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Electrochemical Migration on the Interconnection Networks Used in Microelectronics, part 2.

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Session: Corrosion Reliability of Electronic Materials and Devices, Keynote lecture

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ELEKTRONIKAI TECHNOLÓGIA TANSZÉK

Outlines

1. Electrochemical migration (ECM) – The process
2. ECM process models
3. Virtual ECM – The process
4. Experimental proves of virtual migration
5. Conclusions for ECM of reduced oxides and „Virtual” migration
6. Problems for further research of ECM

7. Activities and facilities for investigation ECM at BMEETT

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The Process of Electrochemical Migration (ECM)

- Catastrophic failures caused by electrical shorts due to dendritic growth
- ECM occurs during electrical operation: climatic conditions and contaminant have determining effect
- Self regeneration is highly possible: failure generation cycles often occur, it is difficult to recognise at closed electrical assemblies
- The process itself:
  - Voltage bias between conductive sites
  - A continuous moisture film is necessary (few molecular thickness is enough)
  - Cations dissolve from the anode
  - Ion migration toward the cathode (modified by the electrolyte)
  - Ion deposition at the cathode forming dendrites
  - Dendrites grow toward the anode
  - Short circuit formation
  - The shorts cut off due to the high current densities
  - Short circuit generation and cut-off cycles occur
  - Massive short circuit failure is formed finally.

ECM process models

The classical ECM model

- non-passivated anodic dissolution (Ag, Cu, Pb, Sb)
- passivated anodic dissolution (Sn)

Anomalous (anodic) dendritic growth (Ni, Cu?)

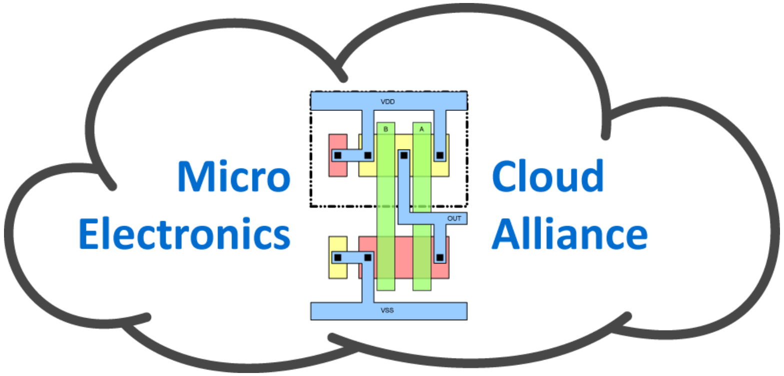
Migration with contaminants

- Contaminant modified migration
- Contaminant induced ECM (Au, Pd, Pt)
- ECM of reduced oxides (Bi, Pb, Cu, Fe)
- „Virtual” migration (Bi, Pb, Cu, Fe)

AVAILABILITY OF THE MODELS:

MICROELECTRONICS CLOUD ALLIANCE

Brings together 18 higher education institutions and SMEs to develop open educational resources in the field of teaching microelectronics.



Entry point to access the open educational resources (OERs):

http://www.ett.bme.hu/meca/EP/

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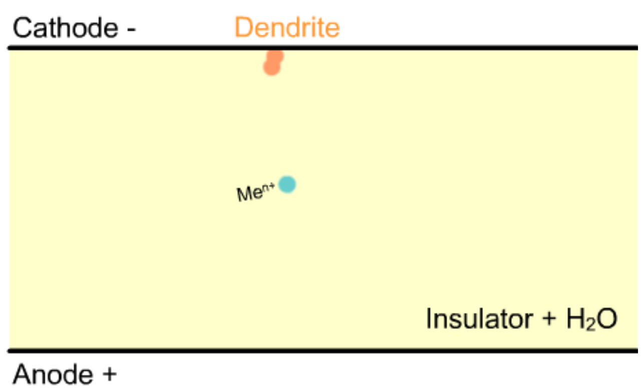
7 - Electronic devices and appliances

7.4. Electrochemical migration

1. Classical model of electrochemical migration ▼



2. Electrolysis of water ▼
3. Electrochemical migration in the case of non-passivated anodic dissolution ▼
4. Electrochemical migration with passivated anodic dissolution ▼
5. Migration process modified by halogen contaminants ▼
6. Halogen-induced migration through complex-ion formation ▼
7. Anodic dendritic growth through negative complex-ion formation ▼
8. Migration of reduced oxides ▼
9. "Virtual" migration ▼

http://www.ett.bme.hu/meca/Courses/TEP/7_4.html

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ECM of reduced oxides (Bi, Pb, Cu, Fe) and „virtual migration”

