KEMET

a YAGEO company

Tantalum Capacitors Technology

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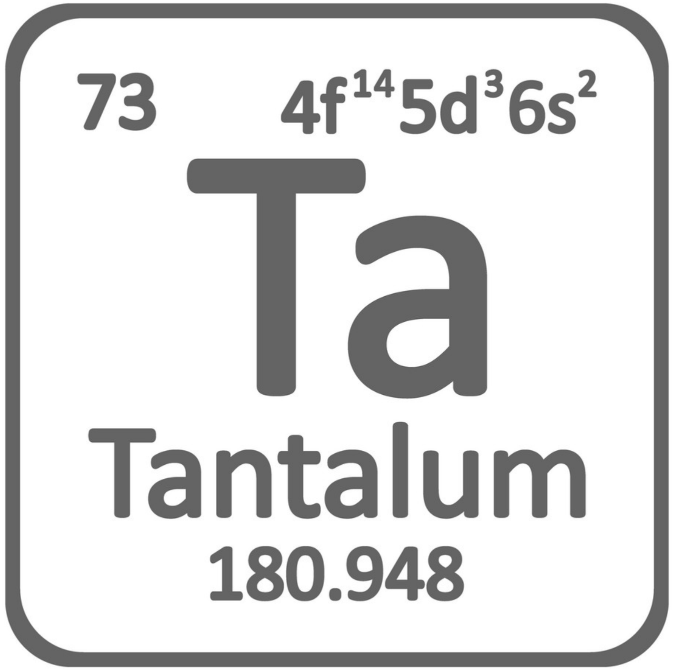
Influences on Capacitors, How Materials and Environmental Effects Influence Capacitor Performance

Workshop 2022 – Houston, TX, USA, 19th March 2022

Outline

- Tantalum Capacitors
  - History and Future Path
  - Polymer Advantages
  - Materials and Manufacturing Technology
- Key Take Aways



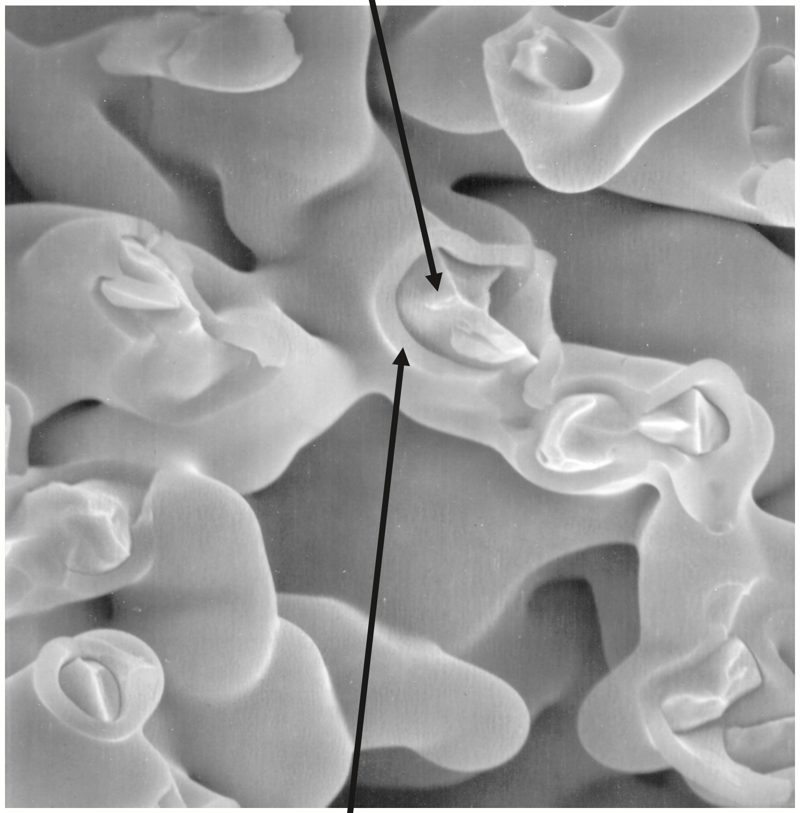
Capacitors manufactured from **Tantalum metal**

- Discover in 1802 by Mr.A.G.Ekeberg

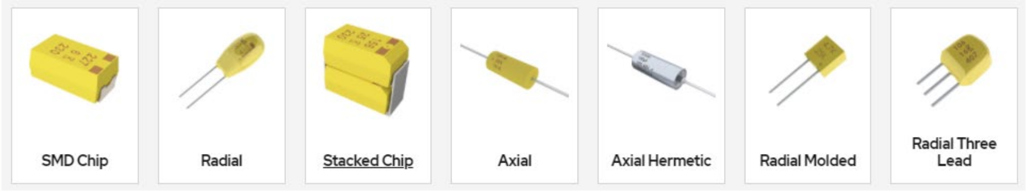
- Explored in Sweden, Finland, Americas, Australia and Africa

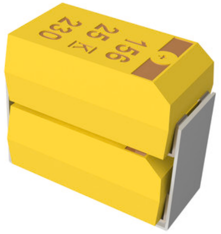
- Presents chemical stability (exceptional resistance to several chemical agents and to a great variety of acids)

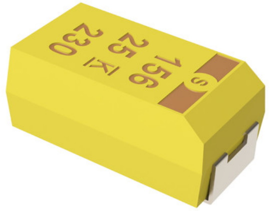
-Ta_2O_5 is quite stable in temperature; and its forming and density are totally controlled by electrochemical.



