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Effect of electron lateral diffusion in the reflection-mode exponential-doping GaAlAs photocathode on resolution

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Resolution of a reflection-mode GaAlAs photocathode which is efficiently characterized by modulation transfer function (MTF) is primarily governed by electron lateral diffusion in this photocathode. As several crucial parameters for the GaAlAs photocathode, the length of electron diffusion L_D, the thickness of emission layer T_e, the coefficient of optical absorption α, and the recombination velocity at back-interface S_V has a significant effect on the degree of lateral diffusion. To obtain a high resolution, by establishing an appropriate model of MTF for reflection-mode exponential-doping GaAlAs photocathode, the effect of L_D, T_e, α, and S_V on corresponding MTF and quantum efficiency for exponential-doping and uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathodes has been researched in detail. And then we have discussed the dependence of electron lateral diffusion on L_D, T_e, α, and S_V. The calculated results demonstrate that the reflection-mode exponential-doping $Ga_{0.37}Al_{0.63}As$ photocathode has a great potentiality in achieving high resolution and high quantum efficiency, compared with its counterpart employed uniform-doping structure. It is mainly because that electron lateral diffusion in this photocathode is bound by electric field which is formed by exponential-doping structure. In practice, for a given reflection-mode exponential-doping $Ga_{0.37}Al_{0.63}As$ photocathode, a compromise between high resolution and high quantum efficiency must be made.

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Keywords: Electron lateral diffusion, Reflection-mode, Exponential-doping, GaAlAs photocathode, Modulation transfer function

1. Introduction

Due to the advantages of high quantum efficiency, low energy spread, low dark emission and high spin polarization, negative electron affinity (NEA) GaAs-based photocathodes are used in a wide range of applications including night vision devices, photomultipliers, and envisaged polarized electron sources [1-4]. Although the versatility of GaAs photocathode is much larger than that of GaAlAs photocathode, the latter is still an ideal photosensitive material for underwater low-light-level detection, which is mainly attributed to its adjustable spectrum range and long working lifetime [5-7]. Specially, most imaging devices employ transmission-mode GaAlAs photocathode which easily separate the optical and electron -optical functions [8, 9]. Whereas, the high quantum efficiency and relatively simple fabrication of reflection -mode photocathodes promote us to develop the reflection-mode GaAlAs photocathode with high performance [10, 11].

Regarding a reflection-mode GaAlAs photocathode used in underwater low-light-level imaging devices, not only must this photocathode detect incident light, but also is must accurately convert the optical image into an electron image. It means that the quantum efficiency and resolution of a GaAlAs photocathode are two crucial parameters [12-14]. However, the obtainment of high quantum efficiency for a GaAlAs photocathode has been studied intensively, and relatively little attention has been paid to its resolution [15-19]. As a matter of fact, during the conversion of incident light into photoelectrons generated by a GaAlAs photocathode, some degradation of resolution must occur within this photocathode. Note that the electron lateral diffusion within the GaAlAs photocathode is responsible for this degradation [20]. More specifically, the lateral diffusion current is directly to proportional to the gradient of electron distribution, and it is illustrated by the effect of several parameters of GaAlAs photocathode on electron transport toward photocathode surface. These parameters mainly include the length of electron diffusion L_D, the thickness of emission layer T_e, the coefficient of optical absorption α, and the recombination velocity at back-interface S_V.

To obtain a high resolution, it is necessary to constrain electron lateral diffusion in GaAlAs photocathode as far as possible. Here, if a proper electric field along the opposite direction of electron transport toward photocathode surface will be formed, electron lateral diffusion can be constrained to some extent. And then it is well illustrated in Fig. 1.

