Supplementary Information

Carbon signal after plasma cleaning

The carbon signal was monitored during a time series to determine whether the plasma cleaning was sufficient. Fig. S 1 shows the EELS carbon signal at the beginning of the measurement and after 30 seconds. As can be seen from the electron energy loss spectra for carbon, no signal is detected. This indicates that the carbon content in the sample, as well as any hydrocarbon formation, is below the detection limit of EELS. Therefore, the plasma cleaning is considered sufficient.

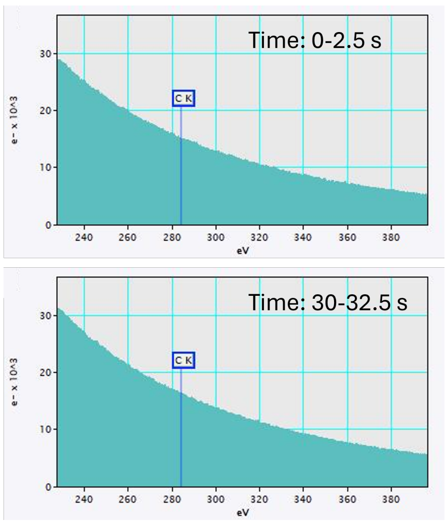


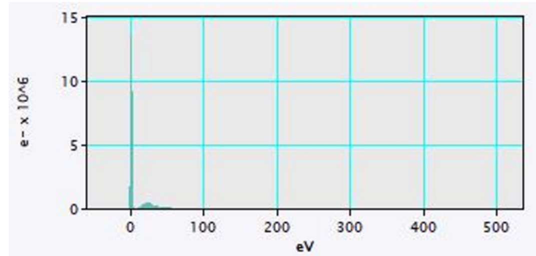
Fig. S 1 Signal from the carbon energy loss range at the beginning of a time series and after 30 seconds of electron beam exposure, corresponding to an accumulated dose of approximately $\sim 5 \cdot 10^8 \mathrm{e}^-/\mathrm{\mathring{A}}^2$

Dose rate calculation

To determine the dose rate, two factors must be known: the number of electrons reaching the sample per second, and the area of the electron beam.

For the calculation of dose rates in this study, the low-loss region of the EELS spectrum is used to determine the number of electrons hitting the sample per second. The sum of the electrons in the low-loss region is divided by the integration time of the spectrum to obtain a value in e^-/s. This estimate will be slightly lower than the actual value, as some electrons are scattered at angles larger than the collection angle. However, since the collection angle is set to 34 mrad, this effect should be minimal, and the low-loss region provides a good approximation of the e^-/s. The analysis is performed in DigitalMicrograph, and an example of the summed low-loss region is shown in Fig. S 2, where the electron count and integration time for the spectrum are listed in the table, resulting in a value of $7 \cdot 10^8\ \mathrm{e}^-/\mathrm{s}$.

The second aspect of calculating the dose rate is estimating the area of the electron beam, which is more uncertain than determining the electron count. In Fig. S 3, a STEM-HAADF image of contamination on the membrane is used to estimate the beam diameter. A profile plot was acquired along the red line shown in the image. As seen in the profile, the transition from high to low intensity occurs within 1–2 pixels. According to the Nyquist sampling criterion, the pixel size should be at least half the size of the beam to resolve it accurately. For this reason it is not possible to determine the beam size precisely from the acquired images. However, it can be inferred that the beam diameter is on the same order of magnitude as the pixel size, which is 0.43 nm for this image. Throughout the paper, the beam diameter is estimated to be 0.4 nm. This approximation may introduce substantial uncertainty in the dose rate — potentially up to an order of magnitude. For this dataset, the calculated dose rate is $1.6 \cdot 10^7\ \mathrm{e}^-/(\mathrm{s} \cdot \mathrm{\mathring{A}}^2)$.



Electron count [e^-]	Integration time [s]
$1.4 \cdot 10^8$	0.198

Fig. S 2 Sum of the low-loss spectra for the time series measurements shown in Fig. 2 and Fig. 3. The dose rate is calculated based on the integrated intensity of the low-loss spectrum.

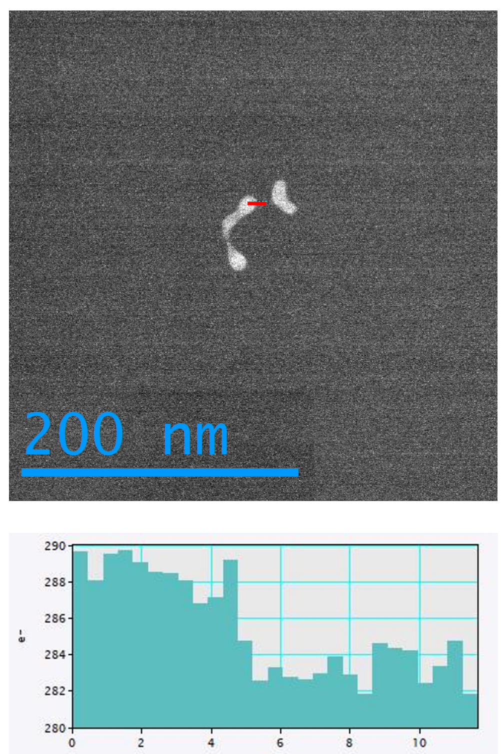


Fig. S 3 STEM image of the membrane with surface contamination. The corresponding intensity profile was acquired along the red line shown in the image. The pixel size is 0.86 nm.

