*Corso di Laurea Magistrale in Ingegneria dell'Innovazione del Prodotto*
*a.a. 2022-23*
*Anno I – Semestre I*

# Tecnologia dei materiali polimerici

# Lezione 12

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E-mail: lisa.biasetto@unipd.it

- Progettazione sostenibile in materiale plastico

- Revisione Attività di Gruppo

# Sviluppo del Progetto

**FASE 1- Scelta del prodotto**: definizione dell'unità funzionale, lista dei materiali ed analisi EcoAudit del prodotto di partenza
**FASE 2- Analisi della funzione** del prodotto: definizione di vincoli ed obiettivi
**FASE 3- Analisi dei materiali** utilizzabili e confronto delle proprietà: definizione curve di trade off
**FASE 4-** Lista delle risorse e delle emissioni nelle varie fasi di vita del prodotto, calcolo degli **EcoAudit** con i materiali originali ed i nuovi
**FASE 5- Confronto** delle diverse soluzioni e soluzione selezionata
**FASE 6-** Stesura **Report e Presentazione** dei risultati

| 04.11.2022 | 11.11.2022 | 25.11.2022 | - | - | Sessione Esami |
|---|---|---|---|---|---|
| **FASE 1** | **FASE 2** | **FASE 3** | **FASE 4** | **FASE 5** | **FASE 6** |
| Scelta del prodotto | Analisi della funzione del prodotto | Scelta di materiali | EcoAudit | Confronto | Report e presentazione |

Step della progettazione sostenibile

- STEP 1 Traduzione delle richieste di progettazione:
  Definizione dell'unità funzionale analisi di EcoAudit del Prodotto
- STEP 2 Definizione di vincoli ed obiettivi
- STEP 3 Individuazione delle soluzioni progettuali
- STEP 4 Ricerca delle informazioni di supporto e confronto con il prodotto di partenza

# FASE 1 SCELTA DEL PRODOTTO

INDIVIDUO IL PRODOTTO O IL COMPONENTE DI UN PRODOTTO
CHE SARA' OGGETTO DELL' ANALISI

CASO 1- FATTO DI MATERIALE PLASTICO MA VOGLIO DIMINUIRNE L'IMPATTO AMBIENTALE
CASO 2- FATTO DI ALTRO MATERIALE, E VOGLIO RIDURNE L'IMPATTO AMBIENTALE SOSTITUENDOLO CON MATERIALE PLASTICO

# FASE 2- ANALISI DELLA FUNZIONE DEL PRODOTTO

| Nome del componente | | | |
|---|---|---|---|
| Funzione del componente | | | |
| Materiale/i con cui è realizzato | | | |
| A. CONDIZIONI OPERATIVE | NORMALE | MIN | MAX |
| Temperatura di servizio (°C) | | | |
| Vita in servizio | | | |
| Carichi applicati (Normali, torcenti…descrivere dettagliatamente a parte) | RIPORTARE A PARTE I DIMENSIONAMENTI DI MASSIMA | | |
| Durata del carico | | | |
| Tempo non sollecitato | | | |
| Altro (impatti, shock, campi elettromagnetici etc.) | RIPORTARE A PARTE I DIMENSIONAMENTI DI MASSIMA | | |
| B. AMBIENTE | Sostanze chimiche | Umidità | Temperatura (non in esercizio) |
| Luce solare diretta | Luce solare indiretta | Disposizioni sullo smaltimento | Rifiuto di fine vita |
| C. RICHIESTE DI PROGETTO | Fattore di sicurezza | Tolleranze | Finitura |
| | Riciclabilità | Disassemblaggio a fine vita | $H_m$ (KJ), $CO_{2eq}$ (mol/unit) |
| D. TEST DI PERFORMANCE | Includere se c'è una richiesta di performance specifica | | |
| F. APPROVAZIONI | Normativa | Classificazione | |
| | Categoria (alimentare, medica, militare, aerospaziale, elettrica etc.) | | |
| G. Aggiungere qui qualsiasi informazione utile a comprendere la funzione del componente, le condizioni di esercizio in termini di temperatura, carichi e «abusi» a cui la parte deve sottostare | | | |

1 Calcoli strutturali, necessari per definire lo stato di tensione e deformazione in esercizio

2 Definizione di eventuali altri carichi e/o della combinazione di sollecitazioni meccaniche e funzionali

3 Eco-Audit (da fare dopo lezione dedicata)

# FASE 3- SCELTA DEI MATERIALI

## LISTA DI VINCOLI  ED OBIETTIVI

ESEMPI DI VINCOLI: RIGIDIZZA, CARICO MASSIMO, DEFORMAZIONE MASSIMA AMMISSIBILE, T ESERCIZIO, COSTO, PROPRIETA' OTTICHE O ELETTRICHE

ESEMPI DI OBIETTIVI: RIDUZIONE DELL'IMPATTO AMBIENTALE, MIGLIORAMENTO DELLE PERFORMANCE

# FASE 3- SCELTA DEI MATERIALI

## Esempio 1

- In apertura e chiusura deve **accompagnare e rallentare il movimento**.
- In apertura deve **sostenere** il portellone in posizione

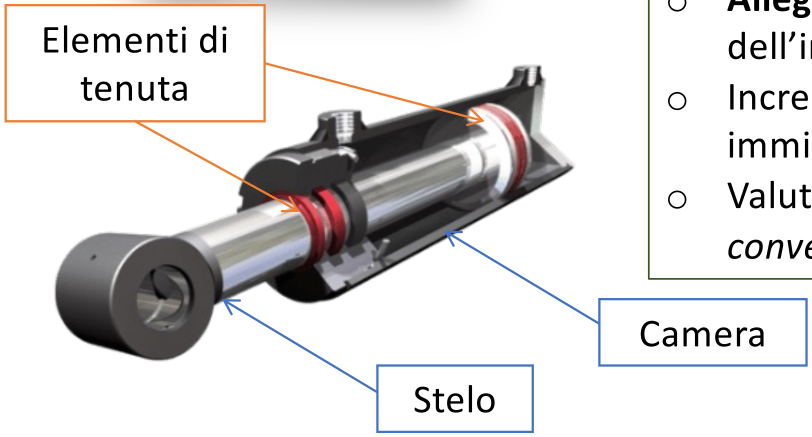
→ FUNZIONE

- Vita utile stimata **10 anni**.
- Resistenza alle temperature **-30/+80 °C**.
- Resistenza alla degradazione da **raggi UV e umidità**.

→ VINCOLI

- **Alleggerimento del prodotto** con conseguente riduzione dell'impatto ambientale nel corso del suo ciclo di vita.
- Incremento della **facilità di riciclo** del prodotto e re-immissione del materiale nel mercato.
- Valutazione del *processo produttivo* più *economicamente conveniente.*

→ OBIETTIVI



# FASE 3- SCELTA DEI MATERIALI

## Esempio 1

**VINCOLI:**

- Costo: ***15* €/kg**
- $\sigma_y$: ***50* MPa**
- E: ***4* Gpa**
- Permeabilità ai gas
- ***Tg>100°C***
- Resistenza all'***umidità***
- Resistenza ai raggi ***UV*** (luce solare indiretta)