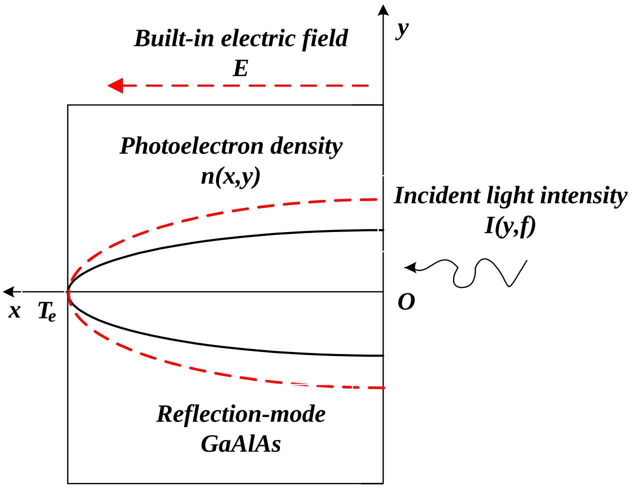

Fig. 1. Schematic diagram of electron lateral diffusion in the reflection-mode GaAlAs photocathode. Solid lines represent electron lateral diffusion with a built-in electric field E; dashed lines represent electron lateral diffusion without E (color online)

Exactly, NEA photocathodes employed exponential -doping structure can generate this built-in electric field E, and obtain higher quantum efficiency which was experimentally verified [21]. On these grounds, it is possible to achieve high resolution and high quantum efficiency via the reflection-mode exponential-doping GaAlAs photocathode. From Fig. 1, it is clear that the diameter of electron lateral diffusion in exponential -doping GaAlAs photocathode appears smaller than that of uniform-doping counterpart owing to the built-in electric field E. That is to say, resolution of GaAlAs photocathode can be improved. Logically, it is time to study the effect of electron lateral diffusion in reflection-mode exponential -doping GaAlAs photocathodes on its resolution. With respect to the structure design of a GaAlAs photocathode, it is of considerable interest to research the dependence of resolution on the length of electron diffusion L_D, the thickness of emission layer T_e, the coefficient of optical absorption α, and the recombination velocity at back-interface S_V. Accordingly, this paper will report the effect of electron lateral diffusion in reflection-mode GaAlAs photocathodes employed exponential-doping and uniform-doping structures on their resolution, respectively.

2. Establishing model of MTF

As an evaluation criterion of resolution characteristics of the imaging device, modulation transfer function (MTF) is effective for that of NEA photocathodes as well [20, 22].

In accordance with physical meaning of MTF, the value of MTF should range from 0 to 1. To be specific: the larger MTF demonstrates the higher image quality, i.e., the higher resolution of this photocathode. To clarify the effect of electron lateral diffusion within the reflection-mode exponential-doping GaAlAs photocathode on its resolution, it is essential to establish a correct model of MTF pertaining to this GaAlAs photocathode.

For purpose of simplifying deduction, we suppose that Al mole fraction of the GaAlAs photocathode keeps fixed, which is given in subsequent calculations. As shown in Fig. 1, a beam of incident light is vertical to GaAlAs photocathode surface, and its light intensity $I(y,f)$ is determined by

$$I(y,f)=\frac{\phi}{2}[1+\cos(2\pi fy)] \tag{1}$$

where ϕ, f are the light flux and the spatial frequency, respectively. In view of the influence of built-in electron field E generated by exponential-doping structure on electron transport, the corresponding diffusion equation of electron is given by

$$\frac{\partial^2 n(x,y)}{\partial x^2}+\frac{\partial^2 n(x,y)}{\partial y^2}+\frac{q|E|}{kT}\frac{\partial n(x,y)}{\partial x}-\frac{n(x,y)}{L_D{}^2} \tag{2}$$
$$+\frac{G(x,y)}{D_n}=0,\quad (x\in[0,T_e],\ y\in Real)$$

where x is the distance between a point within emission layer of the GaAlAs photocathode and this photocathode surface, $n(x,y)$ is photoelectron density, q is electronic charge, k denotes Boltzmann's constant, T represents temperature, L_D is the diffusion length of electron, D_n is the diffusion coefficient of electron, and T_e stands for the thickness of emission layer. Besides, $G(x,y)$ is the generation function of electron, and its expression takes the form of

