

MICROWAVE DISHES CONTAINERS

Selecting Materials and Process



Learn and live
the microwave!

CONTENT

- 1. Introduction**
- 2. Function**
- 3. Objectives**
- 4. Constraints**
- 5. Free variables**
- 6. Results**
- 7. Conclusion**

1. Introduction

Microwave dishes principal applications:

- Fast food
- Reheating food

Common materials:

- Polymers such as PP and PE
- Polymer foams of PS
- Traditional glass and ceramic dishware



2. Function

Principal function :

- Contain food heated by microwaves

Microwave oven :

- Microwave: radiation of 2.45 GHz through the food
- Water, fat and other substances in the food absorb energy from the microwaves in a process called dielectric heating

3. Objectives

Choice of materials and process

- Scenario 1
 - Disposable microwave dishes
 - very cheap
- Scenario 2
 - Reusable dishes
 - cost less critical
 - very good resistance to fresh water

4. Constraints

- Minimal microwave absorption Z_ε
 - Minimal dielectric constant ε
 - Minimal power factor Z
- Minimal thickness to limit absorption
- Stiff and strong enough to cope with ordinary handling loads
- Support service temperature of about 100° C
- Good thermal insulation for handling and keep dishes hot

4. Constraints

- Estimation of mechanical properties required

$$\delta = \frac{Fw^3}{384EI} \quad \text{with} \quad I = \frac{wt^3}{12} \quad \Rightarrow \quad E = \frac{Fw^3}{384I\delta}$$

$$\sigma = \frac{Ftw}{16I} = \frac{3F}{4t^2}$$

Numerical application :

