For the Same Oxide Film, Whether the Stop Is Set by Itself or by a Voltage Changes the Thickness by Four Orders

— aluminium's native oxide stops itself at about **3** nm, while an anodic film grows in direct proportion to the voltage, reaching **140.000000** nm at **100** V — the separator is whether growth is stopped by the film's own growth or by an externally applied potential — [Paper 714]

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— *From thinking to syncing.* —

Abstract

Aluminium oxidises at its surface with nothing done to it. Making the same oxide electrically changes the thickness by four orders.A stop set from inside and a stop set from outside are placed side by side in the same units.No new theorem or law is claimed. First, the native oxide stops itself——once formed it blocks the path for oxygen, and growth halts at about 3 nm (Section 2). **Second, in anodising the voltage sets the stop——roughly 1.4 nm/V in direct proportion, giving 21.000000 nm at 15 V and 140.000000 nm at 100 V** (Section 2). **Third, the proportionality is exact——the film at 100 V is exactly 100.000000 times that at 1 V, and the design variable moves from chemistry to electricity** (Section 2). **Fourth, and this is the core. The gap is four orders——a hard coating of 50000 nm is 16666.666667 times the native oxide, and the proportionality alone would call for 35714.285714 V** (Section 3). **Fifth, read backwards the gap is sharper still——the native oxide corresponds to only 2.142857 V, less than a single dry cell** (Section 3). **Sixth, the separator is whether the stop lies inside or outside——inside, the thickness is settled for you; outside, it can be chosen** (Section 4). **Keywords**: anodising, passivation, self-limitation, film thickness and voltage, location of the stop, orders of magnitude.

Scope of this paper (scope note): **No new theorem or law is claimed——the self-limiting nature of passive films and the proportionality of anodic film thickness to voltage are both standard (Cabrera and Mott 1949, Schlesinger and Paunovic 2010).The growth mechanism of porous films is not derived——the split into barrier and porous layers is not entered; only the proportionality is used, and it is stated where hard coatings leave it.1.4 nm/V is a representative value——it moves with material and electrolyte; real process conditions are not claimed.Sealing and colouring are not treated——the uses of the film are not discussed.Corrosion rates are not discussed——what the film prevents, and by how much, is not treated.Relation to earlier papers**: **Paper 441 showed that the metal which reacts most readily is the one that does not corrode——there, a metal stopping itself with a thin film was the advantage. Here that stop is replaced from outside by a voltage, and the same "oxide film" spreads four orders on the location of the stop alone.**What is added is **tabulating thickness against voltage**, **showing the proportionality as an exact factor of** **100.000000**, **putting the gap between hard coating and native oxide at** **16666.666667**, **showing the native oxide to correspond to only** **2.142857** **V**, and **placing the separator on where the stop lies**.

1. Notation and the Question

Setting: **the thickness of an anodic film is nearly proportional to the applied voltage. Native oxidation applies no voltage, so the film itself stops the growth.**

$$d_{\text{anodic}} = k\,V, \qquad k \simeq 1.4\ \text{nm/V}, \qquad d_{\text{native}} \simeq 3\ \text{nm}$$

k is a representative value that moves with electrolyte and material. Below it is held fixed and only the voltage is varied.

Question: **under the one word "oxide film", how far apart can the thicknesses be?**

2. The Voltage Sets the Stop

Computation 2.1: **the thickness was derived for each voltage.**

voltage	thickness	times the native oxide
1 V	**1.400000** nm	**0.466667**
15 V	**21.000000** nm	**7.000000**
100 V	**140.000000** nm	**46.666667**
500 V	**700.000000** nm	—

Observation 2.2

the proportionality is exact.The film at 100 V is exactly 100.000000 times that at 1 V——one number, nanometres per volt, states the thickness.

Observation 2.3

so the design variable moves from chemistry to electricity.The film wanted can be specified on the dial of a power supply——with native oxidation the thickness was not chosen but simply arrived.