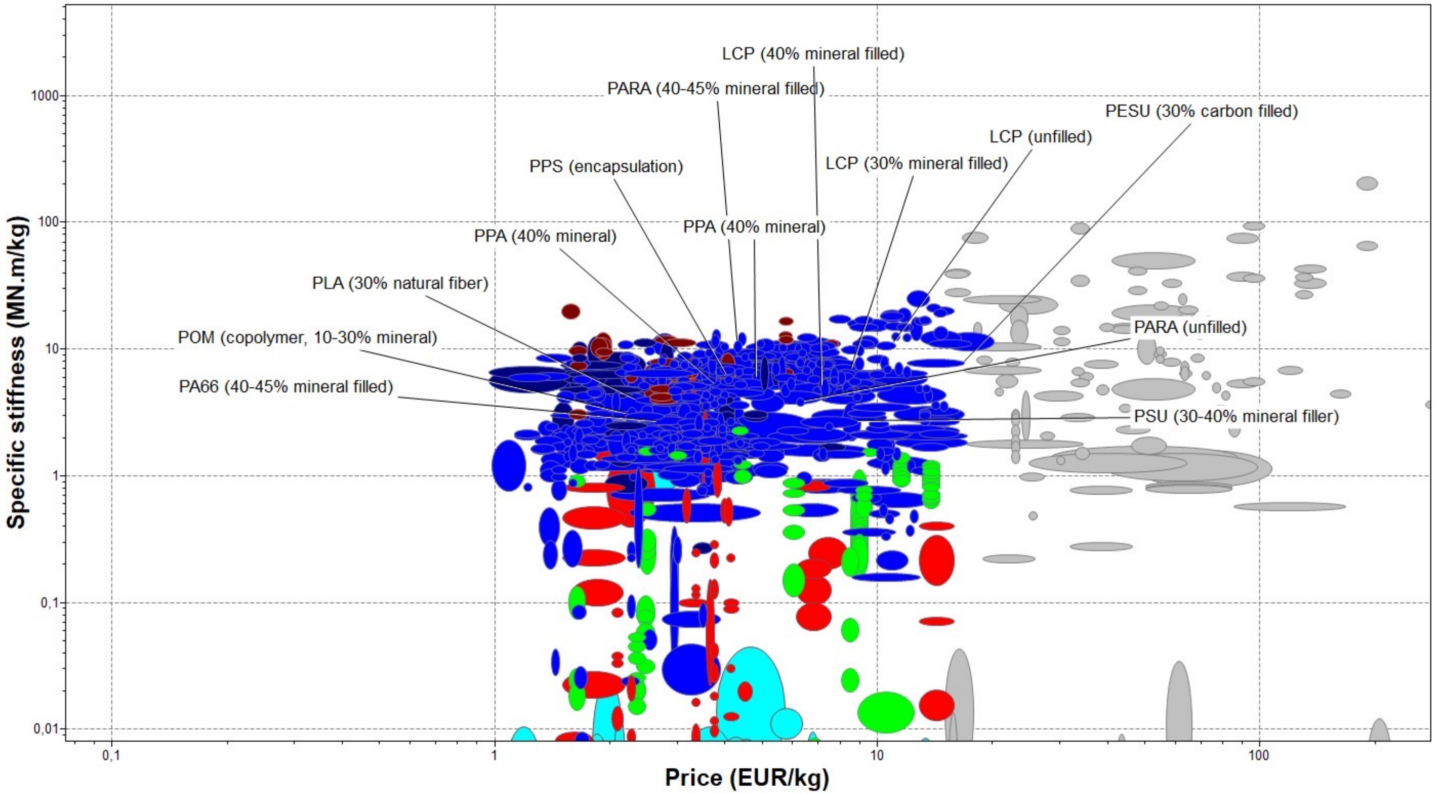
**OBIETTIVI:**

- Riduzione impatto ambientale rispetto pistone in acciaio
- Riduzione del peso -> Elevata rigidezza specifica

# FASE 3- SCELTA DEI MATERIALI

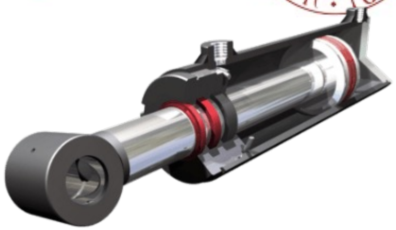
## Esempio 1

2. Limitazione sul prezzo (*15* €/kg).

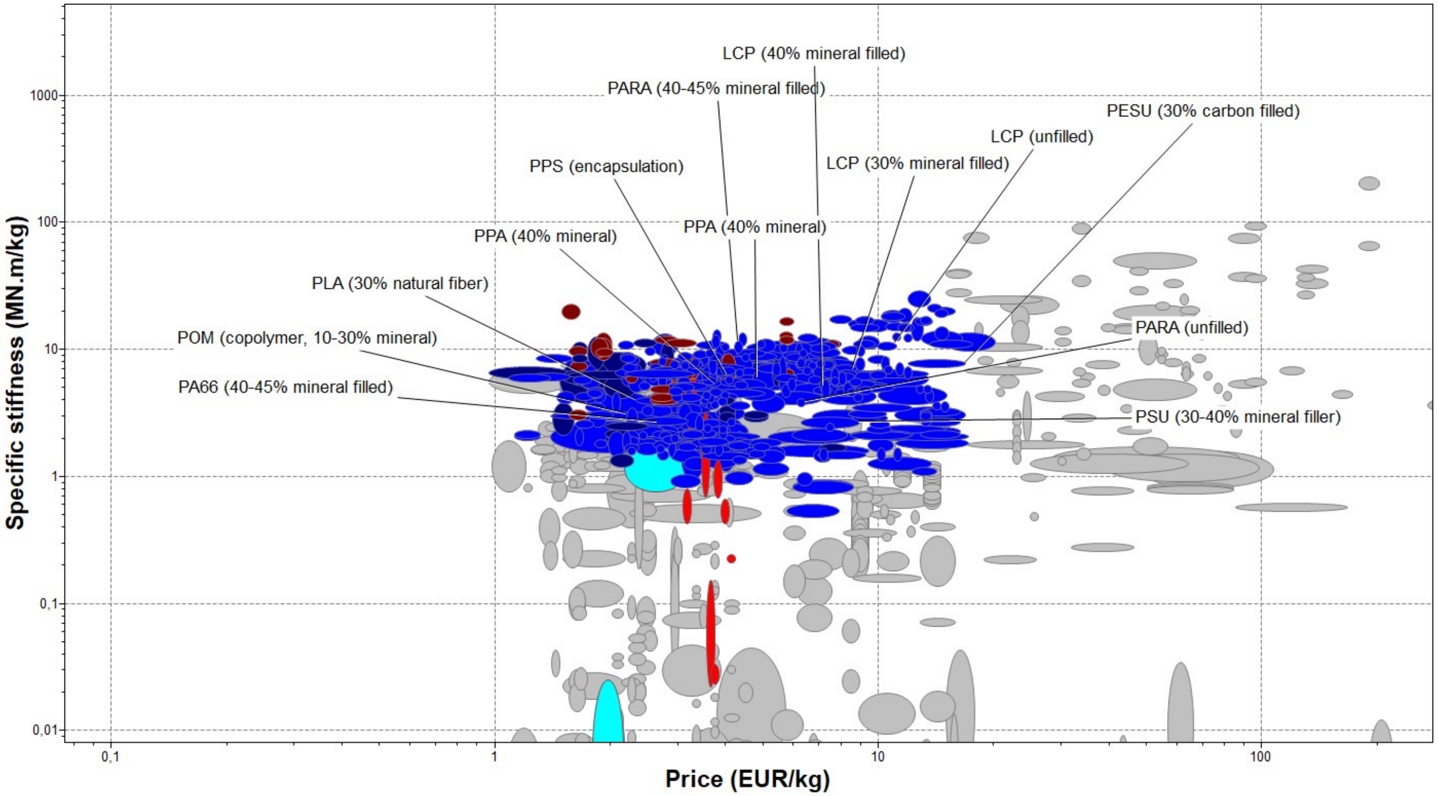


# FASE 3- SCELTA DEI MATERIALI

## Esempio 1



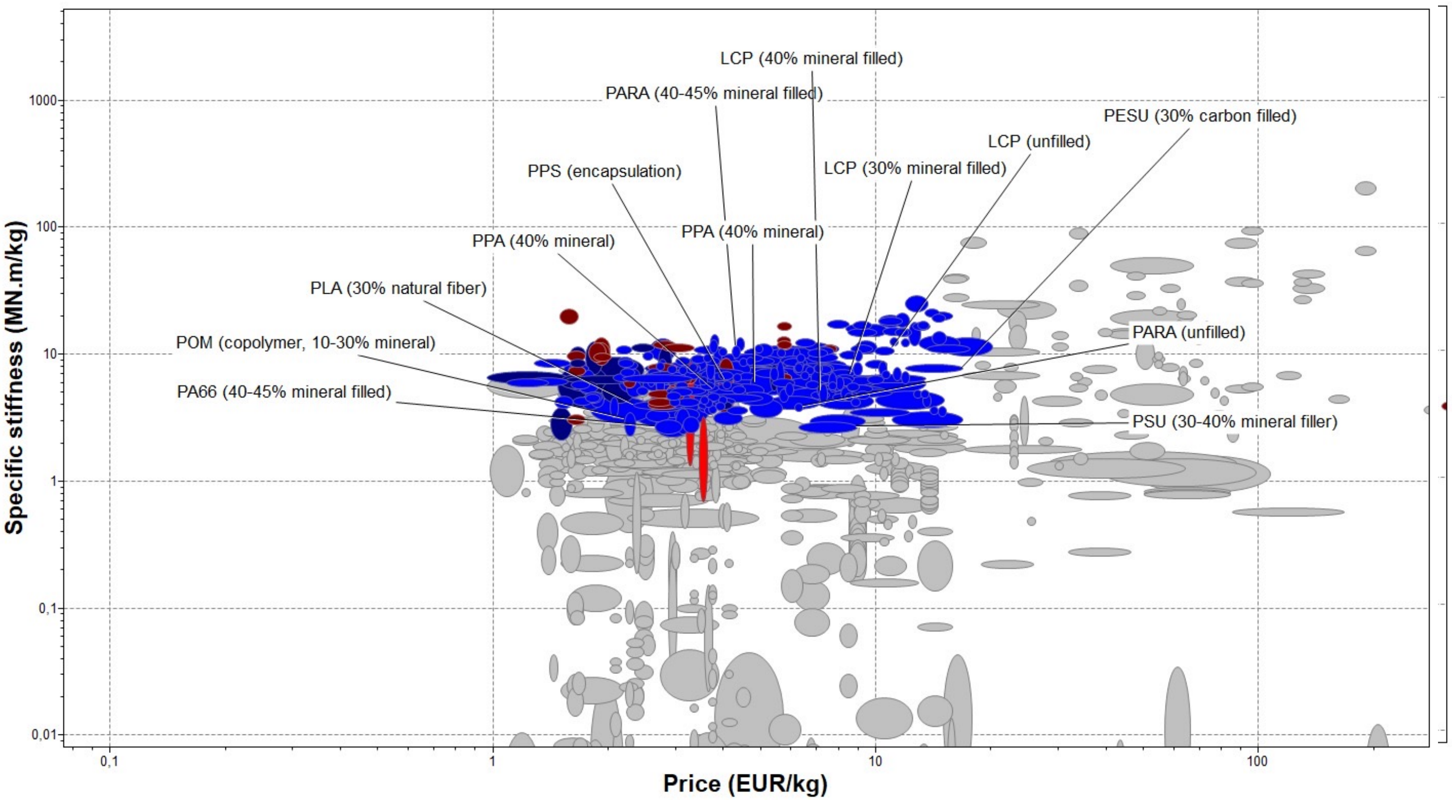
3. Limitazione sullo snervamento (*50* MPa).