$$F = 10 \text{ N}$$

$$\delta = 10 \text{ mm}$$

$$w = 200 \text{ mm}$$

$$t = 2 \text{ mm}$$



$$E = 156.25 \text{ MPa}$$

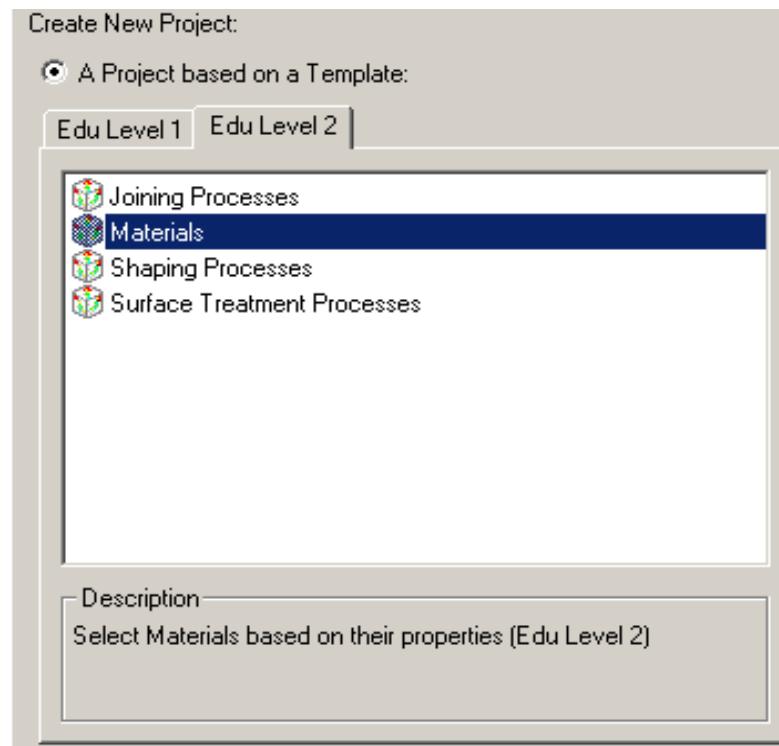
$$\sigma = 1.875 \text{ MPa}$$

5. Free variables

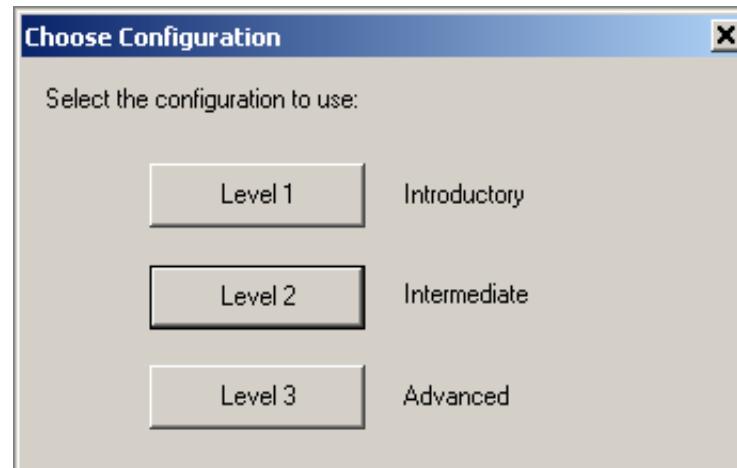
- Choice of materials
- Choice of process

6. Approach - Scenario 1

Selection data :
Edu Level 2 - Materials



Configuration :
Level 2 - Intermediate



6. Approach - Scenario 1

Choice of materials :
Stage 1 - Limit Stage

Mechanical properties		
Young's modulus	Minimum 0.15625	Maximum GPa
Shear modulus		
Bulk modulus		
Poisson's ratio		
Yield strength (elastic limit)	1.875	MPa
Tensile strength		
Thermal properties		
Thermal conductor or insulator?	<input type="checkbox"/> Good conductor <input type="checkbox"/> Poor conductor <input checked="" type="checkbox"/> Poor insulator <input checked="" type="checkbox"/> Good insulator	
Thermal conductivity	Minimum	Maximum W/m.K
Thermal expansion coefficient		μ strain/ $^{\circ}$ C
Specific heat		J/kg.K
Melting point		$^{\circ}$ C
Glass temperature		$^{\circ}$ C
Maximum service temperature	100	$^{\circ}$ C
Minimum service temperature		$^{\circ}$ C

6. Approach - Scenario 1

Calculated values

Mechanical properties

- Young's modulus: 0.15625 GPa
- Shear modulus
- Bulk modulus
- Poisson's ratio
- Yield strength (elastic limit): 1.875 MPa
- Tensile strength

Thermal properties

- Thermal conductor or insulator?
 - Good conductor
 - Poor conductor
 - Poor insulator
 - Good insulator
- Thermal conductivity
- Thermal expansion coefficient
- Specific heat
- Melting point
- Glass temperature
- Maximum service temperature: 100 °C
- Minimum service temperature

Resources

Stage 1 37 of 94 pass

- Bamboo
- Borosilicate glass
- Brick
- CFRP, epoxy matrix (isotropic)
- Cement
- Ceramic foam
- Concrete
- Dough (Bulk) molding compound, D...
- Epoxies
- GFRP, epoxy matrix (isotropic)
- Glass ceramic
- Granite
- Hardwood: oak, across grain
- Hardwood: oak, along grain
- Leather
- Limestone
- Marble
- PTFE
- Phenolics
- Plaster of Paris
- Plywood
- Polyamides (Nylons, PA)
- Polycarbonate (PC)
- Polyester
- Polyetheretherketone (PEEK)
- Polyethylene (PE)
- Polypropylene (PP)
- Polystyrene (PS)
- Rigid Polymer Foam (HD)
- Rigid Polymer Foam (MD)
- Sandstone
- Sheet molding compound, SMC, po...

