4. Reliability of Aluminum Electrolytic Capacitors

4 – 1 Aluminum Electrolytic Capacitor Failure

Failure modes are roughly classified as follows.

- Failure mode
  - Aluminum electrolytic Capacitor body failure
    - Catastrophic failure ·········· Air tightness failure of the vent (gas generation)
    - Degradation failure (Wear) ············ Capacitance reduction, tan δ increase, Leakage
  - Capacitor peripheral failure
    - Disconnected pattern ············ Corrosion
    - Short pattern ············ Ion migration

Degradation failure can not be found for most other capacitors.

Aluminum electrolytic capacitor increases the failure rate by passing time shown in Fig.6, then, all become open.

In catastrophic failure, the function of the capacitor is completely lost, so it is easily judged as failure, but since the characteristics gradually deteriorate in degradation failure, the stage at which it is judged as a failure will vary greatly with the performance required by the electronic device in which it is used. In the case of degradation failure, variation from the

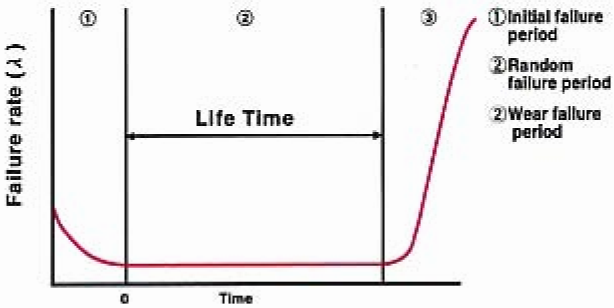
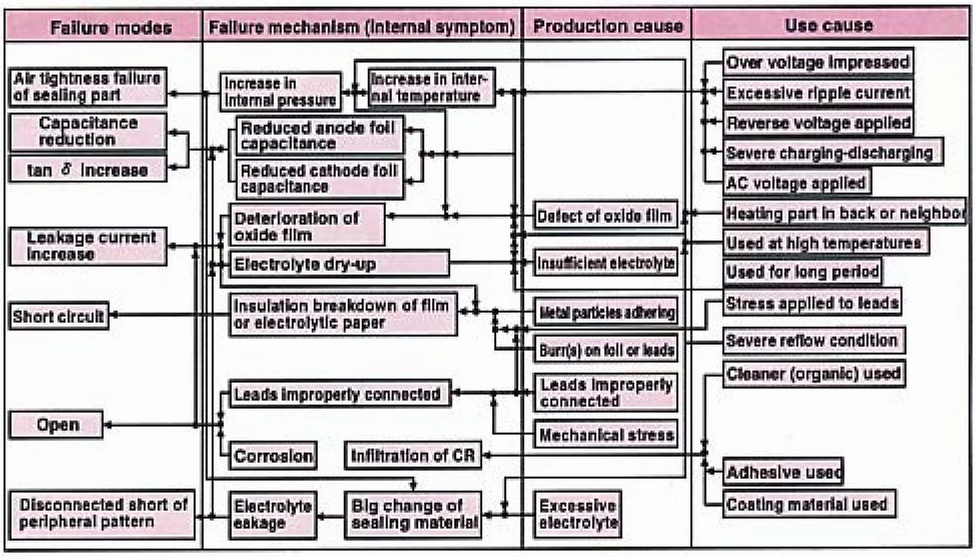


Fig.6 Degradation failure of aluminum electrolytic capacitor

Table-2 Failure mode • mechanism of Aluminum electrolytic capacitor



☆ **Point:Mounting condition greatly influences on the reliability of capacitors.**

(1) Airtightness failure of the vent (gas generation)

Aluminum electrolytic capacitors have characteristics which quickly repair film defects by the mechanism shown in Fig.7. However, as in a battery, oxidation at the anode will cause reduction at the cathode, resulting in the generation of hydrogen gas (H_2).

When used under conditions within the guaranteed ranges noted in the catalog or delivery specifications the hydrogen gas generated is extremely small, and any that generated is dissipated by the depolarization action of the electrolyte or through the sealing element, so there is no problem, but if used under conditions, such as temperature, overvoltage, reverse voltage and excess ripple current, exceeding the guaranteed ranges, damage to the film will increase, causing a sudden increase in the amount of hydrogen gas generated by the self-repairing action. This will cause the internal pressure to rapidly in-

(2) Open Failure

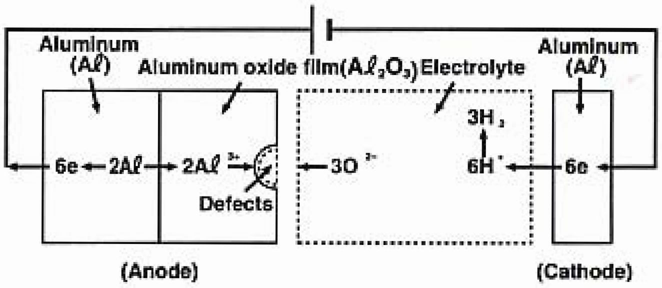
Open failure can occur due to any of the following conditions.

