*Supporting information for*

# Planar, narrowband, and tunable photodetection in the near-infrared with Au/$TiO_2$ nanodiodes based on Tamm plasmons

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## Details on the Metal-Semiconductor Carrier Injection Model

Upon the absorption of photons with energy $E_{\mathrm{ph}}$, an electron with energy $E - E_{\mathrm{ph}}$ below the Fermi level is promoted to a higher energy state $E$. The hot-electron initial energy distribution is described by the product of the electron density of state (EDOS) and the respective Fermi functions at the initial and final states [S1, S2].

$$D(E) = \frac{\rho(E - E_{\mathrm{ph}})f(E - E_{\mathrm{ph}})\rho(E)[1 - f(E)]}{\int_0^{\infty} \rho(E - E_{\mathrm{ph}})f(E - E_{\mathrm{ph}})\rho(E)[1-f(E)]dE} \tag{S1}$$

where $\rho(E-h\upsilon)$ [$\rho(E)$] is the EDOS at the initial [final] energy level, and $f(E-h\upsilon)$ [$f(E)$] is the corresponding Fermi distribution function. Taking into account the resistive loss ($\eta_{\mathrm{res}} = 0.4$ [S3]) of the absorbed energy without the generation of hot electrons, the spatial distribution of the hot-electron generation rate ($G$) can be obtained as [S4]:

$$G(z,\omega) = \left(1 - \eta_{\mathrm{res}}\right)\varepsilon_i |E(z,\omega)|^2/(2\hbar) \tag{S2}$$

where $\omega$ is the angular frequency, $\varepsilon_{\mathrm{i}}$ is the imaginary part of the permittivity, $\hbar$ is the reduced Planck constant, $E$ is the electric field. Based on the exponential attenuation model and the assumption of an isotropic momentum distribution, the probability of an electron with energy $E$ arriving at Schottky interface under the diffusing angle $\theta$ is evaluated by [S5]:

$$P_{etr}(E,\theta,z) = \begin{cases} \frac{1}{2}\exp\left(-\frac{d(z)}{l_{MFP}(E)\cos\theta}\right), & if \ -\frac{\pi}{2} < \theta < \frac{\pi}{2} \\ 0, & otherwise \end{cases} \tag{S3}$$

where $d$ is the distance from the hot-electron initial positon to the Schottky interface and $l_{\mathrm{MFP}}$ is the energy-dependent mean free path of hot electrons [S3]. The flux of electrons $N_{\mathrm{int}}$ ($E$, $\theta$) to reach the interface under an angle $\theta$ is:

$$N_{int}(E,\theta) = \int_0^{d_{\mathrm{Au}}} G(z) \times D(E) \times P_{etr}(E,\theta,z)dz \tag{S4}$$

Then, the injection efficiency is obtained as:

$$\eta_{inj}(E) = \frac{\int_0^{\Omega} 2\pi sin\theta d\theta \times N_{int}(E,\theta) \times T}{\int_0^{\frac{\pi}{2}} 2\pi sin\theta d\theta \times N_{int}(E,\theta)} \quad (S5)$$

where $T$ is the electron transfer propabablity under the diffusing angle $\theta$ across the interface considering the possible reflection at the Au/$TiO_2$ interface arising from the momentum mismatch in both media [S6].

Finally, the photocurrent density can be expressed as:

$$J = e\int_{\varphi_{SB}}^{\infty} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} N_{int}(E,\theta) d\theta \times \eta_{inj}(E)\, dE \quad (S6)$$

## More Information on Hot Electron Energy Collection and Loss Contribution

For clarity, we show how the data of the collection and loss contribution can be calculated with the optoelectronic model in detail [S7].

From the optical model, we get the optical absorption ($A$) in the metal, reflection ($R$) and transmission ($T$) of the hot-electron device.

1) Considering the incident photon flux of $N_{\text{ph}}$, the optical reflection loss ($N_{\text{ph\_ref}}$) and transmission loss ($N_{\text{ph\_tra}}$) are:

$$N_{\text{ph\_ref}} = N_{\text{ph}} \times R \quad (S7)$$

$$N_{\text{ph\_tra}} = N_{\text{ph}} \times T \quad (S8)$$

2) The resistive dissipation loss ($N_{\text{ph\_resis}}$) is:

$$N_{\text{ph\_resis}} = N_{\text{ph}} \times A \times \eta_{res} \quad (S9)$$

where $\eta_{res}$ is the efficiency of resistive loss of the absorbed energy.

The hot-electron generation flux ($N_{\text{ph\_excited}}$) is:

$$N_{\text{ph\_excited}} = N_{\text{ph}} \times A \times \eta_{eh} \quad (S10)$$

where $\eta_{eh}$ is the efficiency of plasmonic decay into hot electrons.

3) The thermalization loss ($N_{\text{ph\_therm}}$) is the flux difference of hot electrons excited and reaching the interface:

$$N_{\text{ph\_therm}} = N_{\text{ph\_excited}} - \int_0^{\infty} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} N_{int}(E,\theta) d\theta dE \quad (S11)$$

where $N_{\text{int}}$ is the flux of electrons with excess energy $E$ to reach the interface under an angle $\theta$.

4) The barrier loss ($N_{\text{ph\_barrier}}$) is the flux of hot electrons reaching the interface with excess energy $E < \varphi_{\text{SB}}$:

$$N_{\text{ph\_barrier}} = \int_0^{\varphi_{SB}} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} N_{int}(E,\theta) d\theta dE \quad (S12)$$

5) The flux of collected hot electrons ($N_{\text{tot\_succ}}$) can be obtained as:

$$N_{\text{tot\_succ}} = \int_{\varphi_{SB}}^{\infty} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} N_{int}(E,\theta) d\theta \times \eta_{inj}(E)\, dE \qquad \text{(S13)}$$

6) The momentum loss ($N_{\text{ph\_momen}}$) is the flux difference of hot electrons reaching the interface with excess energy $E > \varphi_{\text{SB}}$ and collected:

$$N_{\text{ph\_momen}} = \int_{\varphi_{SB}}^{\infty} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} N_{int}(E,\theta) d\theta dE - \int_{\varphi_{SB}}^{\infty} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} N_{int}(E,\theta) d\theta \times \eta_{inj}(E)\, dE \qquad \text{(S14)}$$

Then each hot-electron collection and loss contribution can be obtained by dividing by $N_{\text{ph}}$. The above are the details on how to calculate the hot-electron collection and loss contribution in Fig. 5a and Fig. 5b.

**References**


[S1] T. Gong and J. N. Munday, *Opt. Mater. Express*, 2015, **5**, 2501–2512.

[S2] T. P. White and K. R. Catchpole, *App. Phys. Lett*, 2012, **101**, 073905.

[S3] A. M. Brown, R. Sundararaman, P. Narang, W. A. Goddard III, and H. A. Atwater, *ACS Nano*, 2016, **10**, 957–966.

[S4] C. Zhang, K. Wu, V. Giannini, and X. Li, *ACS Nano*, 2017, **11**, 1719–1727.

[S5] T. Gong and J. N. Munday, *Nano Lett.*, 2014, 15, 147–152.

[S6] H. Chalabi, D. Schoen, and M. L. Brongersma, *Nano Lett.*, 2014, 14, 1374–1380.

[S7] C. Zhang, G. Cao, S. Wu, W. Shao, V. Giannini, S. A. Maier, and X. Li, *Nano Energy*, 2019, 55, 164–172.