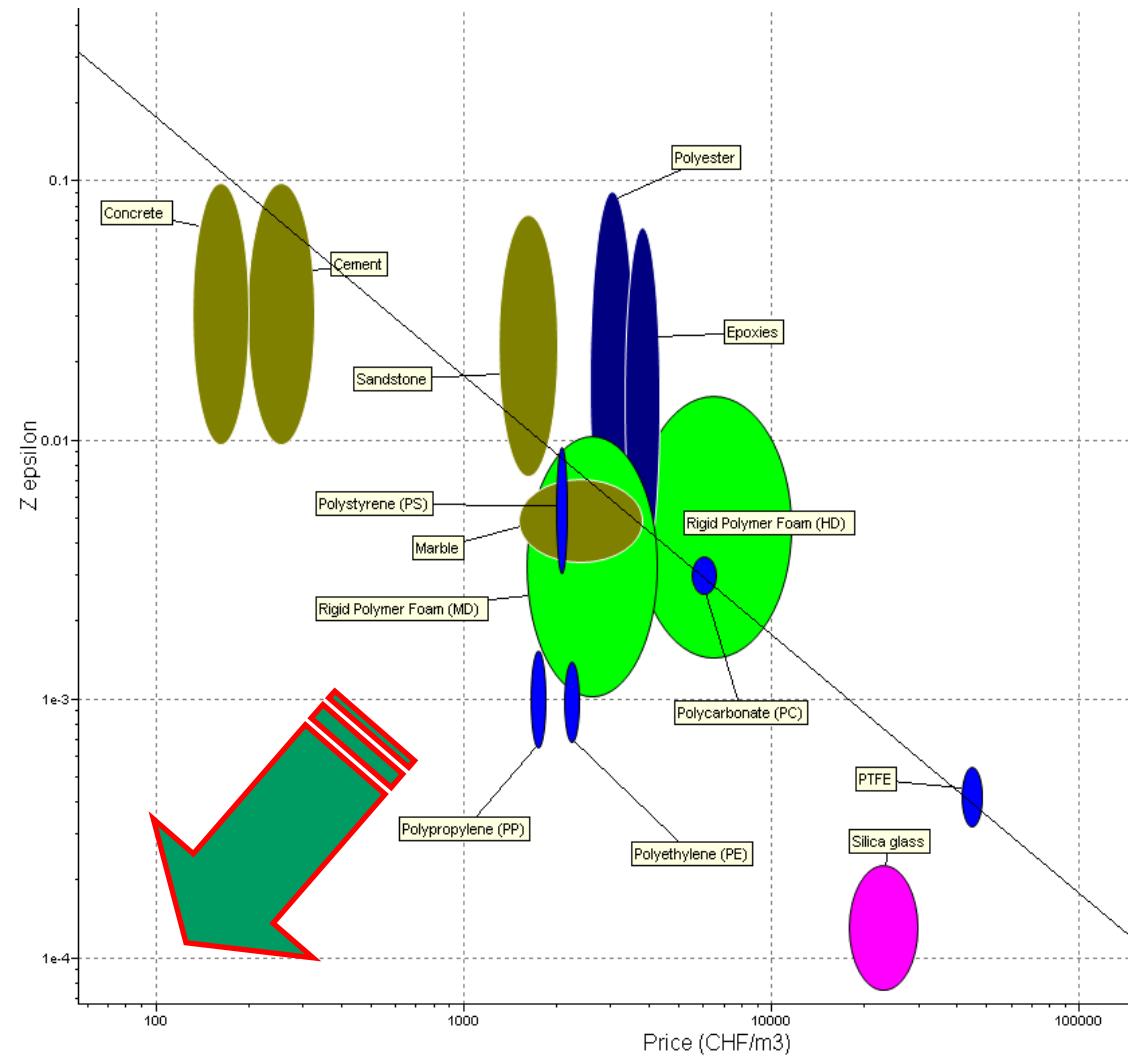
