

Femtosecond Photonic Viral Inactivation Probed Using Solid-State Nanopores

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I. Nanopore conductance

This material is intended to provide details on methodology adopted to understand the connection between ionic conductance and physical diameter of viruses. At the open state, when the pore is not occupied by viruses, the resistance inside a nanopore, R_o is the sum of the series combination of the pore's geometric resistance, R_p and its access resistance, R_a , which is a consequence of ions converging to a small aperture from a semi-infinite reservoir.[1] One simple model is to consider the nanopore as a cylinder with effective height of h_{eff} . As shown in Fig. 1a The total resistance of an open pore can be written as

$$R_o = R_p + R_a \quad (1)$$

$$R_p(h_{eff}) = \frac{h_{eff}}{\sigma \pi (d_p / 2)^2}, R_a = \frac{1}{\sigma d_p}$$

where d_p is the pore diameter and σ is the salt conductivity. The open pore resistance can provide a simple method for estimating the effective pore height based on the open current which in our case is 35 nA.

When a spherical virus with diameter d , is translocating through the pore (Fig. 2b) so that $h_{eff} \geq d$, the pore resistance can be obtained as:

$$R_b = \frac{1}{\sigma} \int_{-h_{eff}/2}^{h_{eff}/2} \frac{dy}{A(y)} + R_a \quad (2)$$

where $A(y)$ is the cross sectional area of the pore and can be approximated as

$$\begin{aligned} A(y) &= \pi((d_p / 2)^2 - (L(y))^2) & \text{if } |y| \leq d/2 \\ A(y) &= \pi(d_p / 2)^2 & \text{if } d/2 \leq |y| \end{aligned} \quad (3)$$

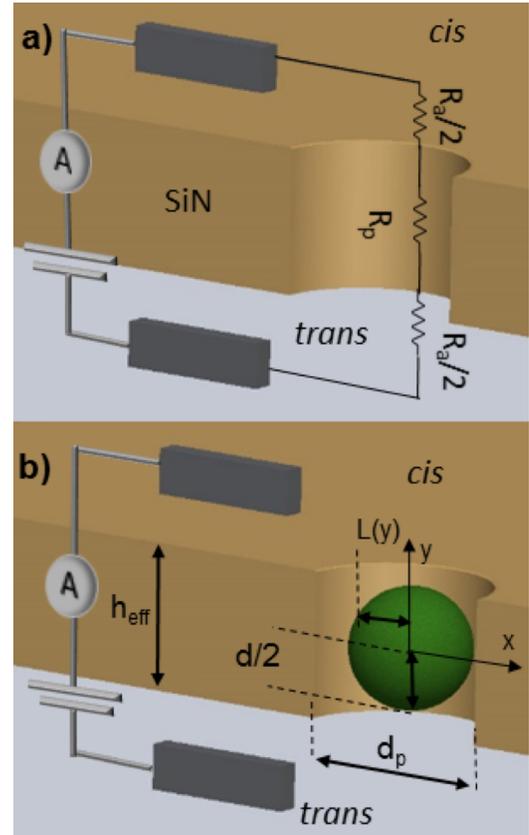


FIG. 1. a) A nanopore device can be shown with a simple electrical circuit. Open pore resistance of a low-aspect-ratio pore consists of cross-pore resistance, R_p , and the access resistance, R_a , connected in series. External DC bias is applied across the membrane using electrodes which are shown with gray boxes. b) Passage of viruses through the pore from *cis* to *trans* chamber, increases transmembrane resistance. In this schematic, pore fabricated in freestanding SiN membrane, is modeled as a cylinder with effective thickness of h_{eff} and diameter of d_p , which is occupied by a spherical virus with diameter d .

with $L(y) = \sqrt{(d/2)^2 - y^2}$. So the pore resistance can be obtained as:

$$R_b = R_a + R_p(h_{eff} - d) + \frac{4}{\sigma\pi\sqrt{d_p^2 - d^2}} \tan^{-1}\left(\frac{d}{\sqrt{d_p^2 - d^2}}\right) \quad (4)$$

Finally, the mean translocation current ratio for spherical virus can be approximated as

$$F_I = \frac{\langle \Delta I \rangle}{I_o} = \frac{V/(R_o) - V/(R_b)}{V/(R_o)} = \frac{R_b - R_o}{R_b} \quad (5)$$

where V is the applied bias.

II. Log - lin plots for the upper bound survival fraction,

Figure 2 shows the normalized ρ_ε function better at small $\rho_\varepsilon / (1 - \varepsilon)$ values. At $\varepsilon = 0.2294$, the data reached the cutoff $\rho_\varepsilon \times N = 5$ so that $\rho_\varepsilon = 0.002$ and the corresponding maximum value of r is 0.0025.

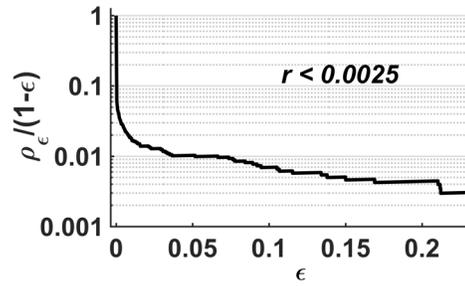


FIG. 2. Log-lin plot of the normalized ρ_ε function for upper bound determination of the survival fraction.

- [1] J. E. Hall, *Access resistance of a small circular pore*, The Journal of general physiology **66**, 531 (1975).