# FASE 3- SCELTA DEI MATERIALI

## Esempio 1

4. Limitazione sul Modulo di Young (*4* GPa).



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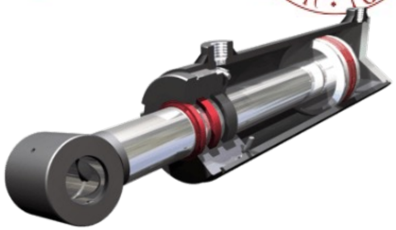
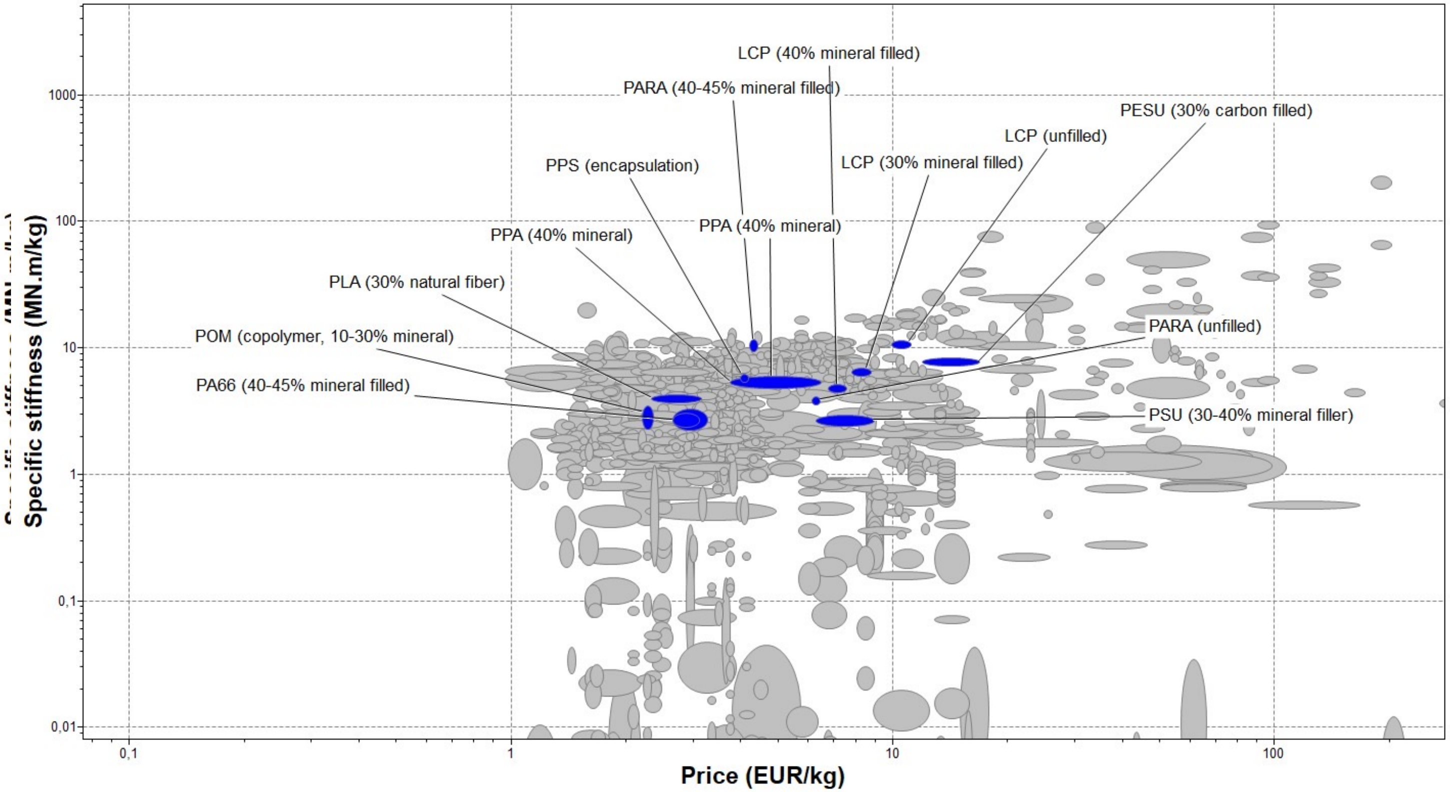
# FASE 3- SCELTA DEI MATERIALI

## Esempio 1



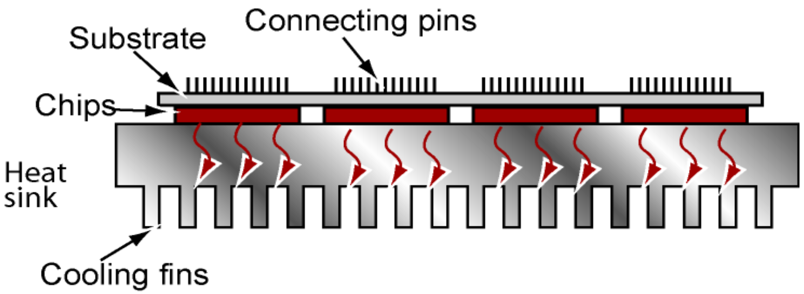
5. Limitazione sulla riciclabilità.



# FASE 3- SCELTA DEI MATERIALI

## Esempio 2

Power micro-chips get hot.  They have to be cooled to prevent damage




**Design requirements**

**Keep chips below 200˚C without any electrical coupling.**

**Translation**

**Constraints**

- **Maximum service temp > 200˚C**
- **Good electrical insulator**
- **Good thermal conductor**

**(or high Thermal conductivity)**

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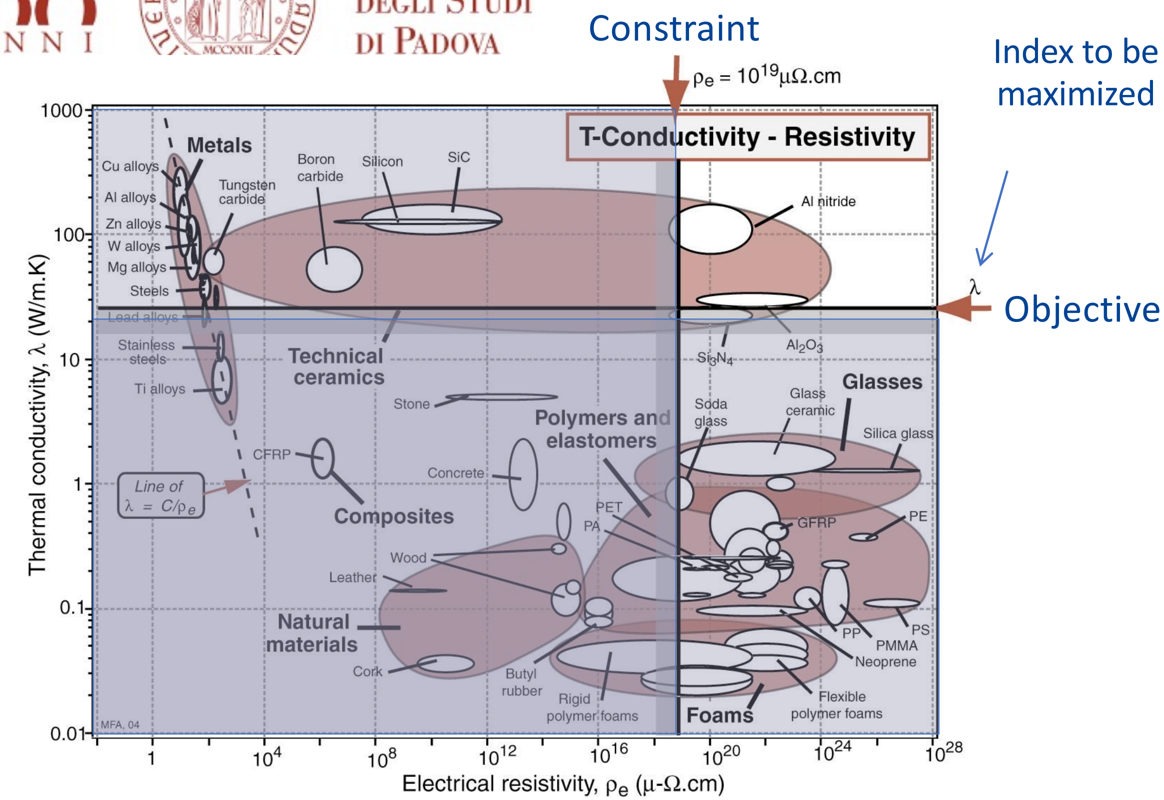
# FASE 3- SCELTA DEI MATERIALI