Experimental proves of virtual migration

- MTTF data of thick film capacitors in THB tests
- XPS spectra of thick film capacitors (TFCs)
- Effect of compsition and process parameters
- In situ X-ray spectra during heat annealing

Table 1.
THB-test results on different conductor-dielectrics systems (95%RH, 40 ºC, 10 V DC)

Conductor comp.	Mean time to failure, hours			
		Dielectrics		
	on alumina	K300	K600	K800
Ag-Pt	130	100	110	130
Ag-Pd	310	90	150	280
Ag-Pd-Pt	>4000	120	300	2500
Au-Pd	>4000	100	350	2800
Au-Pt	>4000	120	330	3000
Au	>4000	130	300	2700

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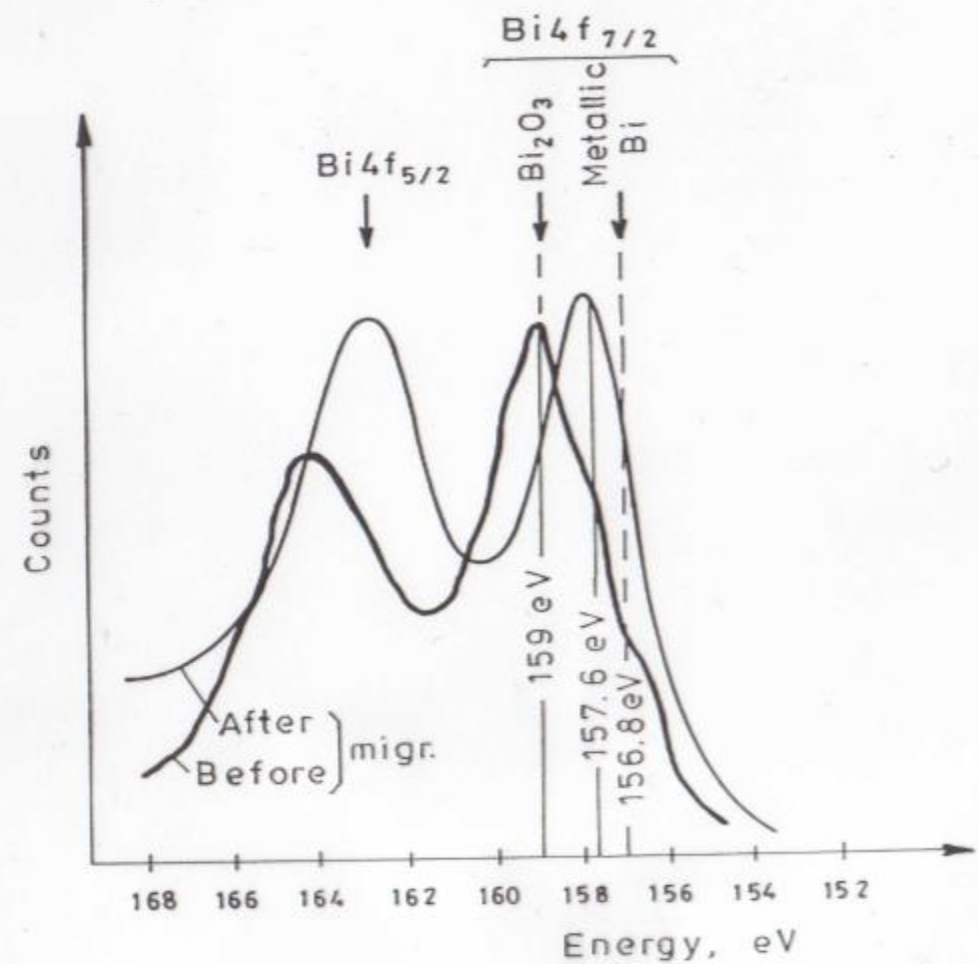
XPS-spectra of Bi2O3 thick-film samples as prepared and after migration test (using AlK$_\alpha$ source, after 5 min of argon-ion sputtering, 4 keV, 7 mA).



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Sample fabrication:

- thick film capacitors
- geometry: 3.32mm x 3.32mm (130 mil sq)
- alumina substrates
- Au conductors
- various firing profiles
- special dielectric pastes:
  - $BaTiO_3$
  - Fe_2O_3 or Bi_2O_3, respectively, in various concentrations
  - (glass frit)
  - organic vehicle