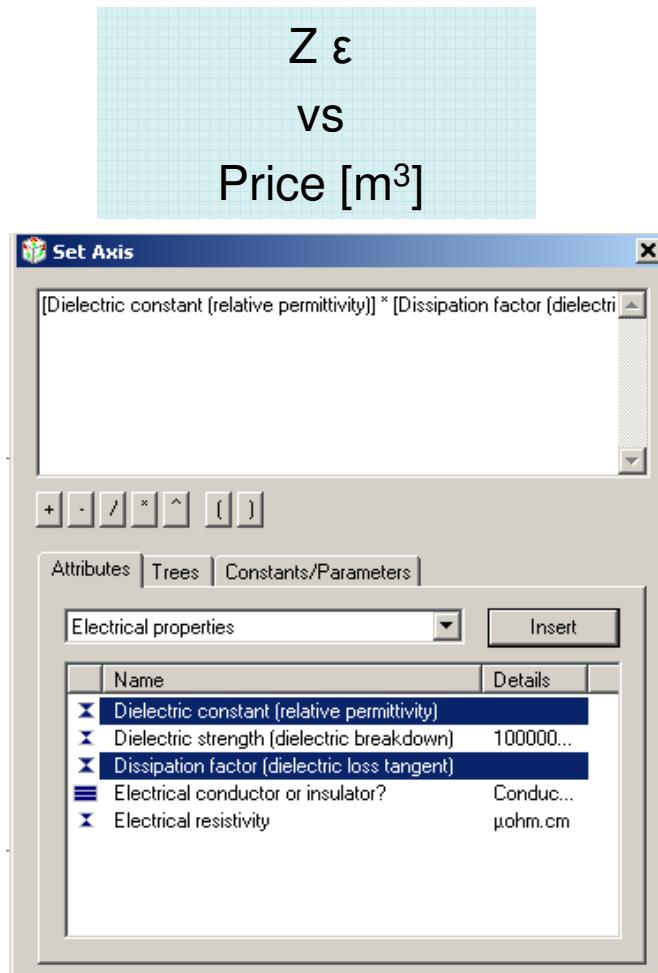
Can be taken & keep dishes hot