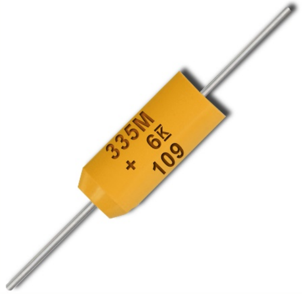
Tantalum Capacitor History





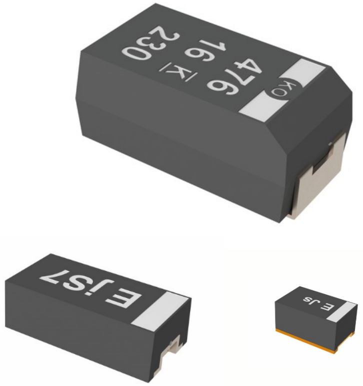


Old Legacy Tantalum MnO_2 Capacitors

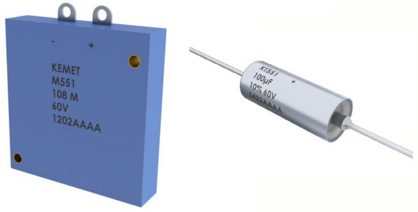


https://www.kemet.com/en/us/capacitors/tantalum.html

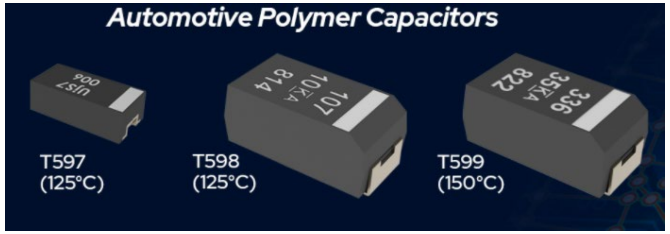
Max Operational Temperature: 125ºC up to 230ºC



New Tantalum Polymer Capacitors



https://ec.kemet.com/polymer/general-purpose/

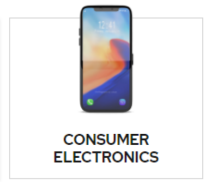
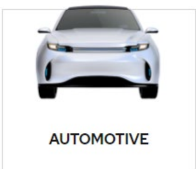


https://ec.kemet.com/polymer-automotive/

https://ec.kemet.com/polymer-high-reliability/

Max Operational Temperature: 85ºC up to 150ºC

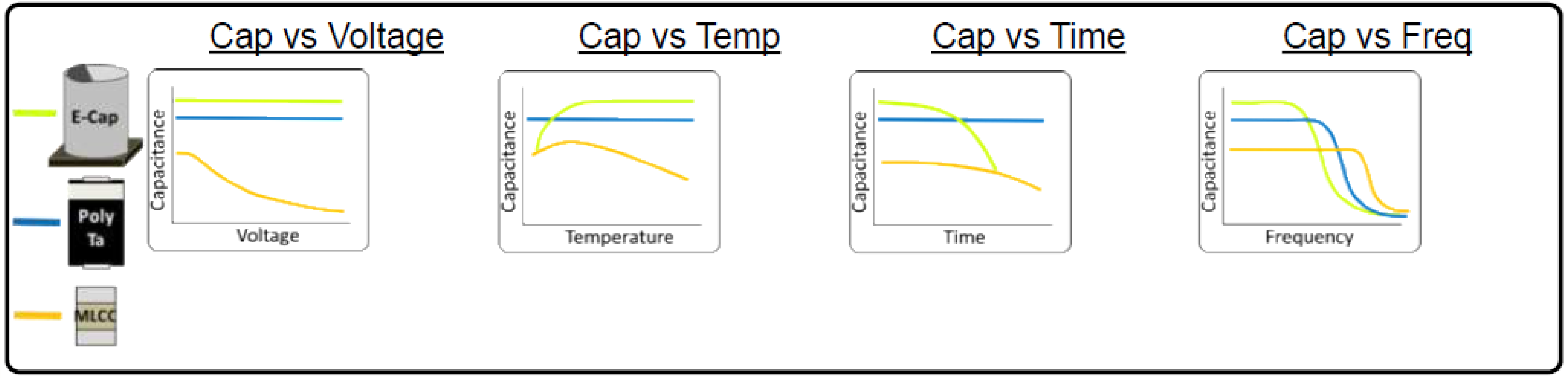
Tantalum Capacitor Future Path

	General Purpose			Automotive	High Reliability
SEGMENTS					
APPLICATIONS	Tablets Laptops USB Type C Smart Phones	Solid State Drives Servers Telecom 5G	Embedded Power Management Industrial Equipment Internet of Things	Infotainment ADAS, Autonomous Driving Safety &Power Train	Radar Systems Communication Launch Systems Satellites Avionics
TRENDS	Ultra Thin Packages High Density Boards	Highest Energy Density Extended Mission Profiles	Miniaturization Higher voltages in smaller case sizes	H/EV = Electrification 48V power lines Autonomous And Connectivity	Power Efficiency GaN Miniaturization Bulk Capacitance

New Tantalum Polymer Capacitors Adoption and Growth will continue!

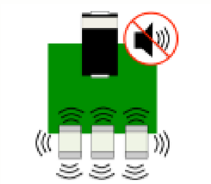
Tantalum Capacitor Polymer Advantages

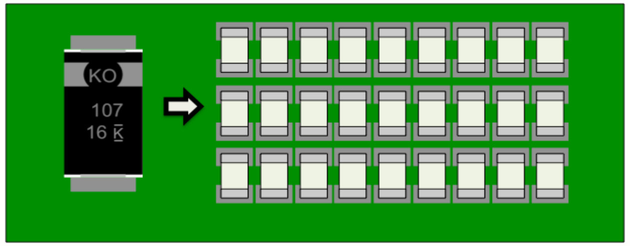
- Polymer Capacitors offer stable capacitance compared to other capacitors



MLCC vs Polymer

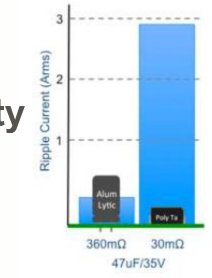
- No Piezo Noise
- Board saving - Piece Count Reduction

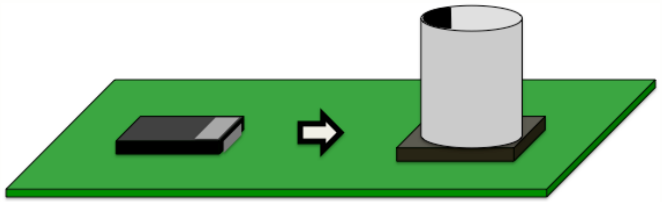




Electrolytic vs Polymer

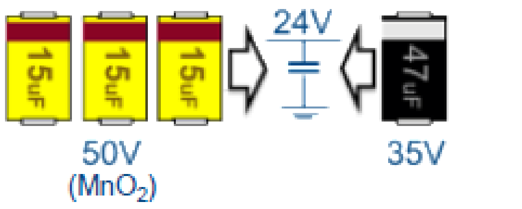
- Low profile
- High Ripple Capability
- Long Life Time