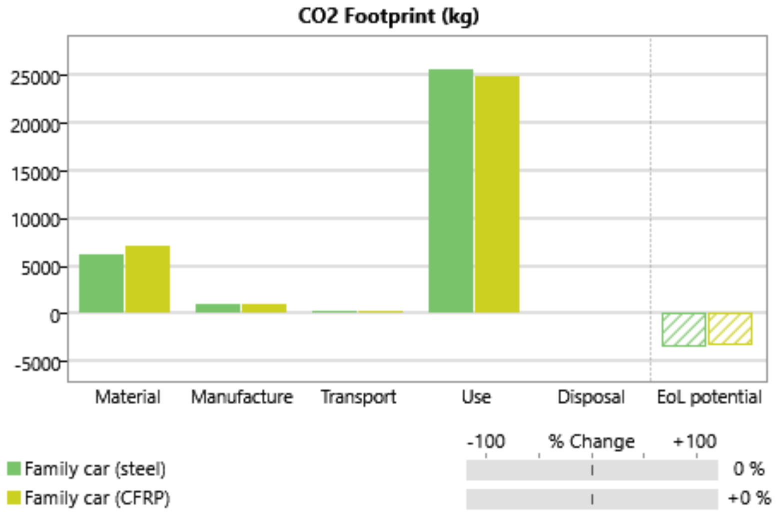


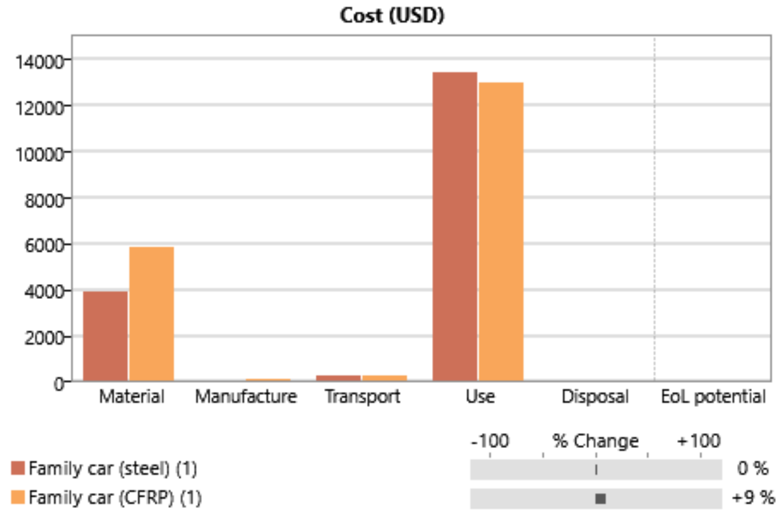

| ***Results*** ***3 out of 100 pass*** | ***Ranking*** ***T-conductivity*** |
|---|---|
| Aluminum nitride | 140 - 200 |
| Alumina | 26 - 38.5 |
| Silicon nitride | 22 - 30 |

Il ranking permette di ottenere un ristretto numero di materiali adatti allo scopo.
Posso restringere ulteriormente la possibilità di scelta facendo un indagine (ricerca bibliografica) che mi permette di valutare  la scelta più opportuna.

# FASE 4- ECO-AUDIT

Definisco 1-2 materiali adatti allo scopo, associati ad eventuali altre azioni (reshaping-processo produttivo) e Confronto le variazioni di costo e di impatto ambientale rispetto al prodotto originario.



# FASE 5- CONCLUSIONI

- Materiale scelto, pro e contro
- Possibili altri scelte, pro e contro se presente
- Nei pro e contro valuto le variazioni di performance, di impatto e di costo

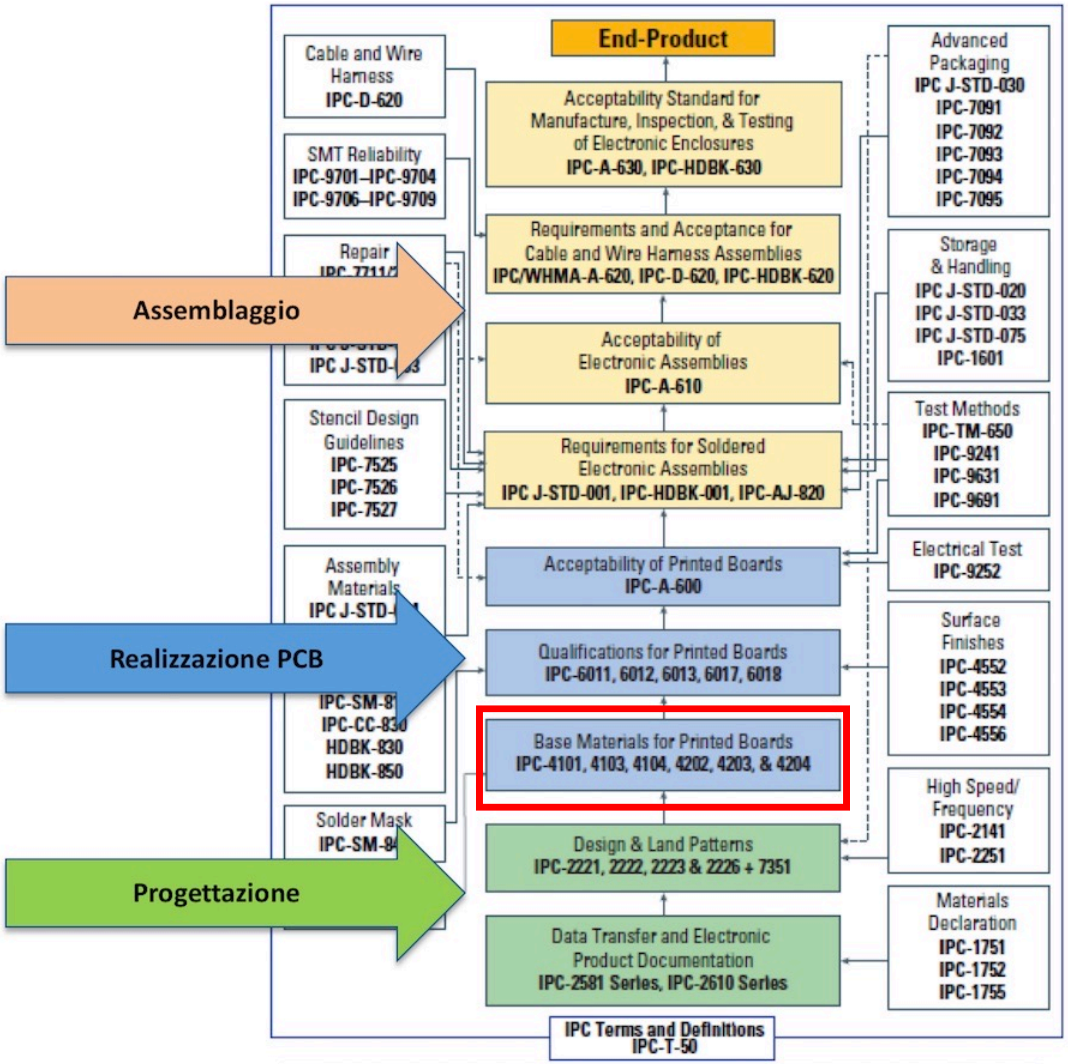
Report in ppt contenente l'analisi fatta
Template ppt scaricabile da moodle

# FASE #1

| Gruppo | MySelf | | |
|---|---|---|---|
| Nome del componente | Rigid Printed Circuit Board-PCB | | |
| Funzione del componente [1] | A printed circuit board (PCB) mechanically supports and electrically connects electrical or electronic components using conductive tracks, pads and other features etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate. | | |
| Materiali con cui è realizzato [2] | Al base (heat sink) Copper+Etchable Solder Mask (electric circuit), insulating substrate of Glass Fiber Reinforced Epoxy (Dielectric Layer) | | |
| **A. CONDIZIONI OPERATIVE** | NORMALE | MIN | MAX |
| Temperatura di servizio (°C) [2] | 40 | 5 | 235-255 for 10 s [welding] |
| Vita in servizio | | | |
| Tipo di carichi | The PCB is expected to be handled, to resist to accidental fall, to support the circuit components | <10 MPa Bending/compression/tensile During loading | <5MPa Load due to circuit components |
| Durata del carico | | Short-Term | Long-Term, during the all life-time |
| Stress indotti termicamente Fatica TERMO-MECCANICA | Shear stress 10-20 MPa | | |
| Sollecitazioni elettriche | Frequency: From 10 MHz to 4 GHz | | |
| **B. AMBIENTE [3]** | Sostanze chimiche methylene chloride resistance (MCR), MCR between 0.01 percent and 0.20 percent. | Umidità moisture absorption value between 0.01 percent and 0.20 percent | Infiammabilità UL94 state that specimens cannot burn for longer than 10 seconds with flaming combustion. |
| Luce solare diretta no | Luce solare indiretta no | Disposizioni sullo smaltimento | Rifiuto di fine vita |
| **C. RICHIESTE DI PROGETTO** | Fattore di sicurezza | Tolleranze | Finitura |
| | Riciclabilità | Disassemblaggio a fine vita | $H_m$ (KJ), $CO_{2eq}$ (mol/unit) |
| **D. TEST DI PERFORMANCE** | Includere se c'è una richiesta di performance specifica | | |
| **F. APPROVAZIONI** | **Normativa** UL94, ICP* | Classificazione | |
| | Categoria (alimentare, medica, militare, aerospaziale, elettrica etc.) | Elettrica | |
| G. Aggiungere qui qualsiasi informazione utile a comprendere la funzione del componente, le condizioni di esercizio in termini di temperatura, carichi e «abusi» a cui la parte deve sottostare | | | |