Water boiling

6. Approach - Scenario 1

Choice of materials :

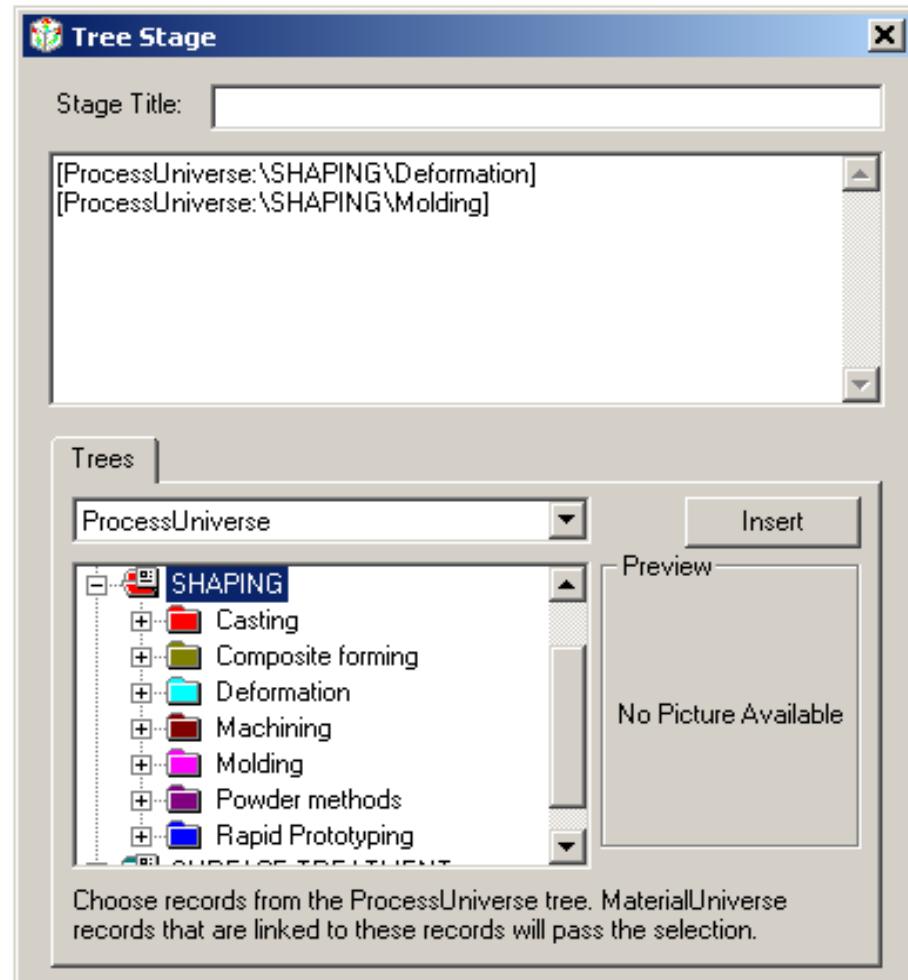
Stage 2 – Graph Stage



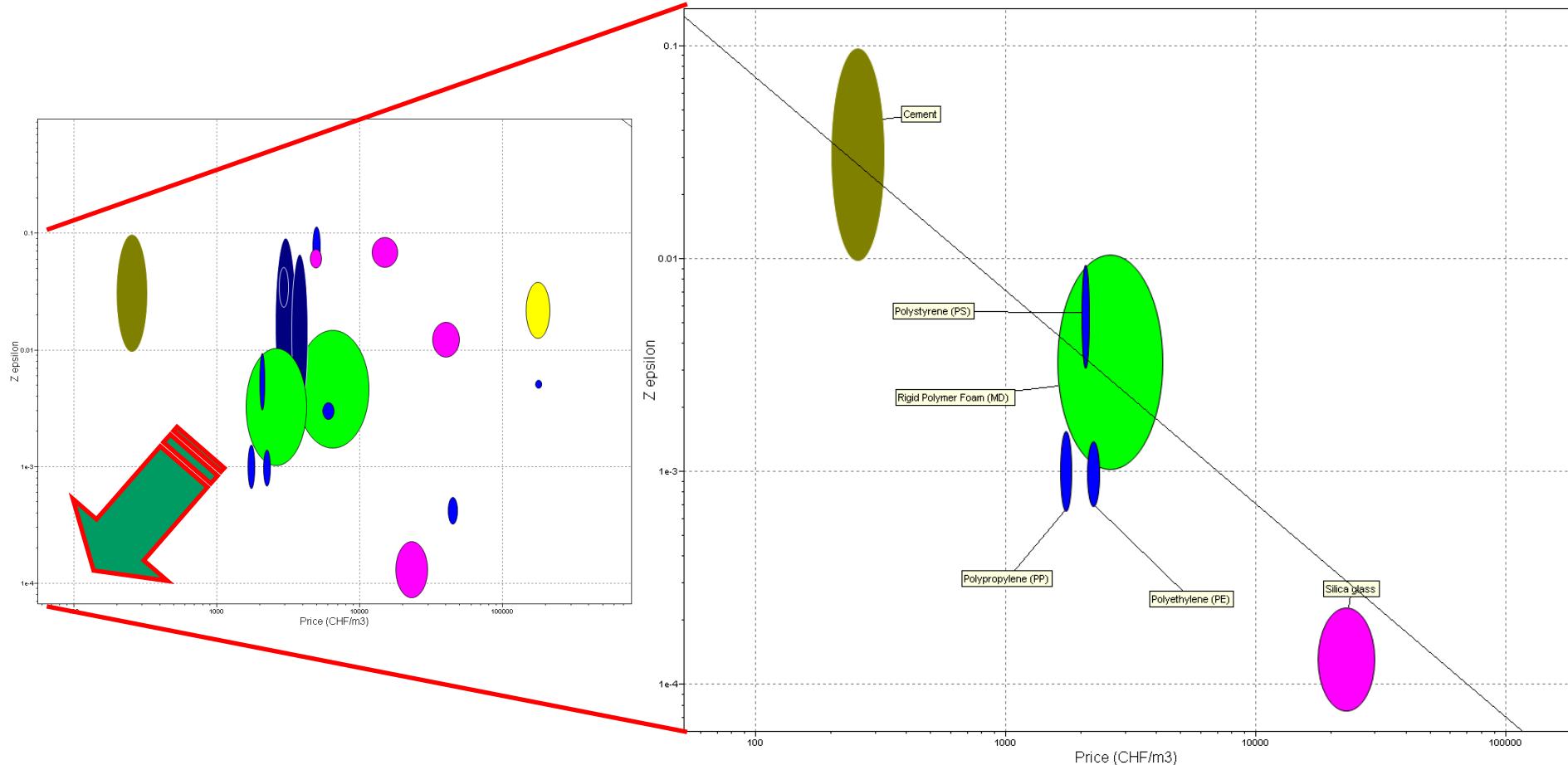
6. Approach - Scenario 1

Choice of process :
Stage 3 – Tree Stage

- Deformation
- Molding



6. Results - Scenario 1

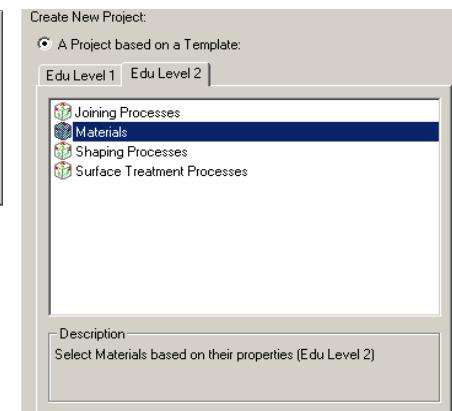


- The best one is Polypropylene (PP), but generally Rigid Polymer Foam (MD) and Polystyrene (PS) are used for disposable microwave dishes containers
- Ribs can be added to the geometrical design to increase mechanical resistance

6. Approach - Scenario 2

From scenario 1 :

- Same data selection & configuration
Edu Level 2 - Materials - Intermediate



- Same choice of process
Molding
Deformation

Added constraint :

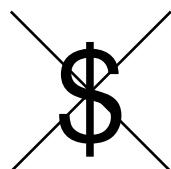
Limit added to stage 1: very good resistance to
fresh water

Mechanical properties	
Young's modulus	Minimum: 0.15625 GPa
Shear modulus	Maximum: GPa
Bulk modulus	Minimum: GPa
Poisson's ratio	Maximum: GPa
Yield strength (elastic limit)	1.875 MPa
Tensile strength	Maximum: MPa

Thermal properties	
Thermal conductor or insulator?	<input type="checkbox"/> Good conductor <input type="checkbox"/> Poor conductor <input checked="" type="checkbox"/> Poor insulator <input checked="" type="checkbox"/> Good insulator
Thermal conductivity	Minimum: W/m.K
Thermal expansion coefficient	Maximum: $\mu\text{strain}/^\circ\text{C}$
Specific heat	Minimum: J/kg.K
Melting point	Maximum: $^\circ\text{C}$
Glass temperature	Minimum: $^\circ\text{C}$
Maximum service temperature	Maximum: $^\circ\text{C}$
Minimum service temperature	Minimum: $^\circ\text{C}$

Analysis :