Tantalum MnO_2 vs Polymer

- No ignition failure mode
- Less De-rating



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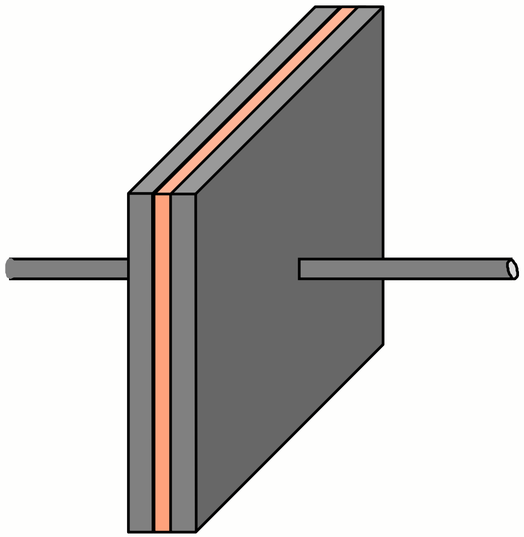
$$C = \varepsilon_0 \varepsilon_r \frac{A}{d}$$



C	capacitance (ability to store electrical energy)
ε_0	natural constant $8{,}85 \cdot 10^{-12}$ F/m
ε_r	dielectric constant (material property)
A	area of the electrode
d	thickness of dielectric layer