Observation 2.4

but 1 V does not reach the native oxide.The film at 1 V is only 0.466667 of it, and 15 V is needed to reach 7.000000 times——applying a voltage does not automatically make the film thicker.

3. The Gap Is Four Orders

Computation 3.1: **hard anodising produces films of about 50000 nm (50 µm). This was compared with the 3 nm native oxide.**

quantity	value
hard coating over native oxide	**16666.666667**
voltage the proportionality alone would call for	**35714.285714** V
voltage corresponding to the native oxide	**2.142857** V

Observation 3.2

this is the core: four orders arise from the stop, not from the material.The metal and the oxide are the same; only what halts the growth differs——the same oxide of the same element spreads by 16666.666667.

Observation 3.3

the proportionality runs out partway.A value of 35714.285714 V cannot be produced by any real apparatus——hard coatings are achievable because the film turns porous and gains a route that grows without more voltage, outside the proportional law.

Observation 3.4

read backwards the gap is sharper still.The native oxide corresponds to only 2.142857 V——a potential smaller than one dry cell is the “setting” of the film that forms with nothing done.

Observation 3.5

so saying “there is an oxide film” says nothing about thickness.Both 3 nm and 50000 nm go by the same name——without naming which mechanism made it, four orders of width remain.

4. The Separator

Observation 4.1

the separator is whether growth is stopped by the film’s own growth or by an applied potential.Inside, the thickness is settled for you; outside, it can be chosen——moving the stop outward is what the technique consists of.

Observation 4.2

beside Paper 441.Paper 441 showed that the metal which reacts most readily is the one that does not corrode——there a self-stopping film was the advantage. Here the same self-limitation is also a ceiling on thickness, and removing it buys four orders. The advantage side and the limit side of one self-limitation.

> **Observation 4.3**
>
> **what is not said.Porous film mechanisms, sealing and corrosion rates are not treated, and 1.4 nm/V is held fixed as representative——what is shown is how many orders the location of the stop is worth.**

5. Roll Call and Closing

1. **native oxide 3 nm** (Section 1): **it stops itself.**
2. **21.000000 nm at 15 V** (Computation 2.1): **the voltage is the stop.**
3. **140.000000 nm at 100 V** (Computation 2.1): **direct proportion.**
4. **exactly 100.000000 times** (Observation 2.2): **the proportion is exact.**
5. **1 V gives 0.466667** (Computation 2.1): **short of the native oxide.**
6. **15 V gives 7.000000** (Computation 2.1): **it passes here.**
7. **hard coating 16666.666667** (Computation 3.1): **the core.**
8. **35714.285714 V called for** (Computation 3.1): **outside the law.**
9. **native oxide is 2.142857 V** (Computation 3.1): **under one dry cell.**
10. **inside or outside** (Observation 4.1): **the separator; Paper 441.**

Closing: **For the same oxide film, whether the stop is set by itself or by a voltage changes the thickness by four orders.Aluminium's native oxide blocks the path for oxygen and halts at about 3 nm, while an anodic film grows at roughly 1.4 nm/V in direct proportion, giving 21.000000 nm at 15 V and 140.000000 nm at 100 V.The proportionality is exact, 100 V giving precisely 100.000000 times 1 V——the quantity that specifies thickness moves from chemistry to the dial of a power supply.A hard coating of 50000 nm is 16666.666667 times the native oxide, and the proportionality alone would call for 35714.285714 V——a value no real apparatus produces, so hard coatings exist only because the film turns porous and leaves the proportional law.Read backwards, the native oxide corresponds to only 2.142857 V——a potential under one dry cell is the setting of the film that forms with nothing done.The separator is whether growth is stopped by the film's own growth or by an applied potential.Placed among the earlier papers——in Paper 441 a self-stopping film was the advantage; here the same self-limitation is also a ceiling.To be honest——porous mechanisms and sealing are not treated, and 1.4 nm/V is held fixed as representative.**

References

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