# Normative per PCBs

## IPC SPECIFICATION SEMPLIFIED TREE




La tabella che segue è un estratto di determinate caratteristiche tratte da classificazioni IPC-4101 ed evidenzia alcuni dei dettagli a cui abbiamo fatto riferimento.

| IPC-4101 | 99 | 101 | 121 | 124 | 126 | 127 | 128 | 129 | 130 |
|---|---|---|---|---|---|---|---|---|---|
| Tg (min) C | 150 | 110 | 110 | 150 | 170 | 110 | 150 | 170 | 170 |
| Td (min) C | 325 | 310 | 310 | 325 | 340 | 310 | 325 | 340 | 340 |
| CTE Z 50-260 C | 3,5% | 4% | 4% | 3,50% | 3% | 4% | 3,50% | 3,50% | 3% |
| T260 (min) minutes | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| T288 (min) minutes | 5 | 5 | 5 | 5 | 15 | 5 | 5 | 15 | 15 |
| Fillers > 5% | Yes | Yes | NA | NA | Yes | Yes | Yes | NA | Yes |
| Dk/Permittivity (max) | 5,4 | 5,4 | 5,4 | 5,4 | 5,4 | 5,4 | 5,4 | 5,4 | 5,4 |

**Le caratteristiche fondamentali dei materiali sono presentate qui di seguito.**

- **CTE – Z axis**(Co-efficient of thermal expansion): This is a measure of how much the base material will expand when heated. Measured as PPM/degree C (both before and after Tg) and also in % over a temperature range.
- **Td** (Decomposition temperature): This is the temperature at which material weight changes by 5%. This parameter determines the thermal survivability of the material.
- **Tg** (Glass transition temperature): The temperature at which the material stops acting like a rigid material and begins to behave like a plastic / softer.
- **T260** (Time to delamination): This is the time it take for the base material to delaminate when subjected to a temperature of 260 degrees C.
- **T288** (Time to delamination): This is the time it take for the base material to delaminate when subjected to a temperature of 288 degrees C.
- **Dk** (Dielectric constant): The ratio of the capacitance using that material as a dielectric, compared to a similar capacitor which has a vacuum as its dielectric.
- **CTI** (Comparative tracking Index): A measure of the electrical breakdown properties of an insulating material. It is used for electrical safety assessment of electrical apparatus. Rating can be seen below.

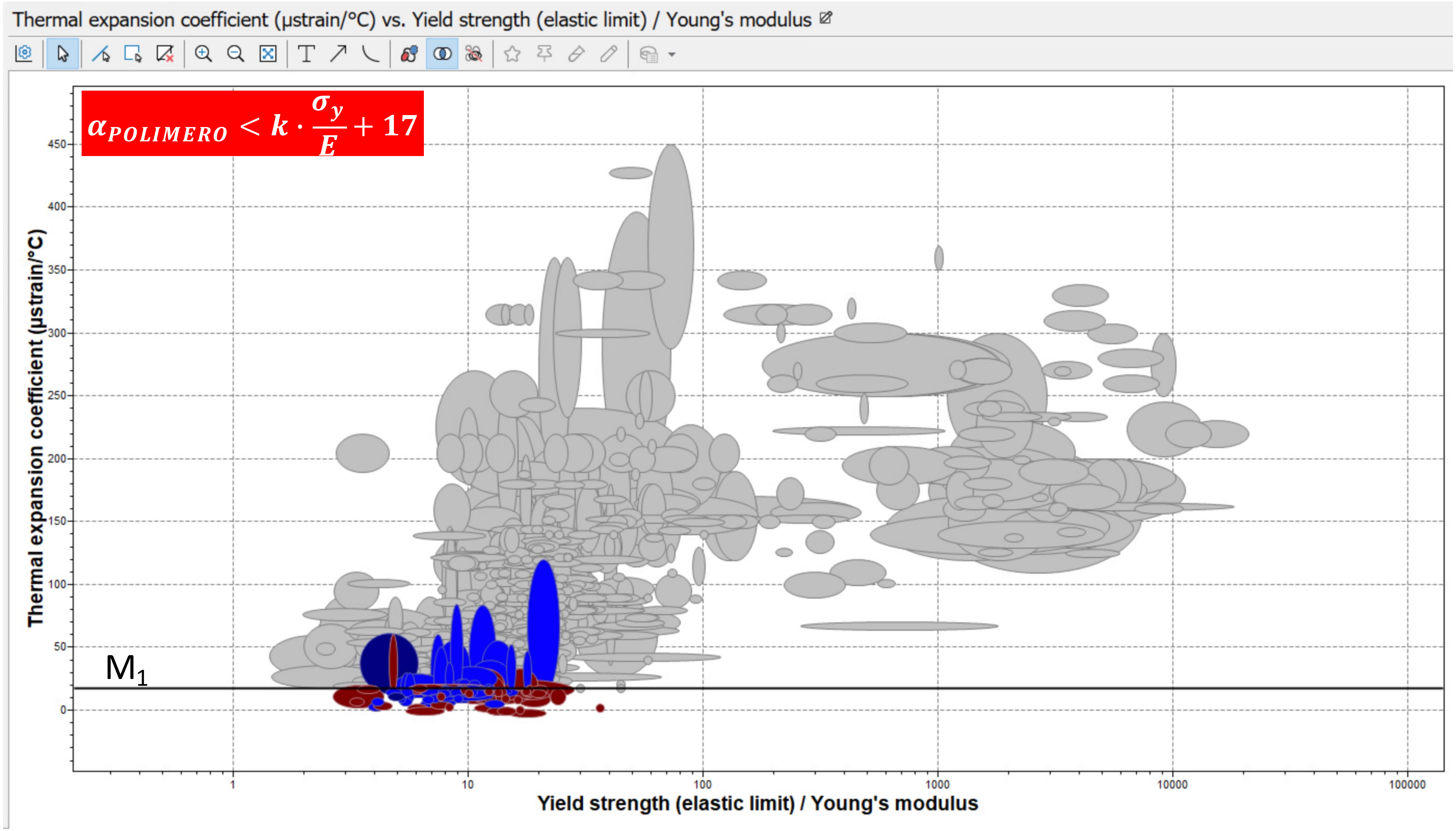
# FASE#2: DEFINZIONE DI VINCOLI ED OBIETTIVI

**VINCOLI**

| PROPRIETA’ TERMICHE | Epoxy+Fibre di Vetro |
|---|---|
| **Tg [°C]** | - |
| **CTE [$10^{-6}K^{-1}$]** | <40 |
| **Infiammabilità** | Non infiammabile o Autoestinguente |
| **PROPRIETA’ ELETTRICHE** | |
| **$\varepsilon$ [–]** | 3.5-5.5 |
| **Tan$\delta$ [–]** | 0.001-0.02 |
| **PROPRIETA’ MECCANICHE** | |
| **E [GPa]** | 15-30 |
| **$\sigma_Y$ [MPa]** | >20 MPa |
| **$\nu$ [–]** | 0.4 |
| **PROPRIETA’ CHIMICHE** | |
| **Resistenza al DicloroMetano $CH_2Cl_2$** | 0.01-0.2% |
| **Assorbimento di umidità** | 0.01-0.2% |

**OBIETTIVI**

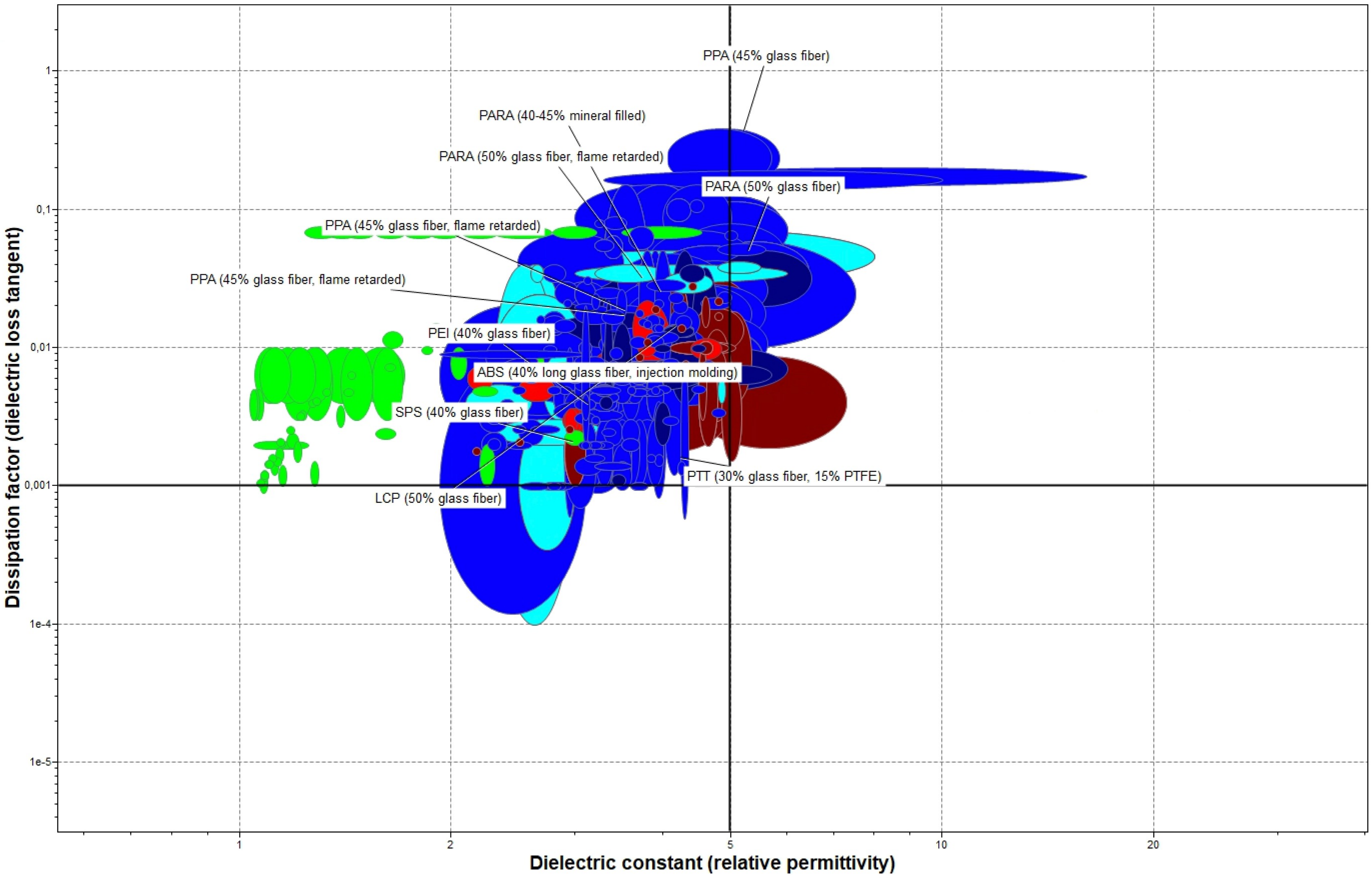
- Utilizzo di un polimero termoplastico
- Riciclabile, o a ridotti $H_m$ e $CO_{2,\,eq}$
- Capacita’ del substrato di lavorare alle alte frequenze, fino a 4GHz