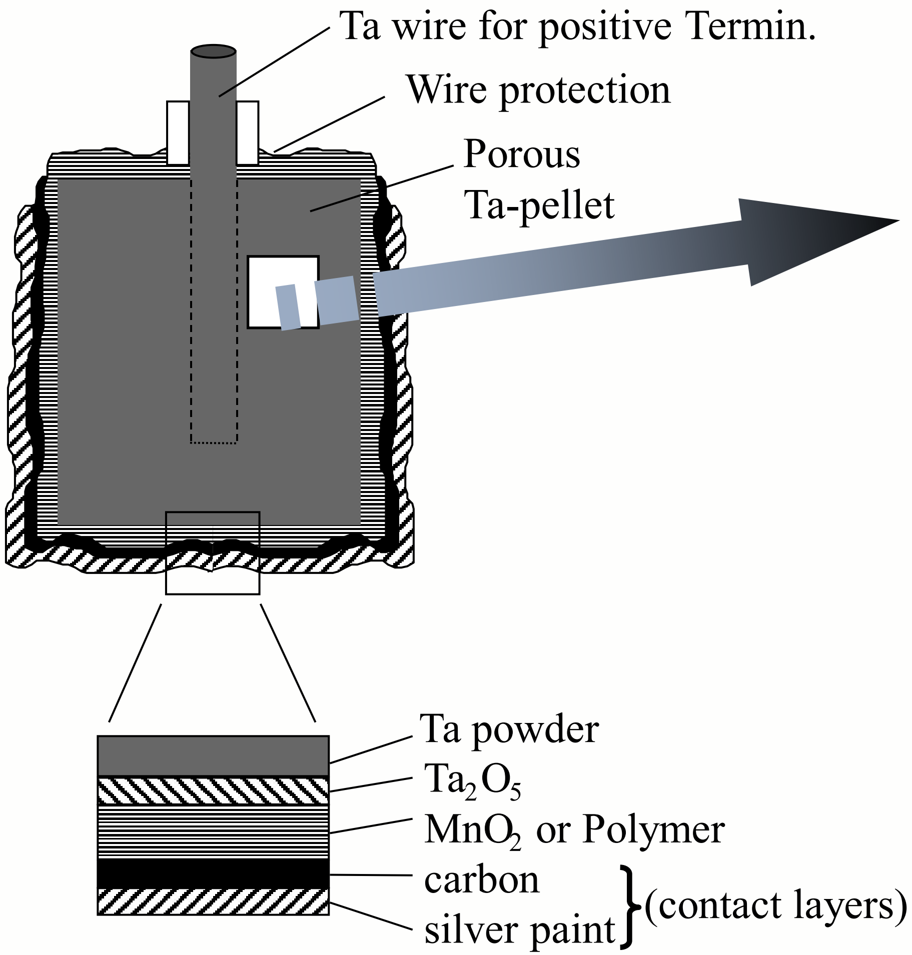
- High volumetric efficiency

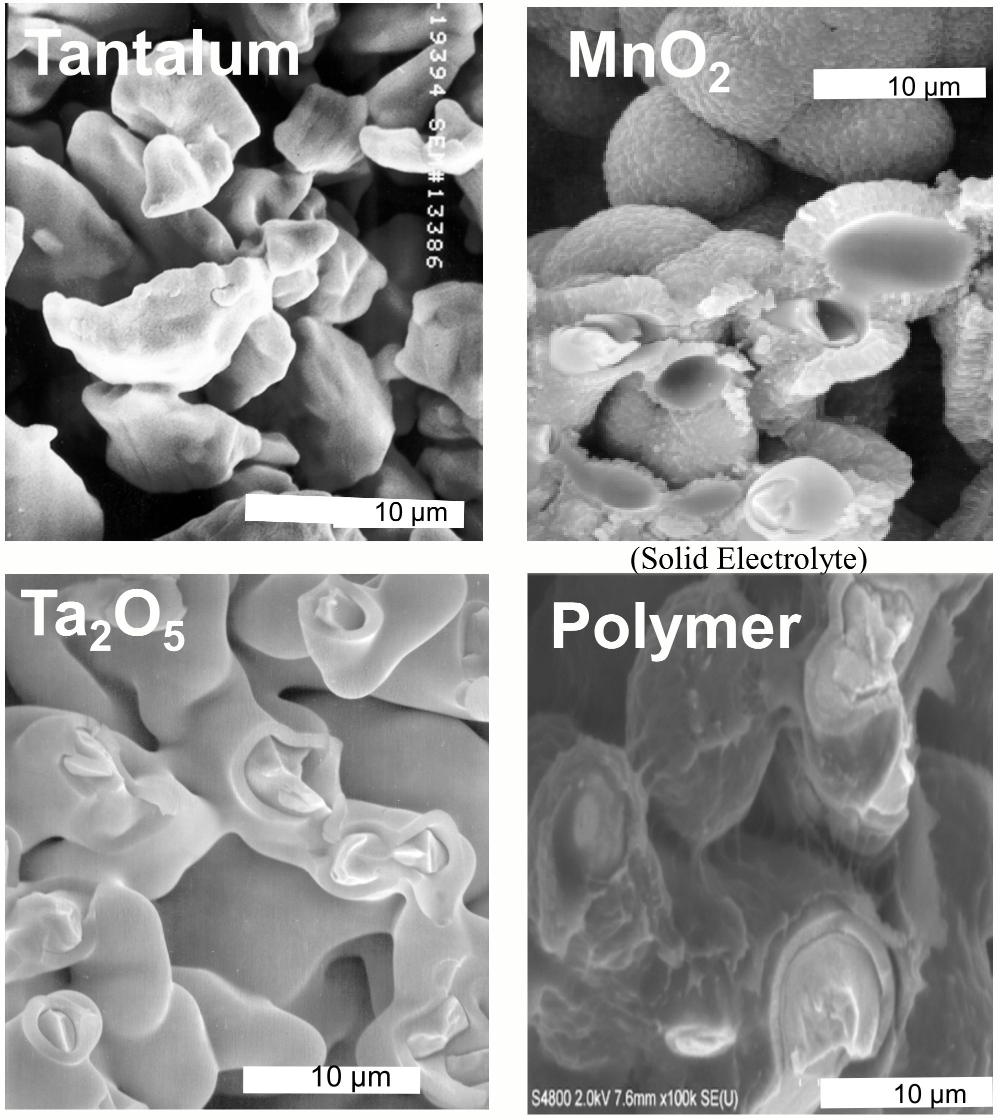
  $\varepsilon_{Ta_2O_5} = 27$

  $\varepsilon_{Al_2O_3} = 9$

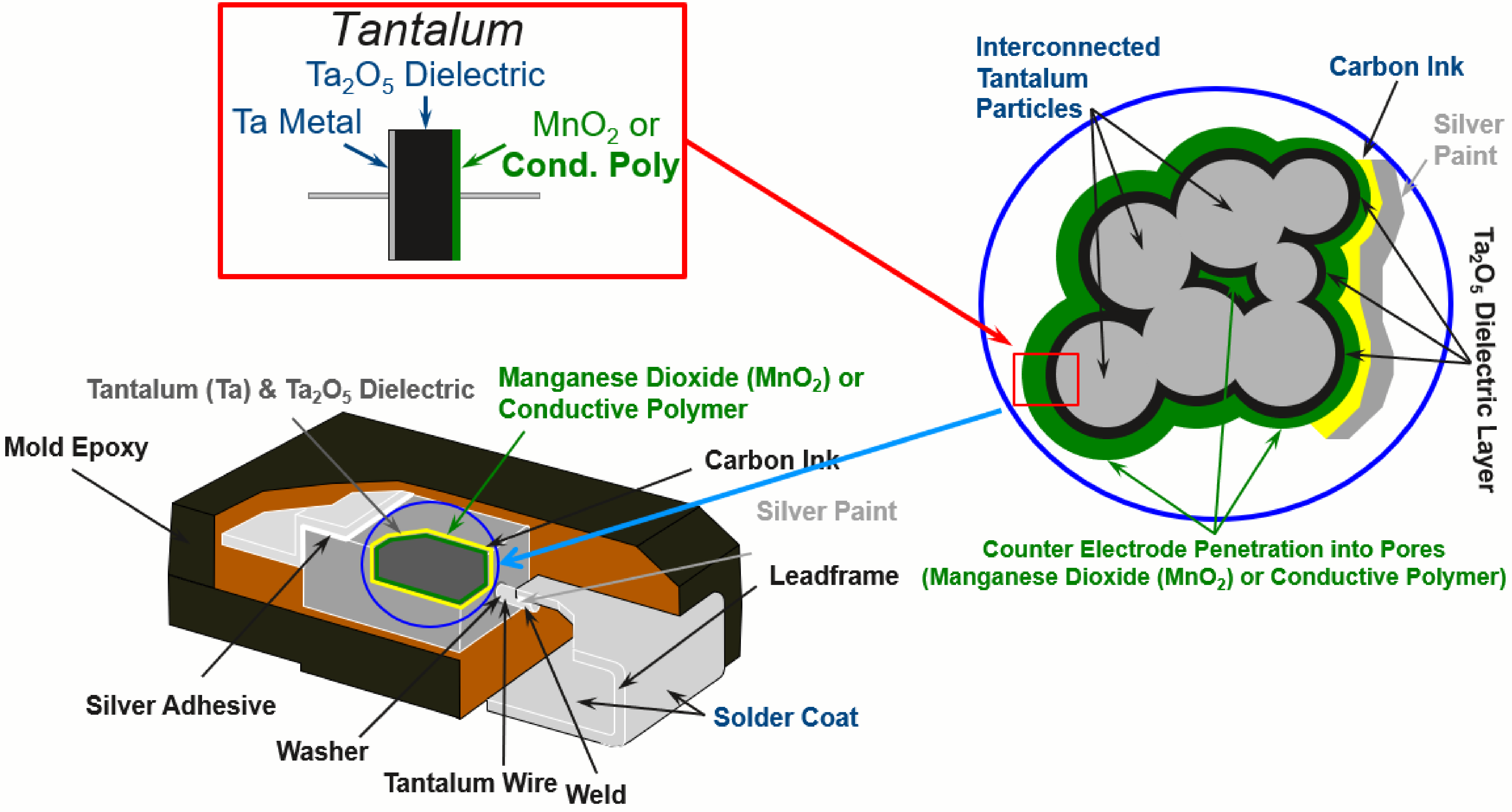
- Suitable for space restricted applications