① Mechanical damage to the lead connection

② Corrosion due to the infiltration of a corrosive material

③ Evaporation of electrolyte due to operation of the vent

④ Final stage of gradual deterioration



$$2Aℓ \rightarrow 2Aℓ^{3+} + 6e^-$$
$$3H_2O \rightarrow 6H^+ + 3O^{2-}$$
$$2Aℓ^{3+} + 3O^{2-} \rightarrow Aℓ_2O_3$$
$$6H^+ + 6e^- \rightarrow 3H_2 \uparrow$$

Fig.7 Self-Repairing Mechanism

The first one occurs due to improper connection at the time of production or the lead being subjected to excessive stress, vibration, or impact. The second one occurs when halogenated ions ($Cℓ^-$) enter during production, or the capacitor is cleaned with a halogenated cleaner or is reinforced with a resin containing halogenated compounds and halogenated substances enter the capacitor. These corrode the leads or electrode foils until an open condition results.

The third one occurs when internal electrolyte evaporates causing the capacitor to dry up. This reduces the capacitance and increases tanδ.

The fourth one occurs at the end of the life of the capacitor through the process of deterioration ; i.e., the final stages of degradation failure in which the electrolyte gradually penetrates through the seal causing the capacitance to drop and tan δ to increases.

(3) Short circuit

We use electrolytes with excellent film repairing characteristics in our aluminum electrolytic capacitors, so any film defects that do occur are quickly repaired and local concentrations of current avoided. Therefore, catastrophic failures such as short circuits or breakdown are normally very rare.

However, if defects such as metal or other conductive particles or burrs on electrode foils or leads are allowed to pass in production, or if, during use of the capacitor, stress is applied to the leads or it is subjected to undue vibration or shock, the capacitor's separator paper may be damaged allowing the anode and cathode foils to come in contact and result in a short circuit.

(4) Degradation failure (life)

Fig.8 shows the relation of electrolyte amount and capacitance tanδ. It has changed (capacitance reduction and tanδincrease) according to aluminum case, contact part of sealing material and lead wire, and penetration・emission of electrolyte from sealing interface.

Judgement of degradation depends on the product type, so that catalog or delivery specifications should be referred.

For capacitance and tan δin Fig.8, the characteristics are drastically changed when the electrolyte amount reduces to a certain point.

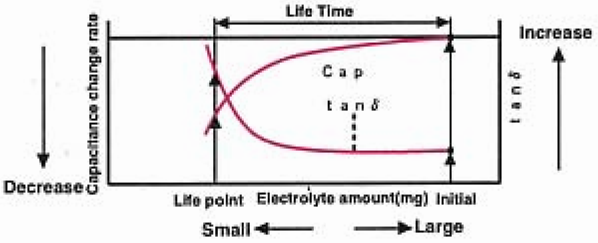


Fig.8 Characteristics degradation & Electrolyte amount

(5) Failures of capacitor periphery

Aluminum electrolytic capacitors may influence on its periphery of PCB (especially, wiring pattern), not only on capacitor itself.

Electrolyte used is gradually penetrated and emitted below the capacitor through one of the two routes, and the following phenomena may happen.

1) Disconnected pattern The pictures of Fig.10 show the capacitor which was forced to drop electrolyte, applied 32V/mm voltage and left for 20 hours at 40°C90~95%RH. (a)
2) Short pattern Where the electrolyte adheres the patterns which have potencial difference over two, copper or silver of pattern materials may make ion migration. (b)

This phenomenon varies a lot depending on environment condition (especially, humidity and dew condensation should be careful) and intensity of electric field.

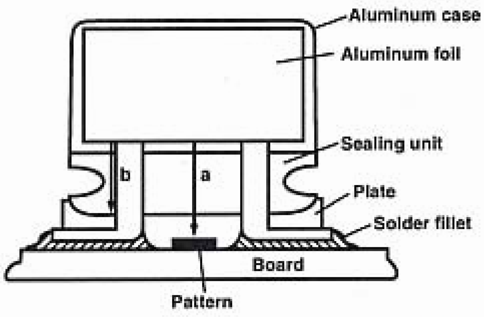
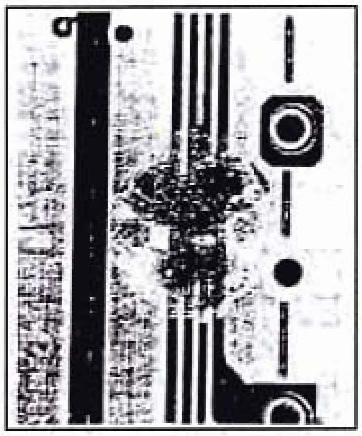
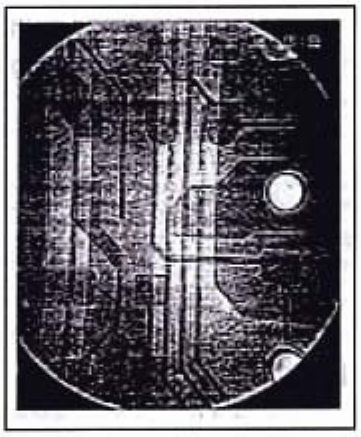


Fig.9 Electrolyte penetration of Aluminum electrolytic capacitor



(a)



(b)

Fig.10 Corrosion at electrolyte dropping test