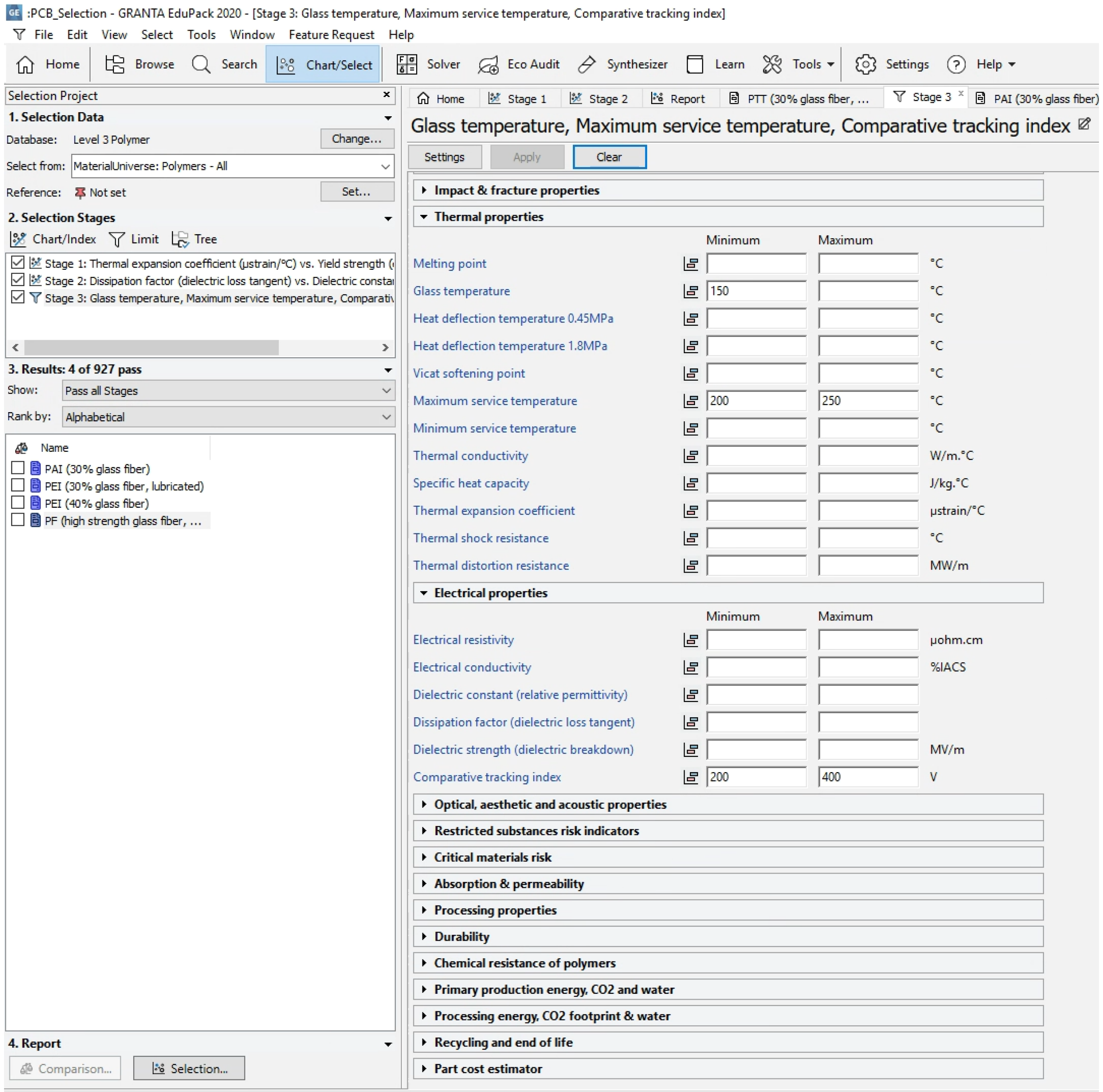


Thermal expansion coefficient (µstrain/°C) vs. Yield strength (elastic limit) / Young's modulus
$\alpha_{POLIMERO} < k \cdot \frac{\sigma_y}{E} + 17$
$M_1$
Thermal expansion coefficient (µstrain/°C)
Yield strength (elastic limit) / Young's modulus
450
400
350
300
250
200
150
100
50
0
1
10
100
1000
10000
100000

**Dati Epoxy**
**Tanδ > 0.014**
**ε > 4 ad 1GHz**

**Normativa IPC**
**ε < 5**




:PCB_Selection - GRANTA EduPack 2020 - [Stage 3: Glass temperature, Maximum service temperature, Comparative tracking index]
File Edit View Select Tools Window Feature Request Help
Home Browse Search Chart/Select Solver Eco Audit Synthesizer Learn Tools Settings Help
Selection Project
1. Selection Data
Database: Level 3 Polymer
Change...
Select from: MaterialUniverse: Polymers - All
Reference: Not set
Set...
2. Selection Stages
Chart/Index Limit Tree
Stage 1: Thermal expansion coefficient (µstrain/°C) vs. Yield strength (
Stage 2: Dissipation factor (dielectric loss tangent) vs. Dielectric consta
Stage 3: Glass temperature, Maximum service temperature, Comparati
3. Results: 4 of 927 pass
Show: Pass all Stages
Rank by: Alphabetical
Name
PAI (30% glass fiber)
PEI (30% glass fiber, lubricated)
PEI (40% glass fiber)
PF (high strength glass fiber, ...
4. Report
Comparison...
Selection...
Home Stage 1 Stage 2 Report PTT (30% glass fiber, ... Stage 3 PAI (30% glass fiber)
Glass temperature, Maximum service temperature, Comparative tracking index
Settings Apply Clear
Impact & fracture properties
Thermal properties
Minimum Maximum
Melting point °C
Glass temperature 150 °C
Heat deflection temperature 0.45MPa °C
Heat deflection temperature 1.8MPa °C
Vicat softening point °C
Maximum service temperature 200 250 °C
Minimum service temperature °C
Thermal conductivity W/m.°C
Specific heat capacity J/kg.°C
Thermal expansion coefficient µstrain/°C
Thermal shock resistance °C
Thermal distortion resistance MW/m
Electrical properties
Minimum Maximum
Electrical resistivity µohm.cm
Electrical conductivity %IACS
Dielectric constant (relative permittivity)
Dissipation factor (dielectric loss tangent)
Dielectric strength (dielectric breakdown) MV/m
Comparative tracking index 200 400 V
Optical, aesthetic and acoustic properties
Restricted substances risk indicators
Critical materials risk
Absorption & permeability
Processing properties
Durability
Chemical resistance of polymers
Primary production energy, CO2 and water
Processing energy, CO2 footprint & water
Recycling and end of life
Part cost estimator

# Selection Report

## *Summary*

Stage Details

### 1. Selection data

| | |
|---|---|
| Database | Level 3 Polymer |
| Table | MaterialUniverse |
| Subset | Polymers - All |
| Reference | |

### 2. Selection criteria (summary)

| Stage | Attribute | Constraints |
|---|---|---|
| 1 | Thermal expansion coefficient (µstrain/°C) | ≤ 17 |
| | Yield strength (elastic limit) / Young's modulus | |
| 2 | Dissipation factor (dielectric loss tangent) | ≥ 0,00101 |
| | Dielectric constant (relative permittivity) | ≤ 4,99 |
| 3 | Material family | Plastic (thermoplastic, semi-crystalline), Plastic (thermoplastic, amorphous) |
| | Glass temperature (°C) | ≥ 150 |
| | Maximum service temperature (°C) | 200 to 250 |

### 3. Selection results

Records passing: All Stages 7 of 927

Ranked by: Alphabetically

Ranked order: Low to high

| Rank | Material |
|---|---|
| 1 | PAI (30% glass fiber) |
| 2 | PEI (30% glass fiber, lubricated) |
| 3 | PEI (40% glass fiber) |
| 4 | PEKK (30% carbon fiber) |
| 5 | PEKK (30% glass fiber) |
| 6 | PEKK (40% carbon fiber) |
| 7 | PEKK (40% glass fiber) |

Change number of records to display...