Materials and Technology — Layer by Layer



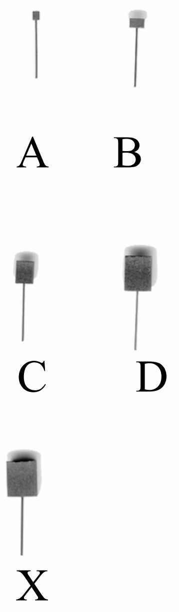


Cross section

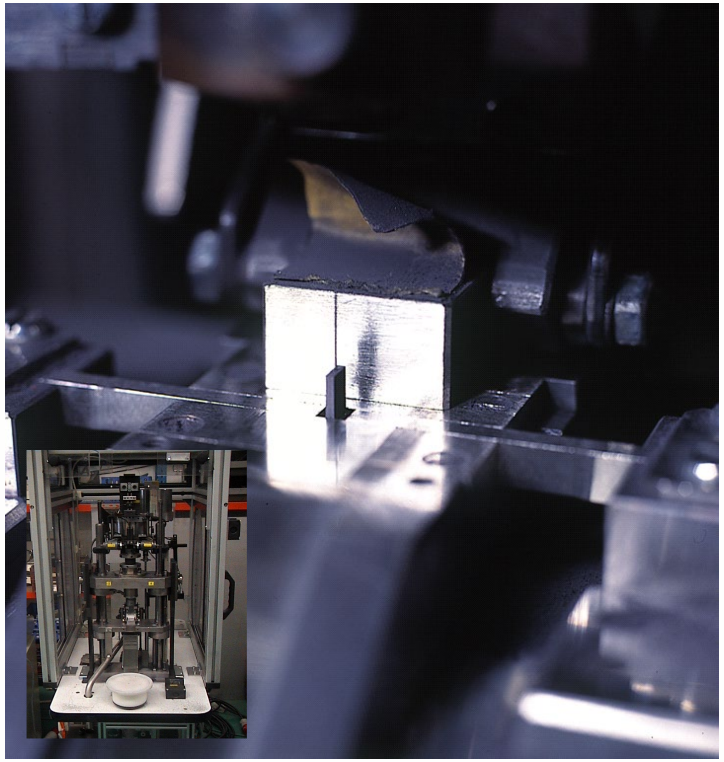


Materials and Technology — Pressing/Sintering

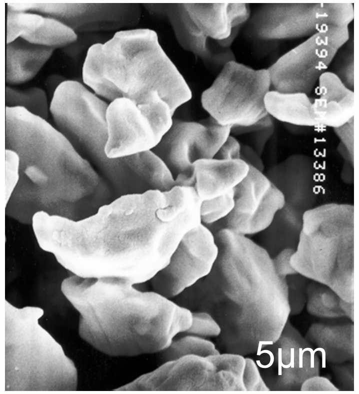
- Tantalum powder preparation (T, t)
- Powder mixed with binder and lubricant



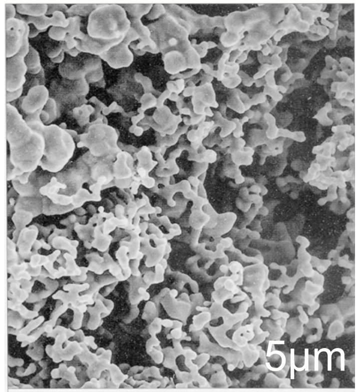
anodes



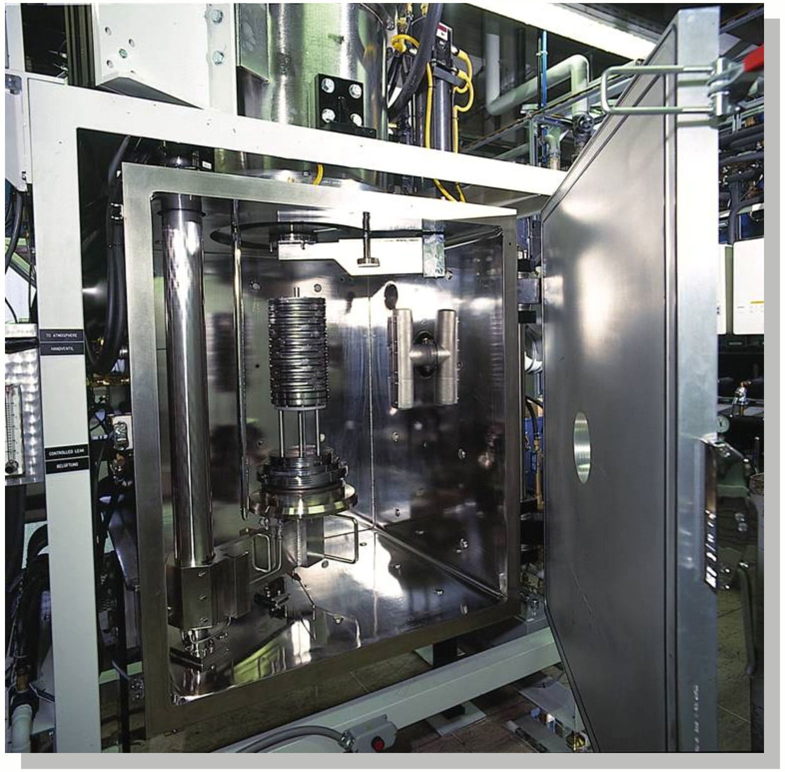
- Pressing anodes (Weight, dimensions – SPC)



High Voltage
Low Capacitance



Low Voltage
High Capacitance



The anodes are sintered in a vacuum chamber at temperatures up to 2000ºC for 15 min and pressures << 1 • 10^{-4} Pa