$$G(x,y)=\alpha(1-R)\exp(-\alpha x)I(y,f) \tag{3}$$

where α indicates the coefficient of optical absorption, and R is the reflectivity at the surface of GaAlAs photocathode. In addition, the boundary condition of Eq. (2) is obtained by

$$D_n\left[\frac{\partial n(x,y)}{\partial x}+\frac{q|E|}{kT}n(x,y)\right]_{x=T_e}=-S_V n(x,y)\big|_{x=T_e} \tag{4}$$
$$n(x,y)\big|_{x=0}=0$$

where S_V denotes the recombination velocity at back –interface of GaAlAs photocathode.

To solve Eq. (2), it is essential to implement Fourier transform of this expression in reference to y. If Fourier transform of $n(x,y)$ is represented as

$$F\left[n(x,y)\right]=N(x,\lambda) \tag{5}$$

corresponding second-order ordinary differential equation concerning x can be given by

$$D_n\left[\frac{d^2N(x,\lambda)}{dx^2}+\frac{q|E|}{kT}\cdot\frac{dN(x,\lambda)}{dx}-\left(\lambda^2+1/L_D{}^2\right)N(x,\lambda)\right]$$
$$+\alpha\left(1-R\right)\exp\left(-\alpha x\right)\cdot \tag{6}$$
$$\left[\sqrt{2\pi}\delta\left(\lambda\right)+\sqrt{\pi/2}\left(\delta\left(\lambda+\omega\right)+\delta\left(\lambda-\omega\right)\right)\right]=0$$

and then the boundary condition for Eq. (6) is easily determined by

$$\left[D_n \frac{dN(x,\lambda)}{dx} + \frac{q|E|}{kT} N(x,\lambda)\right]\Bigg|_{x=T_e} = -S_V N(x,\lambda)\big|_{x=T_e}$$
$$N(x,\lambda)\big|_{x=0} = 0 \tag{7}$$

After solving Eq. (6) for $N(x, \lambda)$, we can obtain the formula of photocurrent density of reflection-mode exponential -doping GaAlAs photocathode with inverse Fourier transform, and its form is as follows

$$J_R(y,f) = PD_n \frac{\partial n(x,y)}{\partial x}\bigg|_{x=0} = \frac{\phi}{2}\left[Y_{Ro} + Y_{R\omega}\cos(2\pi fy)\right] \tag{8}$$

where P is escape probability of photoelectrons from photocathode surface, Y_{Ro} and $Y_{\mathrm{R}\omega}$ are quantum efficiency of photoemission generated by incident light with homogeneous distribution and cosinusoidal distribution, respectively. More specially, the expressions of Y_{Ro} and $Y_{\mathrm{R}\omega}$ are given by

$$Y_{Ro} = \frac{P(1-R)\alpha L_D}{\alpha^2 L_D{}^2 - \alpha L_o - 1} \left\{ \frac{B_o(S-\alpha D_n)\exp\left[\left(L_o/2L_D{}^2 - \alpha\right)T_e\right] - H_o}{A_o} + \alpha L_D \right\} \tag{9}$$

$$Y_{R\omega} = \frac{P(1-R)\alpha L_D{}'}{\alpha^2 L_D{}'^2 - \alpha L_\omega - 1} \left\{ \frac{B_\omega(S-\alpha D_n)\exp\left[\left(L_\omega/2L_D{}'^2 - \alpha\right)T_e\right] - H_\omega}{A_\omega} + \alpha L_D{}' \right\} \tag{10}$$

where,

$$L_o = \frac{q|E|}{kT} L_D{}^2 \tag{11}$$

$$S = S_V + \frac{q|E|}{kT} D_n \tag{12}$$

$$B_o = \sqrt{L_o{}^2 + 4L_D{}^2} \tag{13}$$

$$A_o = \left(D_n B_o / L_D\right)\cosh\left(B_o T_e / 2L_D{}^2\right) + \left(2SL_D - D_n L_o / L_D\right)\sinh\left(B_o T_e / 2L_D{}^2\right) \tag{14}$$