Stage Details

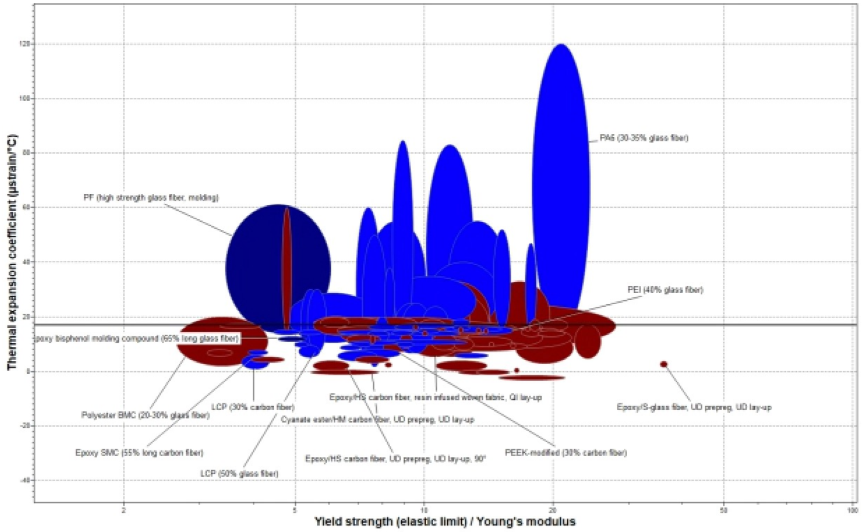




# Selection Report

## Stage 1: Yield strength (elastic limit) / Young's modulus, Thermal expansion coefficient (µstrain/°C)

Summary




### Constraints

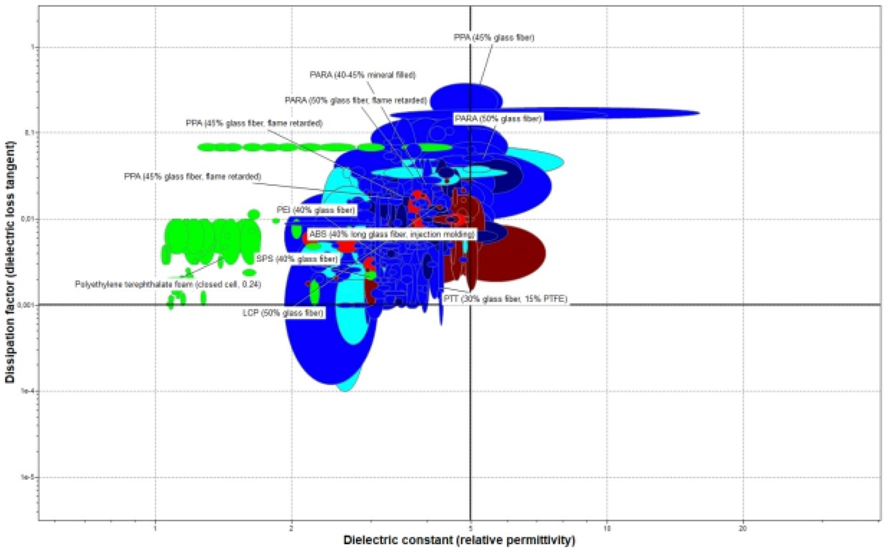
| Attribute | Value |
|---|---|
| Yield strength (elastic limit) / Young's modulus | |
| Thermal expansion coefficient (µstrain/°C) | ≤ 17 |

**Display & selection settings:**
Show results from all enabled stages: Off, Pass records with no data: Off, Fail estimated records: Off
Pass when: Any part of record within selection

**Records passing:** 114 of 927

# Selection Report

| Stage 2: | Dielectric constant (relative permittivity), Dissipation factor (dielectric loss tangent) | Summary |
|---|---|---|




## Constraints

| Attribute | Value |
|---|---|
| Dielectric constant (relative permittivity) | ≤ 4,99 |
| Dissipation factor (dielectric loss tangent) | ≥ 0,00101 |

**Display & selection settings:**
Show results from all enabled stages: Off, Pass records with no data: Off, Fail estimated records: Off
Pass when: Any part of record within selection

**Records passing:** 531 of 927



# Selection Report

| Stage 3: | Limit | Summary |
|---|---|---|

## Constraints

| Attribute | Constraints |
|---|---|
| Material family | Plastic (thermoplastic, semi-crystalline), Plastic (thermoplastic, amorphous) |
| Glass temperature (°C) | ≥ 150 |
| Maximum service temperature (°C) | 200 to 250 |

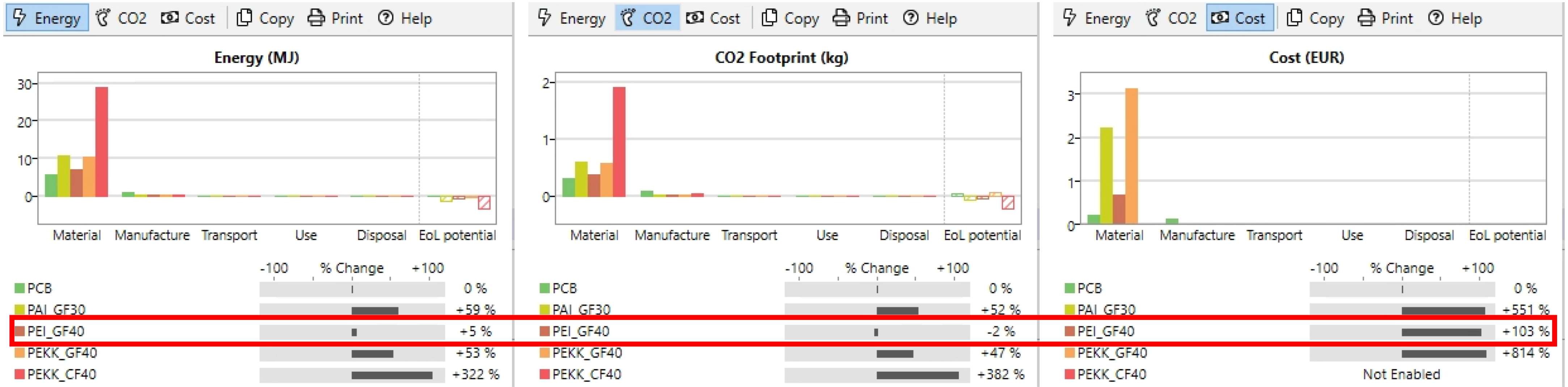
**Display & Selection settings:**

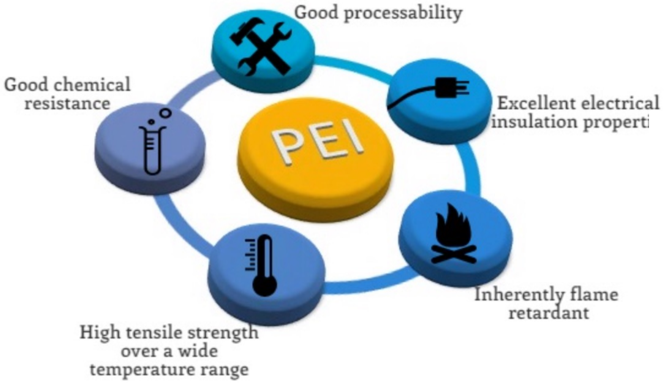
Pass when: Any part of record within selection

Fail estimated records: Off

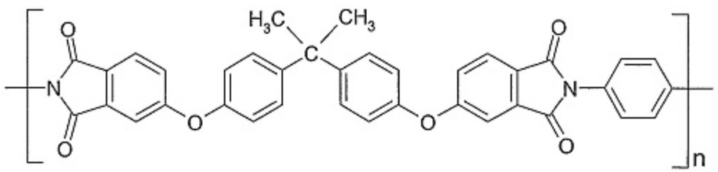
**Records passing:** 40 of 927

# FASE #3: ECO-AUDIT




PoliEterImide



Molecular Structure of Polyetherimide (PEI)

This high-performance polymer also exhibits high tensile strength, good flame resistance and low smoke emission making it an ideal material of choice in automotive, **electrical,** medical and other industrial applications.