Ta_2O_5 Build Up

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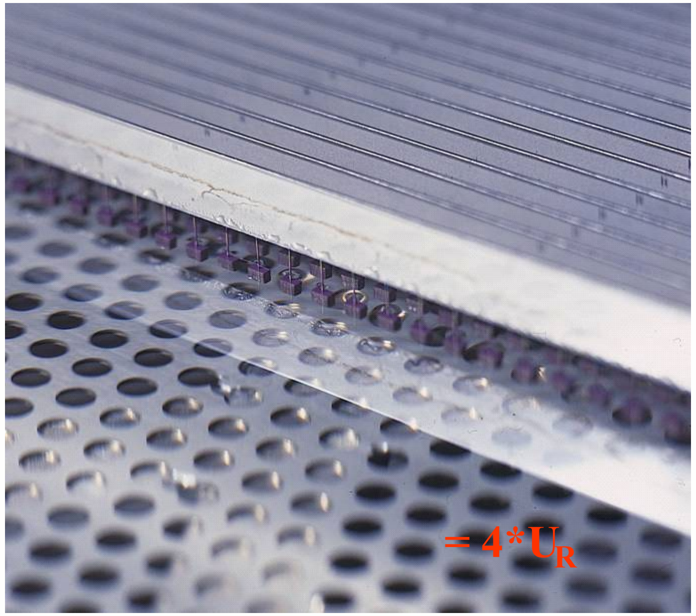
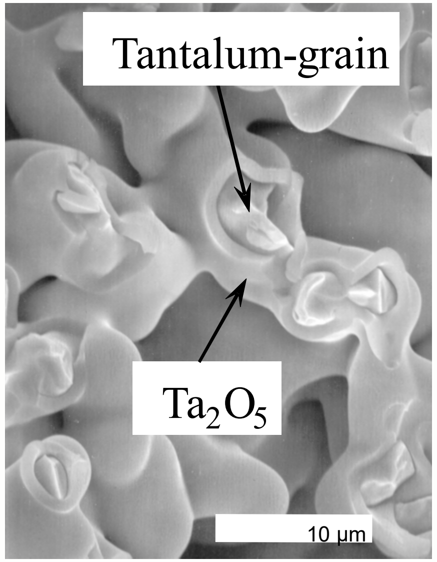




SEM Picture

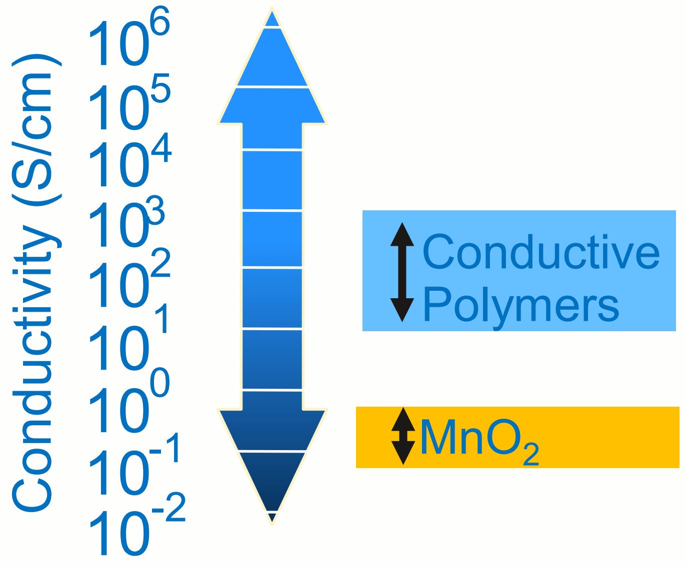
- Conductivity
- Temperature
- Current
- Time
- Voltage
- Capacitance
- Electrolyte [ ]
- Fe/Al contaminations

Anodic Oxidation: The anodes are immersed in electrolytic baths. By applying voltage, the dielectric Ta_2O_5 of the capacitor is formed.

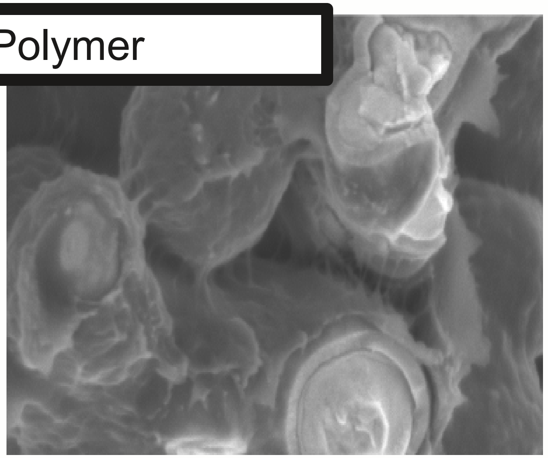
Dependence of the interference colour and the formation voltage

10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

Materials and Technology — Counter Electrode



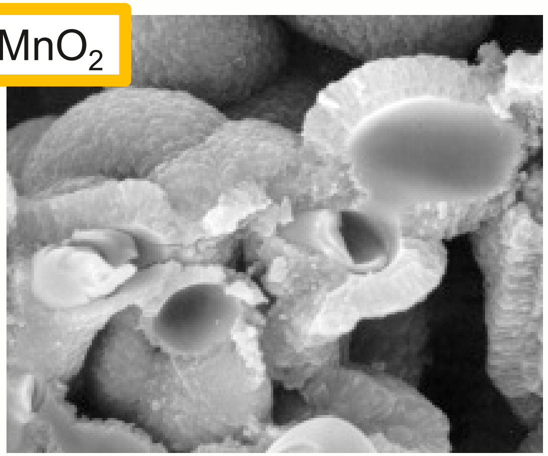
Polymer



- Conductive Organic Polymer

  Polymerization reaction with monomer and oxidant at lower temperature; ‘soft thin film’. Different chemistry settings available.