$$H_o = B_o S\cosh\left(B_o T_e / 2L_D{}^2\right) + \left(SL_o + 2D_n\right)\sinh\left(B_o T_e / 2L_D{}^2\right) \tag{15}$$

$$L_D{}' = \sqrt{L_D{}^2 / \left(\omega^2 L_D{}^2 + 1\right)} \tag{16}$$

$$L_\omega = \frac{q|E|}{kT} L_D{}'^2 \tag{17}$$

$$B_\omega = \sqrt{L_\omega{}^2 + 4L_D{}'^2} \tag{18}$$

$$A_\omega = \left(D_n B_\omega / L_D{}'\right)\cosh\left(B_\omega T_e / 2L_D{}'^2\right) + \left(2SL_D{}' - D_n L_\omega / L_D{}'\right)\sinh\left(B_\omega T_e / 2L_D{}'^2\right) \tag{19}$$

$$H_\omega = B_\omega S\cosh\left(B_\omega T_e / 2L_D{}'^2\right) + \left(SL_\omega + 2D_n\right)\sinh\left(B_\omega T_e / 2L_D{}'^2\right). \tag{20}$$

In reality, the definition of MTF is the ratio of C_ω to C_o for the image formed by light with cosine distribution at a certain spatial frequency f, where C_ω to C_o indicate the contrast of this image plane and that of the objective plane, respectively. In particular, for a GaAlAs photocathode, C_ω to C_o are actually the contrast of photocurrent density. Therefore, the model of MTF for a reflection-mode exponential-doping GaAlAs photocathode is described by

$$MTF(f) = \frac{C_\omega}{C_o} = \frac{Y_{R\omega}}{Y_{Ro}} \tag{21}$$

More specifically, with substituting Eqs. (9) and (10) into Eq. (21), this model of MTF is established as

$$MTF(f) = \frac{L_D{}' A_o(\alpha^2 L_D{}^2 - \alpha L_o - 1)}{L_D A_\omega(\alpha^2 L_D{}'^2 - \alpha L_\omega - 1)} \left[\frac{B_\omega(S-\alpha D_n)\exp\left[\left(L_\omega/2L_D{}'^2 - \alpha\right)T_e\right] - H_\omega + A_\omega \alpha L_D{}'}{B_0(S-\alpha D_n)\exp\left[\left(L_o/2L_D{}^2 - \alpha\right)T_e\right] - H_o + A_o \alpha L_d} \right]. \tag{22}$$

To achieve the goal of finding MTF difference between the reflection-mode exponential-doping GaAlAs photocathode and the reflection-mode uniform-doping counterpart, it is necessary to obtain the model of MTF for the latter. Exactly, if the effect of electric field E on electron laterals diffusion is neglected, in other words, the value of E in Eq. (2) is zero, the model of MTF for reflection-mode uniform-doping GaAlAs photocathode can be established.

3. Results and discussion

It is important to notice that determination of some requisite calculation conditions must precede the analysis on MTF properties for reflection-mode exponential-doping GaAlAs photocathode. In particular, considering that the change in Al mole fraction has a virtual impact on the spectral response of GaAlAs photocathode, we select the value of Al mole fraction as 0.63, which is mainly attributed to $Ga_{0.37}Al_{0.63}As$ applied into underwater low-light-level detection [23]. At the same time, other calculation conditions are shown that the amount of bent-band induced by exponential-doping structure is 0.06 eV as the doping concentration shifts from 1×10^{18} cm^{-3} to 1×10^{19} cm^{-3}, P = 0.36, R = 0.21, and D_n = 10 cm^2/s at room temperature [9, 11]. Based on these values of parameters and expression (22), we have obtained MTF curves for reflection-mode exponential-doping and uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathodes, and subsequently researched both resolution characteristics. More precisely, we have discussed the dependence of resolution and quantum efficiency on L_D, T_e, S_V, and α in detail. By changing L_D, T_e, S_V, and α individually, a family of MTF curves have been plotted. Meanwhile, these curves for each set of parameter values along with corresponding values of quantum efficiency when f ranges from 0 to 800 lp/mm are shown in Figs. 2 to 5.