Standards for MLLS analysis

EELS standards for silicon nitride and silicon oxide were used in the MLLS analysis of the silicon edge to track the evolution from silicon nitride to silicon oxide.

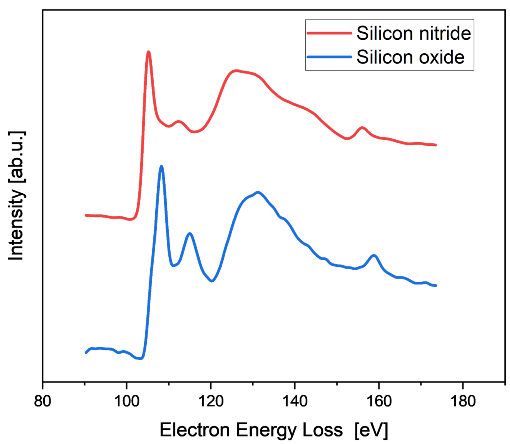


Fig. S 4 Standards for the silicon nitride and silicon oxide signal [19].

Signal from the membrane without water

As a control, the silicon edge of the membrane was recorded in the absence of water, on the membrane between two channels in a chip where water had not crept between the membranes.

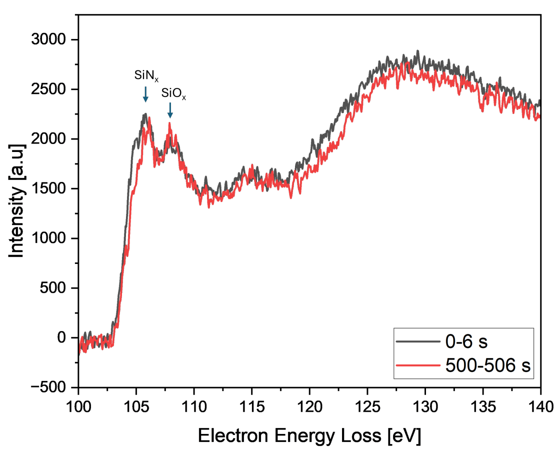


Fig. S 5 Signal from the membrane (adjacent to a channel), where no water is present. The measurement was acquired at a dose rate of $8 \cdot 10^6$ e$^-$/(Å$^2 \cdot$s).

Profile plot for estimation of the beam affected diameter

Profile plot acquired across the beam-affected area from an image of the integrated silicon nitride signal, as shown in Fig. 4.c. To estimate the diameter of the oxidized region, multiple profile plots were taken from the same area, and the average diameter was calculated along with the uncertainty from the pixel size and standard deviation of the diameter measurements.

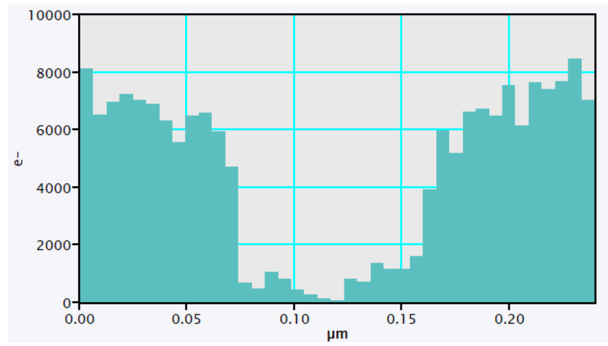


Fig. S 6 Profile plot across the oxidized (beam-affected) area. Multiple profile plots were acquired, and the diameter of the affected region was extracted from these measurements.

Gas references

EELS standards for nitrogen and oxygen gas were used for comparison with the gas formed between the membranes in the delaminated chip.

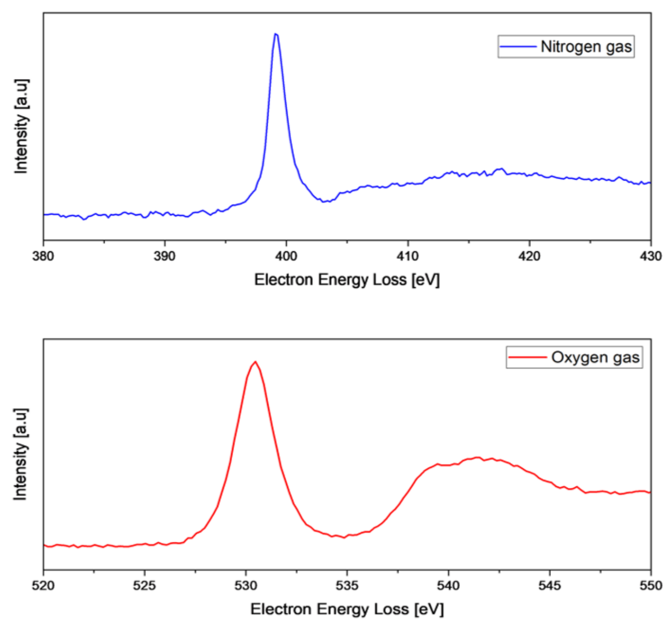


Fig. S 7 Standards for the nitrogen gas [19] and oxygen gas from the Gatan EELS Atlas.