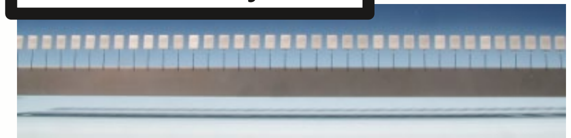
MnO_2



- MnO_2 is Manganese Dioxide

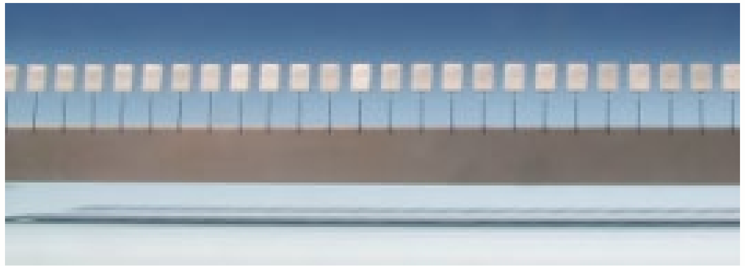
  Brittle semiconductor material obtained by thermal decomposition at ~260ºC of manganese nitrate

External Layers

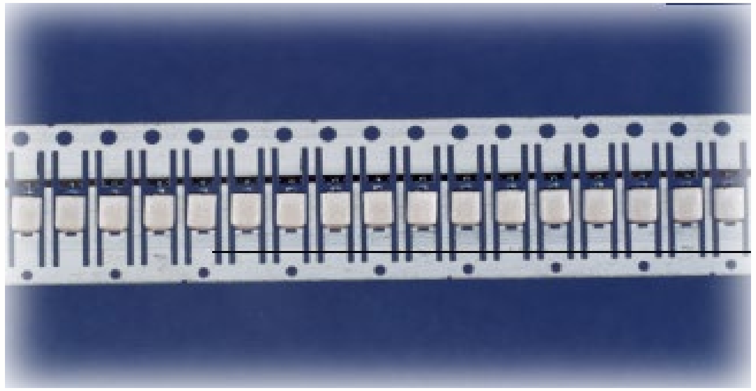


Interface Layers (carbon / silver)

Assembly

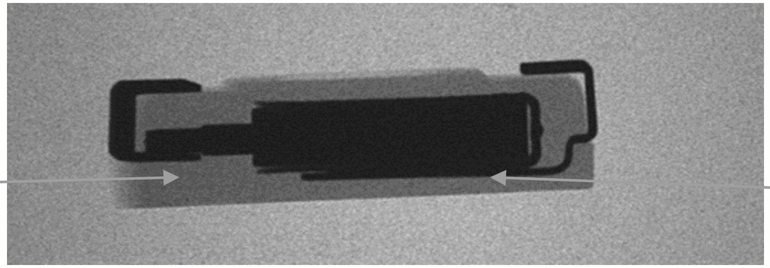


- ® Capacitor is mounted on the leadframe
- ® Glued with silver adhesive
- ® The wire is cut and welded to the leadframe
- ® Support bar is removed



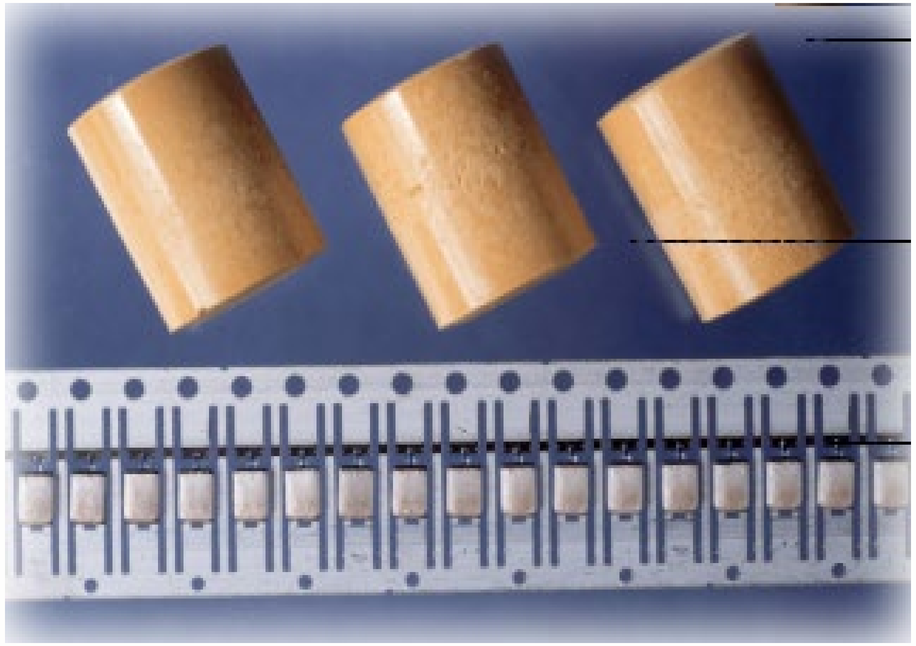
- ® Control cameras for:
  - the adhesive quantity
  - pellet position
- ® Defects are marked and removed later

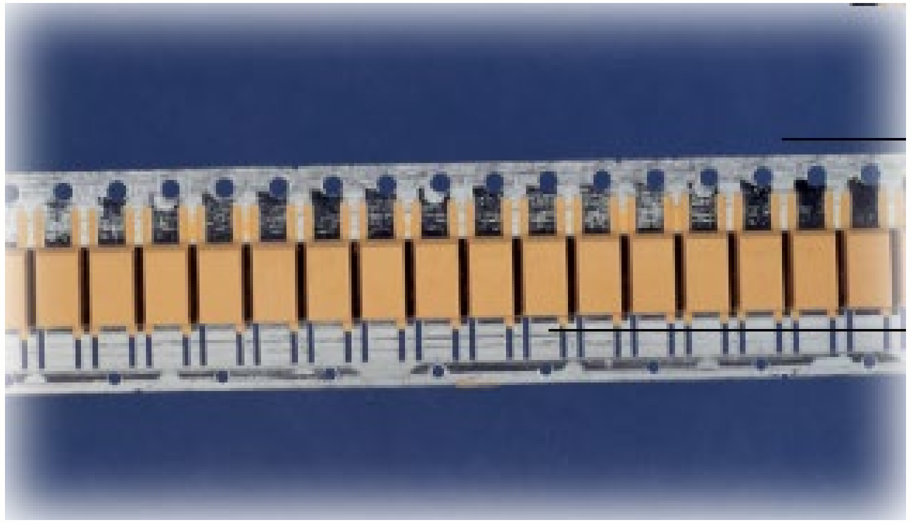
***Anode*:**
Welding



***Cathode*:**
Silver Adhesive

Molding





MOLDING: the capacitor is encapsulated to give mechanical stability and to allows laser marking.