The price is less critical
The mechanical durability is more critical



6. Approach - Scenario 2

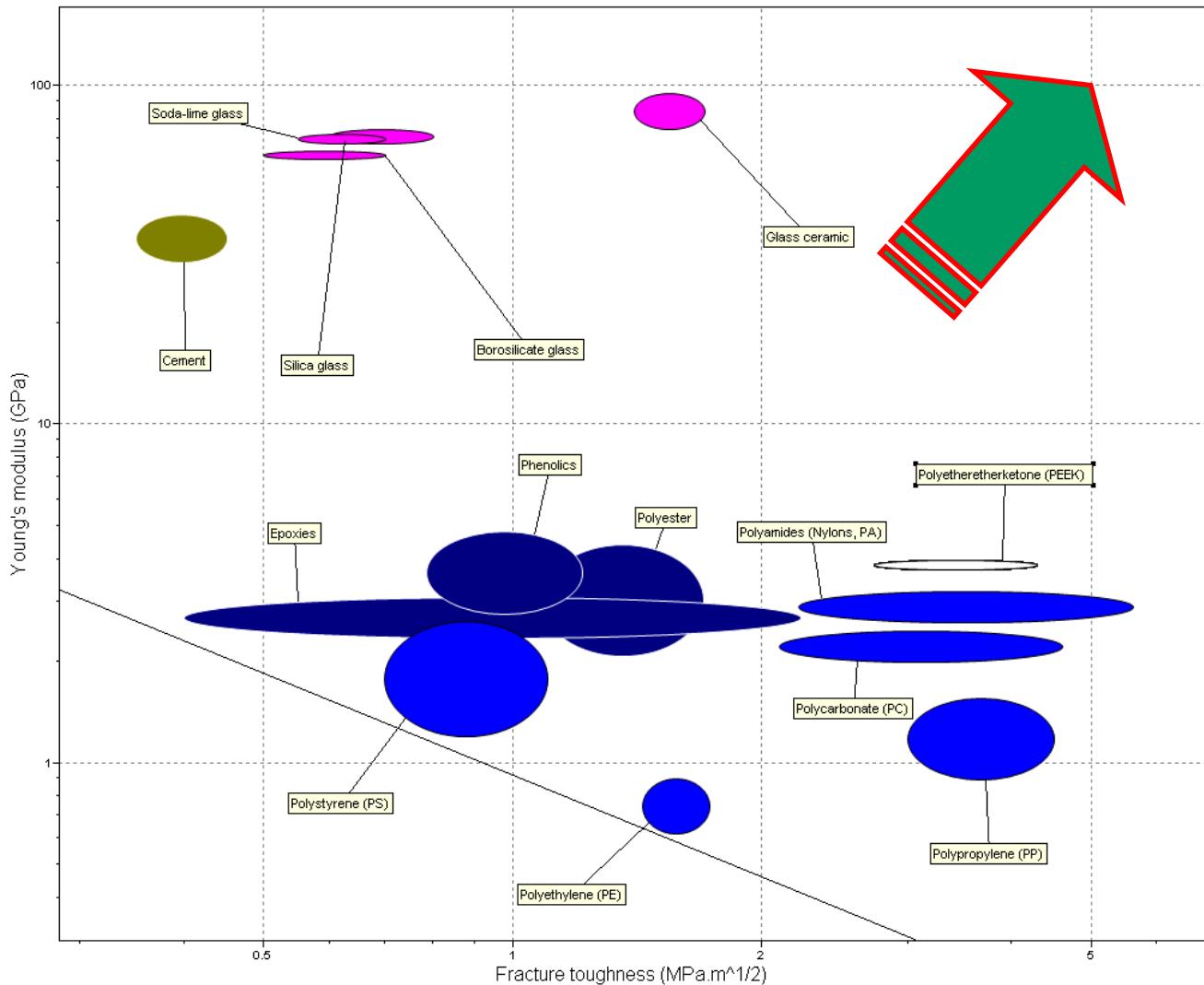
Choice of materials :
Stage 4 – Graph Stage

- Mechanical performances

Young modulus
[GPa]