The marked feature in Figs. 2 to 5 is each MTF curve drops with increasing spatial frequency f, and it is attributed to electron lateral diffusion. From the viewpoint of mathematics, the MTF of $Ga_{0.37}Al_{0.63}As$ photocathode is clearly a monotonically decreasing function in regard to f.

What's more, for a stationary f, a virtual symbol of the effect of electron lateral diffusion on resolution of this photocathode is the MTF dependence on L_D, T_e, S_V, and α.

Of particular interest is the fact that the exponential-doping structure can improve resolution of the $Ga_{0.37}Al_{0.63}As$ photocathode in most situations. And thus, the discussion pertaining to the effect of L_D, T_e, S_V, and α on resolution has been given in detail. In the meantime, corresponding quantum efficiency Y_{RE} of a reflection-mode exponential-doping $Ga_{0.37}Al_{0.63}As$ photocathode and quantum efficiency Y_{RU} of a reflection-mode uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathode have been calculated, respectively.

3.1. Effect of L_D on resolution

When T_e = 1.6 μm, $\alpha = 2\times10^4$ cm^{-1}, S_V = 0 cm·s^{-1}, L_D = 1.0 μm and 3.0 μm, the MTF curves of reflection-mode exponential-doping and uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathodes have been obtained as shown in Fig. 2. From Fig. 2, it is evident that these curves rise with reducing L_D, while corresponding values of quantum efficiency become smaller. What's interesting is that the MTF of uniform -doping $Ga_{0.37}Al_{0.63}As$ photocathode rises obviously. For instance, when f is 400 lp/mm, the value of MTF for exponential-doping $Ga_{0.37}Al_{0.63}As$ photocathode rises by 13.03%, whereas that of uniform-doping photocathode rises by 25.37%. It should be noted that there is little variation for both curves for L_d = 1.0 μm, however, the variation of them become larger when L_d = 3.0 μm. Namely, a shorter L_D has a weaker influence on resolution. This is mainly caused by the fact that most electrons cannot reach back-interface of $Ga_{0.37}Al_{0.63}As$ photocathode and thus will not be affected by the conditions there on account of a shorter L_D. From the perspective of electron transport, the strength of electron lateral diffusion is minimized because most of electrons escaping into the vacuum come from the region close to photocathode surface. Naturally, the influence of built-in electric field caused by exponential -doping structure is gradually dampened with reducing L_D. More meaningfully, in structure design of a $Ga_{0.37}Al_{0.63}As$ photocathode, it should be emphasized that a shorter L_D can improve resolution but at the cost of a low quantum efficiency.

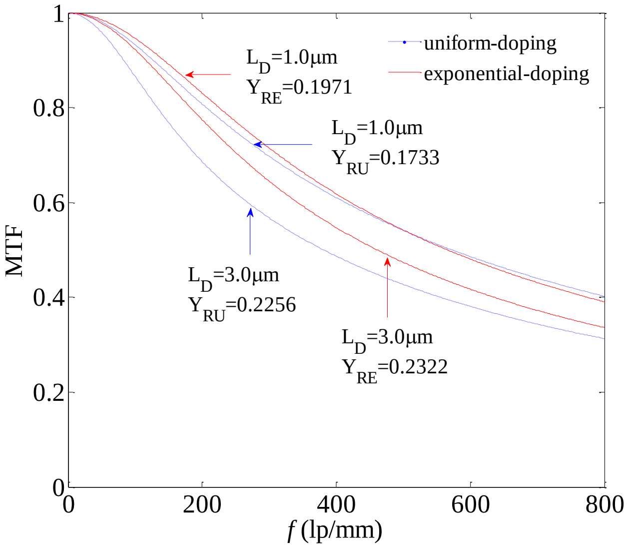

Fig. 2. Effect of L_D on resolution of reflection-mode exponential-doping and uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathodes (color online)

