# 電荷差均一化によるナノポアデバイスの絶縁破壊の回避

# Prevention of Dielectric Breakdown of Nanopore Device by Charge Neutralization

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To achieve DNA sequencing using solid-state nanopores, it is necessary to reduce an electric noise current ($I_{rms}$) [1]. In this study, the noise was decreased by reducing the capacitance ($C$) of the nanopore device. We coated an insulating material near a nanopore on a membrane of the device, and confirmed that the capacitance of the device needs to be decreased down to 100 pF in order to reduce the noise.

However, fabricated low-capacity devices had some initial defects, and initial leakage current ($I_{ini}$) flowed through the defects when applying low voltage (0.1 V). The defected devices had a feature that there was a correlation between $I_{rms}$ and $I_{ini}$. We observed the membrane using TEM at each stage of a measurement setup. The observation showed that the membrane didn't have pores after pouring the KCl electrolyte onto the one side of the membrane, but it had pores after pouring the KCl electrolyte onto the both sides of the membrane (Figure 1). These results indicated that the electric-charge difference between electrolyte in the one and the other chamber occurred the dielectric breakdown.

Then, we hypothesized that there is an electric-charge difference ($\Delta Q$) between the electrolyte in the one and the other chamber, and a decrease of capacitance ($C$) increased a potential difference $\Delta V$ (= $\Delta Q/C$) between the electrolyte in the one and the other chamber. The potential difference was considered to defect the membrane by dielectric breakdown (Figure 2).

In order to prevent the dielectric breakdown, we established new procedures using a bypass channel or a bypass wiring (Figure 3). First, a bypass channel or a bypass wiring was connected between the one and the other chamber. Second, electrolyte was poured into the both chambers. In the case of the bypass channel, electrolyte was poured into one chamber, and the both chambers were full with the same electrolyte via the bypass channel. In the case of the bypass wiring, after electrolyte was poured into the one chamber, electrolyte was poured into the other chamber with contacting the poured electrolyte to the bypass wiring. Third, two electrodes for measuring ionic current were connected to electrolyte in both chambers. At last, the bypass channel or the bypass wiring was removed. As a result, no initial leakage current was observed in the devices when applying low voltage (Figure 4). Thus, we verified the hypothesis, and established a procedure of the measurement setup for the low-capacity device.

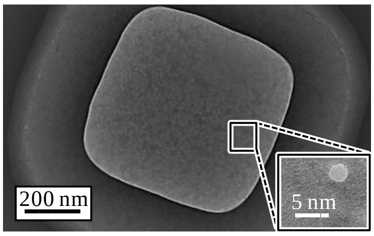


Fig. 1. TEM image of a defected membrane after pouring onto the both sides of the membrane.

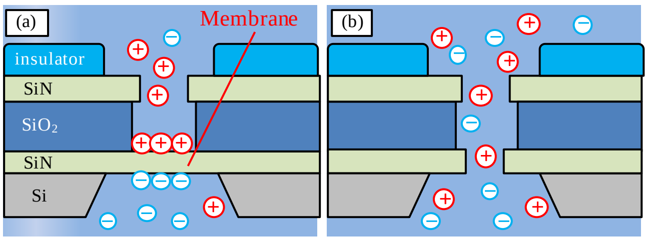


Fig. 2. Schematic images of hypothetical mechanism of initial defects. (a) There is an electric-charge difference between electrolyte in the one and the other chamber. (b) Dielectric breakdown fabricates pores onto the membrane.

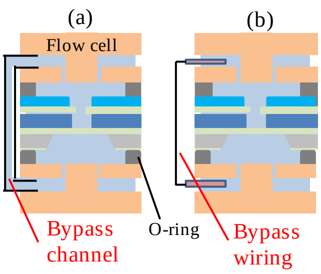


Fig. 3. Schematic images of setups using (a)bypass channel and (b) bypass wiring.

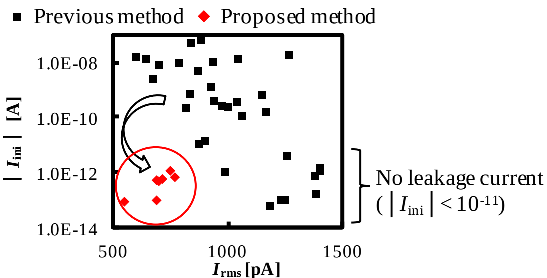


Fig. 4. | $I_{ini}$ | versus $I_{rms}$. There was no leakage current of the device with the setup procedure using the bypasses.

**References**

[1] Balan, A. *et al.*, *Nano Lett.* DOI: 10.1021/nl504345y (2014).