Supporting Information

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How Much Oxygen Can a MXene Surface Take Before It Breaks?

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How much oxygen can a MXene surface take before it breaks?

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Figure S1. EELS spectra of Ti-L2,3(456 eV), O-K (529 eV) and F-K (680 eV) prior to O₂ exposure. The fluorine has been removed by the high temperature treatment.
Figure S2. HRTEM overview (25 nm x 25 nm) of the lattice out of which selections are presented in figure 1a-f in the manuscript. A close inspection reveals that O\textsubscript{2} exposure results in a gradual decrease in hexagonal ordering from a) RT to b-d) 400 °C, this is also seen at larger scale and not just local effect. e) False color HRTEM image at 400 °C after 2 mbar O\textsubscript{2} exposure that depicts the final disordered surface before breakdown. f) False color HRTEM image at 450 °C after 2 mbar O\textsubscript{2} exposure confirm the presence of nanoparticles and the hexagonal lattice has completely degraded.
Figure S3. An overview images of the flake investigated in the ETEM before and after O$_2$ exposure at 450 °C. Note that the 2D flake remains intact although the MXene structure is amorphized.
Figure S4. EELS spectra of Ti-L_{2,3} edges acquired from Ti_3C_2T_X flakes after exposure to 2 mbar O_2 gas for 0.5 h, at RT, 100 °C, 150 °C, 175 °C, 250 °C, 350 °C, 400 °C and 450 °C.
To rule out the possible contribution of trapped and/or intercalated species as a contributor to the O-K quantification EELS spectra is presented on pure O\textsubscript{2} and compared to the signal of terminating O on Ti\textsubscript{3}C\textsubscript{2}T\textsubscript{X}.

![EELS spectra](image)

Figure S5: EELS spectra showing the O-K signal for; O\textsubscript{2} during 2 mbar exposure, and Ti\textsubscript{3}C\textsubscript{2}T\textsubscript{X} in high vacuum at RT (before O\textsubscript{2} exposure), 375 °C, and 450 °C after O\textsubscript{2} exposure.
Figure S5 presents an electron diffraction (ED) pattern acquired after exposure to O$_2$ at 450 °C. A number of additional diffraction spots are observed in contrast to the pattern presented in figure 2b at lower temperatures.

Figure S6. ED pattern of the Ti$_3$C$_2$Tx flake after exposure to O$_2$ at 450 °C

In order to index the reflections, rotational averaging was performed using built-in routines in Gatan Digital Microscopy Suite and ED patterns were simulated with CrystalMaker using standard crystal models of Ti$_3$C$_2$Tx, TiC, TiO$_2$ (brookite, anatase, rutile).
Table S1. List of measured distances for lattice spacings and simulated d-spacings resulting in a close match.

| Measured d-spacings (Å) | Simulated d-spacings | MXene | TiO₂ |
|-------------------------|-----------------------|-------|------|
| 5.38                    |                       |       |      |
| 4.16                    | 011 anatase (3.516)   |       |      |
| 3.66                    | 110 rutile (3.249)    |       |      |
| 3.42                    | 111 brookite (3.462)  |       |      |
| 3.11                    |                       | 111 rutile (2.187) | 221 brookite (2.131) |
| 2.74                    | 010 T₃C₂Tₓ (2.672)    |       |      |
| 2.12                    | 020 anatase (1.892)   | 120 rutile (2.055) | 302 brookite (1.967) |
| 1.98                    | 110 rutile (2.187)    |       |      |
| 1.78                    | 015 anatase (1.700)   | 121 rutile (1.688) | 402 brookite (1.711) |
| 1.68                    | 121 anatase (1.666)   | 220 rutile (1.624) | 230 brookite (1.689) |
| 1.54                    | 110 T₃C₂Tₓ (1.543)    | 123 anatase (1.493) |      |
| 1.43                    | 024 anatase (1.481)   | 130 rutile (1.453) | 213 brookite (1.437) |
| 1.32                    | 200 T₃C₂Tₓ (1.336)    | 220 anatase (1.338) | 112 rutile (1.346) | 213 brookite (1.437) |