3.2. Effect of T_e on resolution

Supposing that L_D = 3.0 μm, $\alpha = 2\times10^4$ cm^{-1}, S_V = 0 cm·s^{-1}, T_e = 0.8 μm and 1.6 μm, the MTF of both reflection-mode $Ga_{0.37}Al_{0.63}As$ photocathodes have been calculated, as shown in Fig. 3. Quite strikingly, the values of all MTF curves are improved evidently when T_e is decreased. Most of all, compared with $Ga_{0.37}Al_{0.63}As$ photocathode employed uniform-doping structure, the MTF for exponential-doping one improves more distinctly. We attribute this discrepancy to the fact that the reduction of lateral diffusion distance of electrons for a reduced T_e. Simultaneously, electron transport can be more easily promoted by a much stronger electric field E with reducing T_e. Conversely, a shorter T_e leads to lower quantum efficiency. In the case of a given reflection-mode $Ga_{0.37}Al_{0.63}As$ photocathode, good spectral response at longer wavelengths can be achieved when T_e is extended, because incident light at long wavelength is predominately absorbed within photocathode. However, the role of T_e in quantum efficiency is partly limited and even can be neglected when T_e is beyond a certain value. From another perspective, the facilitation of electron transport toward photocathode surface which is provided by E is slowed down, namely, the constraint strength of E on electron lateral diffusion is diminished. The fact that the strength of E is gradually weakened with extending T_e is responsible for this point. Clearly, the determination of an optimal value of T_e is crucial to find a balance between quantum efficiency and resolution for reflection-mode exponential -doping $Ga_{0.37}Al_{0.63}As$ photocathodes.

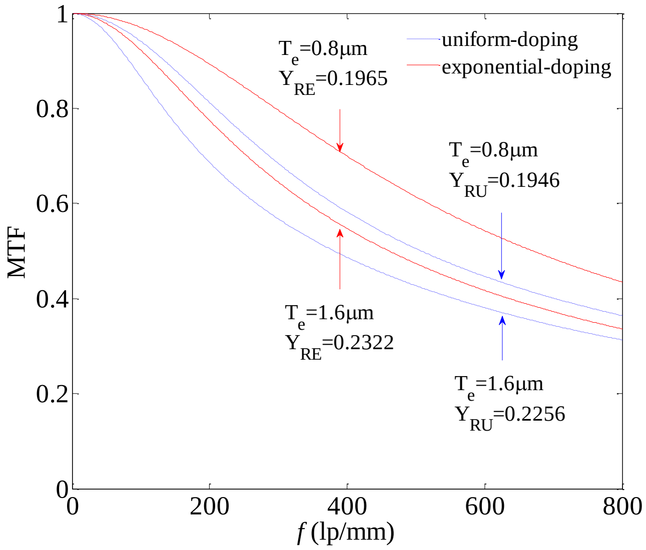

Fig. 3. Effect of T_e on resolution of reflection-mode exponential-doping and uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathodes (color online)

3.3. Effect of α on resolution

Assuming L_D=3.0 μm, T_e=1.6 μm, S_V=0 cm·s^{-1}, α=1× 10^4 cm^{-1} and 3×10^4 cm^{-1}, corresponding MTF curves and values of quantum efficiency for reflection-mode exponential-doping and uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathodes are given and shown in Fig. 4. The outstanding feature in Fig. 4 is the improved MTF for both $Ga_{0.37}Al_{0.63}As$ photocathodes as the coefficient of optical absorption α is increased. To a great degree, this improvement is attributed to the production of more electrons near photocathode surface with increasing α. As is well known, increasing α indicates that the distance of electron transport toward the surface of $Ga_{0.37}Al_{0.63}As$ photocathode is shortened, i.e., the degree of electron lateral diffusion is further bound accordingly. Within spectral response range of a given reflection-mode $Ga_{0.37}Al_{0.63}As$ photocathode, the larger α denotes more photons are absorbed at shorter wavelengths, and thus a higher resolution can be achieved. Similarly, for an optimal thickness of emission layer T_{em}, the quantum efficiency is improved by increasing α because the increased number of excited photoelectrons, most of which can escape into the vacuum.

