C depending on the discharge conditions.

The study of η_{254} and η_{185} at different Ar pressures show narrow tubes with R=0,3÷0,8 cm to exhibit weaker dependence of η_{254} on P_{ar} as compared with wide tubes for R=1,3÷1,8 cm.

The advantages of Ar or Kr filling as to η_{254} depend on P_{fg}, P_c, R.

For all the values of R at low P_{fg}<266 Pa and P_c<20-25 W/M, the value of $h_{254}^{Kr} > h_{254}^{Ar}$. At P_{fg}=266 Pa and Pc>25 W/M the value of $h_{254}^{Ar} > h_{254}^{Kr}$. With a transition to Kr filling η_{185} slightly decreases as compared with Ar filling. The qualitative character of the dependences is valid for all supply conditions studied.

Special attention is paid to physical phenomena in discharge in tubes with small radius (0,3-0,8 cm) used for compact and new generation of linear fluorescent lamps.

It has been established that transition to narrow tubes leads to the appearance of some characteristic features: marked changes in electrokinetic discharge plasma characteristics; sharp increase of losses fraction on the tube walls; shift of the maximum radiation 254 nm to the region of higher argon and mercury pressure; more than 1,5 increase of the hard UV 185_{nm} radiation in relation to 254_{nm} radiation ; decrease of temperature dependence of energy flux 254_{nm}. The latter imply a larger stability of the fluorescent lamps characteristics with decreased diameter when environmental temperature is changed and a weaker dependence of flux and efficiency of the resonance radiation on argon pressure than in wide tubes.

Furthermore, the concentration and the density of fast electrons on the discharge tube walls are growing.

Radius decrease to 0,3-0,5 cm causes growth of hard radiation load W_{185}>2,5-3 times more in comparison with R=1,3÷1,8 cm.

Radiation load of the hard UV radiation 185 nm in compact fluorescent lamps reaches radiation load level of 254 nm for wide tubes with R=1,3-1,8 cm.

At high frequency (20-40 kHZ) operation of compact fluorescent lamps phosphor intensity irradiation 185 nm in contrast to 50 Hz regime is not changed by the period of current. It may result in phosphor depreciation enhancement.

Radiant flux 185 nm increases particularly significantly in pulse HF(20-40 kHz) regimes. During the active pulse phase hard UV radiant flux falls on the tube walls. It is 1,5-2 times more than its maximum value at 50 Hz for corresponding radius. The percentage relationship change of Ar-Kr gas mixture has a weak influence on UV radiation efficiency 185 nm. F_{185} deterioration can be reached through argon pressure increase, of application of film coatings.

Since 15%-20% of the column power goes on radiation 185 nm in narrow tubes (R=0,3-0,8 cm) it is necessary to use this radiation for the lamp luminous efficiency improvement through phospors with high guantum efficiency for radiation 185nm and resistant to hard radiation action.

References:

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