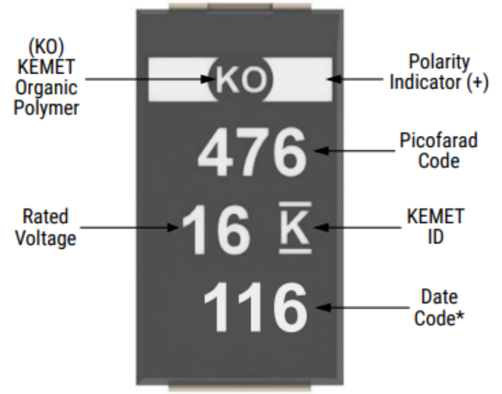
Marking/Aging

Lasermarking and Inspection:

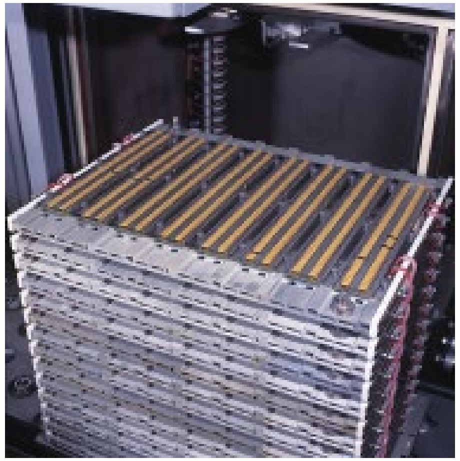
-The capacitors are inspected (

- Not completely molded or dirty parts are removed.

- Marking is applied, the date code allows traceability



* 116 = 16th week of 2021



Aging:

-The capacitors are stressed by applying a voltage (>U_R) and high temperature (125ºC).

-A series resistance is used.

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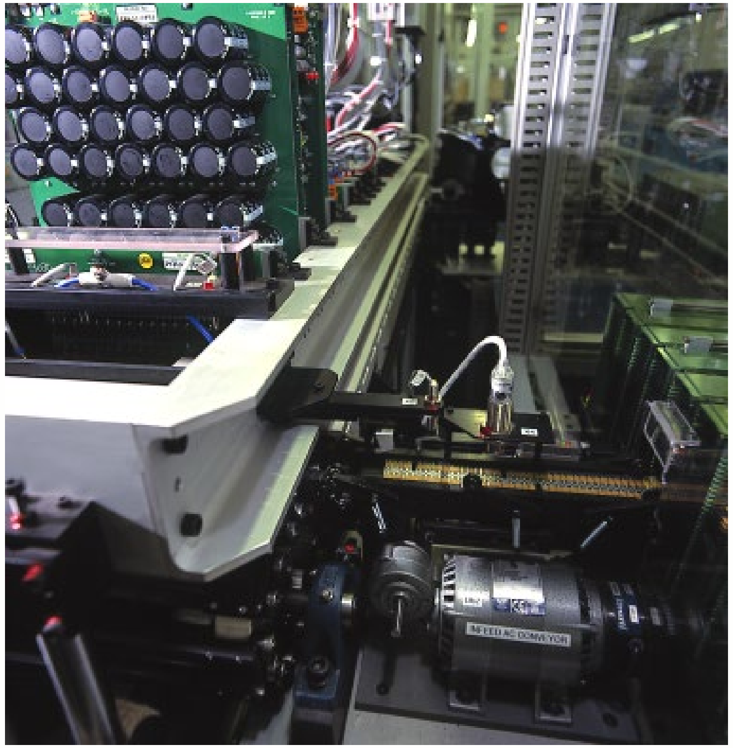


100% testing of electrical parameters for all the capacitors

- capacitance (120Hz)
- leakage current
- impedance (100kHz)
- dissipation factor (120Hz)

- Internal limits stricter than the specified limits

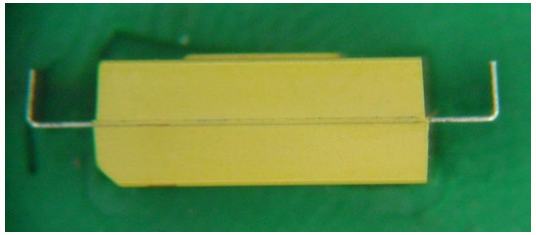
- 100 In-rush test is applied (several pulses, low series resistance, high current)

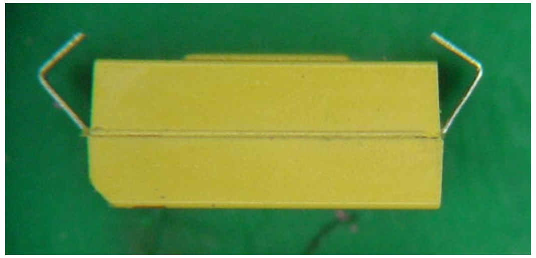
- The bad parts are cut out of the leadframe

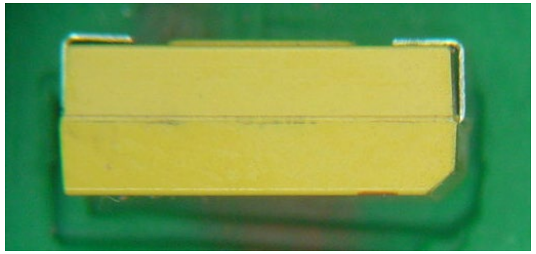
- Detail test protocol for each lot with statistic information of the tested parameters

-Before Tape and Form the protocols are evaluated by the Conformity tests personal

Form/Tape/Shipment







Final Inspection before warehouse delivery
(visual inspection, documentation check)

Key Take Aways

- Tantalum Capacitors are solid electrolyte capacitors and were introduced in the 50’s using legacy MnO_2 counter electrode.
- On the 90’s the new Polymer conductive counter electrode technology started mass production and during the last 2 decades R&D and NPD has supported adoption and business growth.
- The design and manufacturing process are complex and are continuously improved;
- KEMET is positioned to take proactive steps with following objectives:
  - Be a competitive permanent supplier of MnO_2 capacitors
  - Continue the expansion of Polymer capacitors into future applications
  - Continue the introduction of Polymer capacitors in Transportation and High Reliability apps.

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Thank You!