3.4. Effect of S_V on resolution

On the condition that L_D=3.0 μm, T_e=1.6 μm, α=2× 10^4 cm^{-1}, S_V=0 cm·s^{-1} and 10^7 cm·s^{-1}, the MTF and values of quantum efficiency for reflection-mode exponential -doping and uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathodes are calculated, as shown in Fig. 5. The important observation from Fig. 5 is that the larger recombination velocity at back-interface S_V results in higher resolution of both reflection-mode $Ga_{0.37}Al_{0.63}As$ photocathodes. In the case of a large S_V, both MTF curves are practically the same properties, in other words, exponential-doping structure does not improve resolution since most electrons are recombined at back-interface. It is recognized that the effect of S_V on performance of a reflection-mode photocathode has often been neglected, whereas of more concern is the influence of S_V on performance of a transmission-mode photocathode. But it should be emphasized that, this influence cannot be by no means ignored for a short T_e which meets the requirement of reflection-mode NEA photocathode.

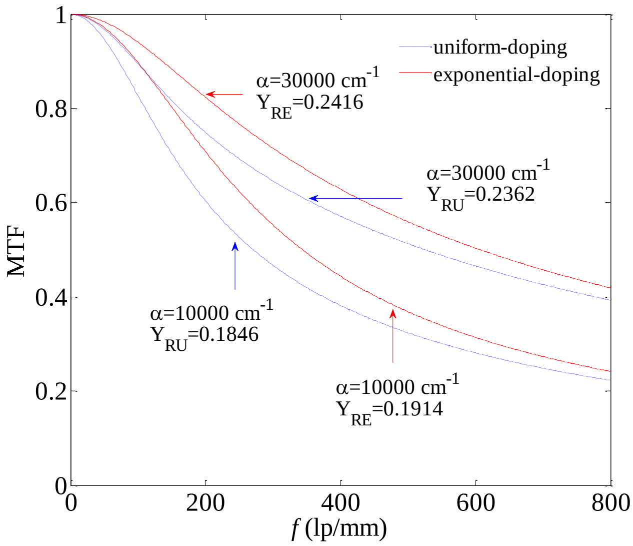

Fig. 4. Effect of α on resolution of reflection-mode exponential-doping and uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathodes (color online)

With a large S_V, photoelectrons would diffuse toward the back-interface and to the photocathode surface. In contrast, if S_V = 0 cm·s^{-1}, it means that electrons would be perfectly reflected from the back-interface, and hence a large amount of emitted photoelectrons must diffuse further laterally. Fortunately, this adverse influence of electron lateral diffusion can be offset by built-in electric field E which is generated by exponential-doping NEA photocathode. So, for a small S_V, the resolution of an exponential-doping $Ga_{0.37}Al_{0.63}As$ photocathode is apparently higher than that of a uniform-doping one. Additionally, if S_V = 10^7 cm·s^{-1} or much higher, this case shows that most of electrons reaching the back-interface are recombined and then lost, namely, the resolution of reflection-mode $Ga_{0.37}Al_{0.63}As$ photocathode is hardly affected by these electrons. As a result, the binding force of E on electron lateral diffusion is trivial. However, the price paid for the high resolution obtainable by increasing S_V is a reduction in the quantum efficiency, and those emitted electrons lowering the quantum efficiency are just the ones improving the resolution.