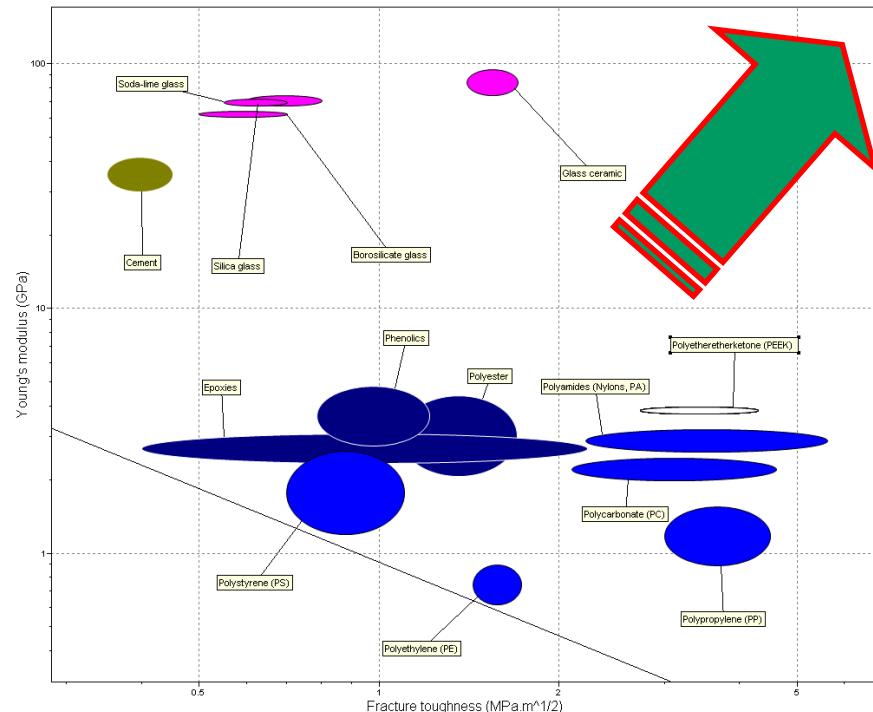
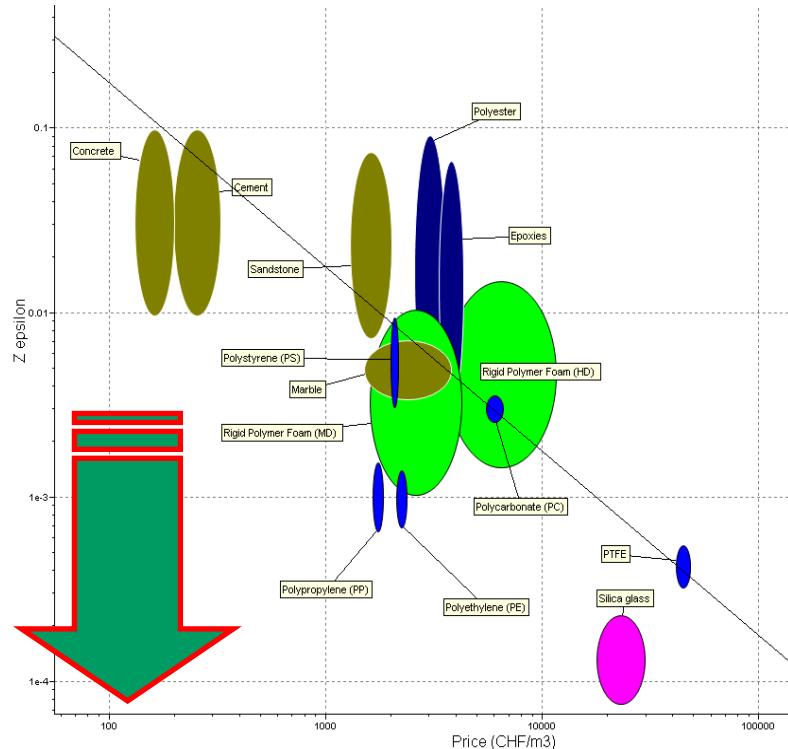
vs.

Fracture toughness
[MPa/m^{1/2}]



6. Results - Scenario 2

For **reusable** microwave dishes containers



- The best material is Silica glass, but Polyethylene (PE) and Polypropylene (PP) are also very good
- Polystyrene (PS) is not good and polymer foams are avoided by the fresh water resistance limit stage

7. Conclusions

- Materials are partially the same for both scenario 1 and 2 (PP, PE) even if constraints change considerably
- There are always several possibilities for materials
- Not a big surprise – commonly used materials are the among the best
- Selected Processes help to limit materials (example cement)
- CES does not say much about food compatibility

→ First approach for selecting the materials but further study necessary