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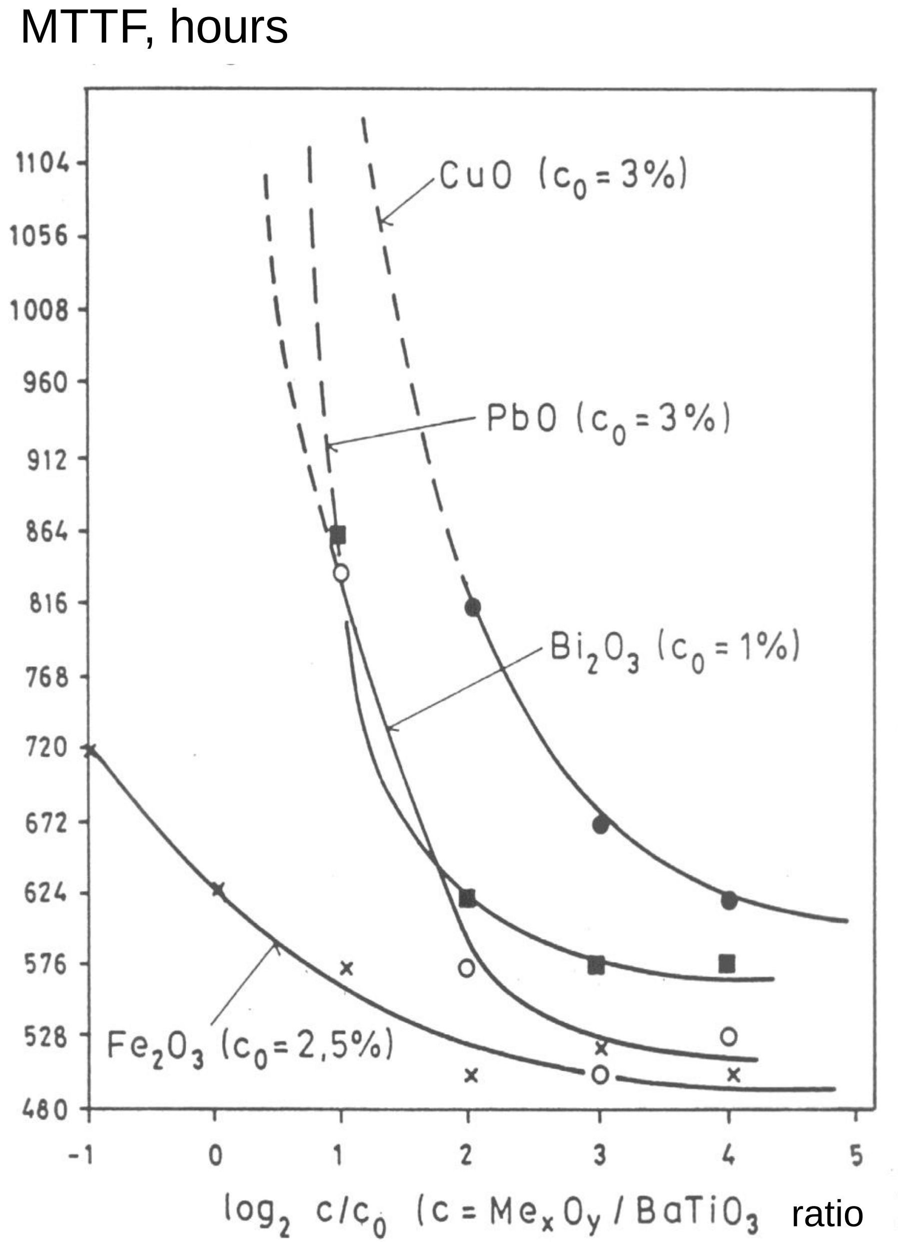
MTTF
(Mean Time to Failure)
data of thick-film capacitors as a function of the dielectrics composition (95%RH, 40^{o}C, 10VDC)



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Thick-film capacitor failure rates during THB tests – process parameter and composition dependency

Oxide type	Me-oxide/ $BaTiO_3$ ratio, %	Failure rate, % (1000 hours, 40 ^oC, 95% RH, 10 V DC) Firing peak temperature (^oC) / peak time (min)					
		800/5	800/10	850/5	850/10	900/5	900/10
Bi_2O_3	1	90±10	80±15	10±2	0	0	0
	0.5	50±10	15±5	0	0	0	0
PbO	3	100	95±5	20±4	0	0	0
	6	100	100	100	95±5	40±5	0
CuO	6	99±1	98±2	30±5	0	0	0
	12	99±1	99±1	100	99±1	60±10	20±3
Fe_2O_3	1.25	100	98±2	100	100	95±4	98±2
	0.6	80±15	90±10	80±10	80±15	90±10	90±10

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Conclusion

- At reactive type oxides (which take part in the physical-chemical reactions during firing), migration lifetime is determined by the excess amount of metal-oxide. Lifetime data can be improved by composition and technology changes (e.g. Bi_2O_3).

- At non-reactive type oxides (which do not take part in any reaction during firing) lifetime data can not be improved significantly by changing the composition and the firing parameters. The use of this oxide-types should be avoided (e.g. Fe_2O_3).