As described above, theoretically speaking, it is clear that the method of using exponential-doping structure can certainly improve the resolution of reflection-mode $Ga_{0.37}Al_{0.63}As$ photocathode, except for a very large S_V. This improvement effect is mainly attributed to the fact that electron lateral diffusion in a reflection-mode exponential-doping $Ga_{0.37}Al_{0.63}As$ photocathode is bound by electric field, in turn, this electric field accelerates electron transport toward photocathode surface. Meanwhile, we should note that the high resolution and the high quantum efficiency for a reflection-mode exponential-doping $Ga_{0.37}Al_{0.63}As$ photocathode can be achieved, which differs from the method for high resolution obtained by decreasing T_e and L_D or increasing S_V, while the latter is achieved at the cost of leading to the low quantum efficiency. More importantly, the practical selection of values for T_e, L_D, α, and S_V is in no way arbitrary. For example, as for a specific $Ga_{0.37}Al_{0.63}As$ photocathode, α relating to the wavelength of incident light is essentially fixed. For another example, the value of L_D is determined by fitting experimental data of quantum efficiency of this given photocathode. If L_D is insufficient to meet demand, it can be optimized by varying the doping level. In reality, T_e and the doping concentration are main factors in the fabrication of $Ga_{0.37}Al_{0.63}As$ photocathode. Therefore, the compatibility between maximum resolution capability and high quantum efficiency cannot be obtained by the variation of these parameters, and the compromise must be made in the structure design of photocathode.

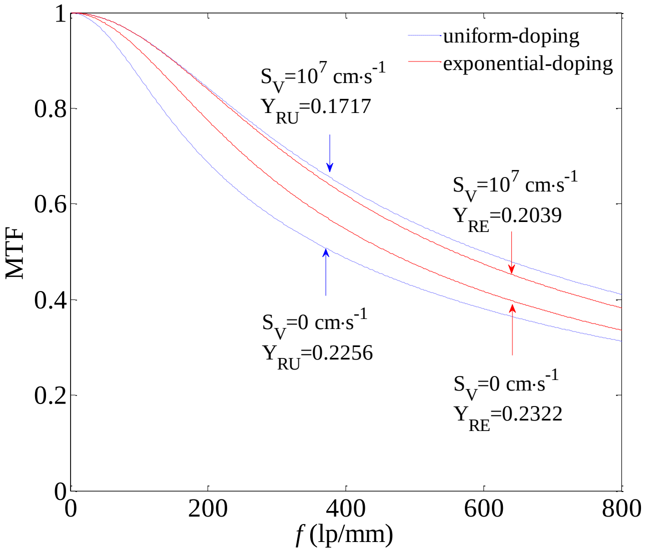

Fig. 5. Effect of S_V on resolution of reflection-mode exponential-doping and uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathodes (color online)

4. Conclusions

In summary, to improve the resolution of reflection-mode $Ga_{0.37}Al_{0.63}As$ photocathode, it is essential to study the effect of electron lateral diffusion in this photocathode on its resolution. By establishing an appropriate model of MTF for reflection-mode exponential-doping GaAlAs photocathode, the MTF of reflection-mode exponential-doping and uniform-doping $Ga_{0.37}Al_{0.63}As$ photocathodes have been obtained. And then we have discussed the dependence of resolution on L_D, T_e, α, and S_V, which is also the dependence of electron lateral diffusion on these parameters in nature. The calculated results demonstrate that the reflection-mode exponential-doping $Ga_{0.37}Al_{0.63}As$ photocathode has a great potentiality in achieving high resolution and high quantum efficiency, compared with its counterpart employed uniform-doping structure. It is mainly because that electron lateral diffusion in photocathode is bound by electric field which is formed by exponential-doping structure. More interestingly, these calculated results are applicable to other reflection-mode GaAlAs photocathodes. Most of all, we must make a compromise between high resolution and high quantum efficiency for a given reflection-mode exponential-doping $Ga_{0.37}Al_{0.63}As$ photocathode. Considering the limited selection of L_D, T_e, α, and S_V, the optimal value of T_{em} for a reflection-mode exponential-doping $Ga_{0.37}Al_{0.63}As$ photocathode needs to be given in follow-up work.

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