**Principali caratteristiche del PEI**
https://omnexus.specialchem.com/selection-guide/polyetherimide-pei-high-heat-plastic

- PEI is an **amorphous thermoplastic** resin with amber transparency
- The resin is characterized by **high deflection temperature** (200°C at 264 psi), high tensile strength and flexural modulus (480,000 psi), and very good **retention of mechanical properties** at elevated temperatures
- It has unique combination of high specific strength, rigidity, flexibility, exceptional dimensional strength etc.
- In addition, the resin exhibits **good electrical properties**, which remain stable over a wide range of temperature and frequencies (including microwave)
- It has good UV-light resistance and weatherability
- PEI is **inherently flame resistance** without the use of additives
- It has a high limiting oxygen index of 47, combined with NBS smoke chamber results which show the lowest specific optical density of any unfilled thermoplastic
- Polyetherimide is resistant to alcohols, acids, and hydrocarbon solvent but dissolves in partially halogenated solvents
- PEI also displays **good hydrolytic stability**
- Most of the PEI grades has a UL94 flame resistance rating of VTM-0, is FDA compliant, EU Food Contact Compliant, and ISO10993 compliant in natural color
- Polyetherimide resin is available in an unreinforced grade for general-purpose processing methods as a transparent resin and in standard and custom colors.

It is also available in:

Four **glass-fiber-reinforced grades** (10, 20, 30, and 40% glass),
- Bearing grades, and
- Several high-temperature grades

**Glass reinforcement** provides even greater rigidity and dimensional stability while maintaining many of the useful characteristics of basic PEI. The glass reinforcement yields a product with an exception strength-to-weight ratio and increased tensile strength.

**Limitations Associated with PEI**
- Very high cost. Applicable for highly demanding applications
- Low colorability
- Attacked by polar chlorinated solvents leading to stress cracking
- A long drying before processing is necessary
- Hot mold during injection molding

**Applicazioni**

- ❖ Automotive and Aerospace
- ❖ Electrical and Electronic
- ❖ Disposable & Reusable Medical Applications
- ❖ Metal Replacing for industrial applications & appliances

**Electrical and Electronical Market**

**Electrical / electronic** is the second most important market for Polyetherimide. In the telecommunications market, there is an increasing need for high heat resistant materials, especially for high-end connectors in the fiber optics segment. PEI resin offers **high heat resistance** as well as great flow for thin wall design.

• applications of Polyetherimide include:

Electrical switches and controls
•Electrical motor parts
•Printed circuit boards, and
•Connectors

Polyetherimide is also used in so-called **molded interconnect devices (MID)**. This is because of its unique plating capabilities. PEI allows the combination of electrical functions with the advantages of injection molded 3-D mechanical components.

The key trend influencing further use of polyetherimide in electrical / electronic applications is new product development. To meet the ongoing needs for **miniaturization in the electronics sector**, (increased packing densities and more lightweight carrier materials) ceramic-filled polyetherimide grades have been developed. These grades have excellent electrical and processing properties, and can also be easily metalized. They are suitable for applications such as:

- Circuit boards operating in the microwave range as well as internal aerials
- Electronic chips, and
- Capacitors

# TECAPEI GF30 natural - Stock Shapes (rods, plates, tubes)

***Chemical Designation***
PEI (Polyetherimide)

***Colour***
amber opaque

***Density***
1.51 g/cm$^3$

***Fillers***
glass fibres

***Main features***
- high dimensional stability
- good heat deflection temperature
- high thermal and mechanical capacity
- high strength
- high creep resistance
- electrically insulating
- resistance against high energy radiation
- sensitive to stress cracking

***Target Industries***
- electronics
- semiconductor technology
- automotive industry
- mechanical engineering
- vacuum technology

| ***Mechanical properties*** | ***parameter*** | ***value*** | ***unit*** | ***norm*** | | ***comment*** |
|---|---|---|---|---|---|---|
| Tensile strength | 5mm/min | 135 | MPa | DIN EN ISO 527-2 | | (1) For tensile test: specimen type 1b<br>(2) For flexural test: support span 64mm, norm specimen.<br>(3) Specimen 10x10x10mm<br>(4) Specimen 10x10x50mm, modulus range between 0.5 and 1% compression.<br>(5) For Charpy test: support span 64mm, norm specimen.<br>(6) Specimen in 4mm thickness |
| Modulus of elasticity (tensile test) | 1mm/min | 5300 | MPa | DIN EN ISO 527-2 | 1) | |
| Tensile strength at yield | 5mm/min | 135 | MPa | DIN EN ISO 527-2 | | |
| Elongation at yield | 5mm/min | 4 | % | DIN EN ISO 527-2 | | |
| Elongation at break | 50mm/min | 4 | % | DIN EN ISO 527-2 | | |
| Flexural strength | 2mm/min, 10 N | 195 | MPa | DIN EN ISO 178 | 2) | |
| Modulus of elasticity (flexural test) | 2mm/min, 10 N | 5500 | MPa | DIN EN ISO 178 | | |
| Compression strength | 1% / 2% 5mm/min, 10 N | 18 / 39 | MPa | EN ISO 604 | 3) | |
| Compression modulus | 5mm/min, 10 N | 4200 | MPa | EN ISO 604 | 4) | |
| Impact strength (Charpy) | max. 7,5J | 51 | kJ/m$^2$ | DIN EN ISO 179-1eU | 5) | |
| Notched impact strength (Charpy) | max. 2J | 6 | kJ/m$^2$ | DIN EN ISO 179-1eA | | |
| Ball indentation hardness | | 325 | MPa | ISO 2039-1 | 6) | |

| Thermal properties | parameter | value | unit | norm | | comment |
|---|---|---|---|---|---|---|
| Glass transition temperature | | 213 | °C | DIN EN ISO 11357 | | (1) Found in public sources. Individual testing regarding application conditions is mandatory. |
| Melting temperature | | | °C | DIN EN ISO 11357 | | |
| Service temperature | short term | 200 | °C | | 1) | |
| Service temperature | long term | 170 | °C | | | |
| Thermal expansion (CLTE) | 23-60°C, long. | 3 | $10^{-5}$ $K^{-1}$ | DIN EN ISO 11359-1;2 | | |
| Thermal expansion (CLTE) | 23-100°C, long. | 3 | $10^{-5}$ $K^{-1}$ | DIN EN ISO 11359-1;2 | | |
| Thermal expansion (CLTE) | 100-150°C, long. | 4 | $10^{-5}$ $K^{-1}$ | DIN EN ISO 11359-1;2 | | |

| Electrical properties | parameter | value | unit | norm | | comment |
|---|---|---|---|---|---|---|
| surface resistivity | | $10^{14}$ | Ω | DIN IEC 60093 | | |
| volume resistivity | | $10^{14}$ | Ω*cm | DIN IEC 60093 | | |

| Other properties | parameter | value | unit | norm | | comment |
|---|---|---|---|---|---|---|
| Water absorption | 24h / 96h (23°C) | 0.04 / <0.1 | % | DIN EN ISO 62 | 1) | (1) Ø ca. 50mm, h=13mm<br>(2) + good resistance<br>(3) - poor resistance<br>(4) Corresponding means no listing at UL (yellow card). The information might be taken from resin, stock shape or estimation. Individual testing regarding application conditions is mandatory. |
| Resistance to hot water/ bases | | + | | - | 2) | |
| Resistance to weathering | | - | | - | 3) | |
| Flammability (UL94) | corresponding to | V0 | | DIN IEC 60695-11-10; | 4) | |

Polymer Resources

Classic® Engineering Plastic Compounds

Friday, December 4, 2020

# PRL PEI-G40

**Polymer Resources Ltd. - *Polyether Imide***

Units English

**Action** **Legend (Open)**

## General Information

| General | | |
|---|---|---|
| Material Status | • Commercial: Active | |
| Availability | • North America | |
| Filler / Reinforcement | • Glass Fiber, 40% Filler by Weight | |
| Additive | • Flame Retardant | |
| Features | • Flame Retardant | • High Heat Resistance |
| RoHS Compliance | • RoHS Compliant | |
| UL File Number | • E113219 | |
| Forms | • Pellets | |
| Processing Method | • Injection Molding | |

## ASTM & ISO Properties [1]

| Physical | Nominal Value | Unit | Test Method |
|---|---|---|---|
| Density / Specific Gravity | 1.60 | | ASTM D792 |
| Melt Mass-Flow Rate (MFR) (337°C/6.6 kg) | 3.0 to 18 | g/10 min | ASTM D1238 |
| Molding Shrinkage - Flow (0.125 in) | 1.0E-3 to 3.0E-3 | in/in | ASTM D955 |
| Water Absorption (24 hr) | 0.13 | % | ASTM D570 |
| Water Absorption (Equilibrium, 73°F) | 0.90 | % | ASTM D570 |
| **Mechanical** | **Nominal Value** | **Unit** | **Test Method** |
| Tensile Modulus (0.125 in) | 1.69E+6 | psi | ASTM D638 |
| Tensile Strength (Yield, 0.125 in) | 25600 | psi | ASTM D638 |
| Tensile Strength (Break, 0.125 in) | 25600 | psi | ASTM D638 |
| Tensile Elongation (Break, 0.125 in) | 2.5 | % | ASTM D638 |
| Flexural Modulus (0.125 in) | 1.69E+6 | psi | ASTM D790 |
| Flexural Strength (0.125 in) | 34000 | psi | ASTM D790 |
| **Impact** | **Nominal Value** | **Unit** | **Test Method** |
| Notched Izod Impact (0.125 in) | 1.8 | ft·lb/in | ASTM D256 |
| Unnotched Izod Impact (73°F, 0.125 in) | 8.0 | ft·lb/in | ASTM D4812 |
| Reverse Notch Izod Impact (73°F, 0.125 in) | 9.0 | ft·lb/in | ASTM D256 |
| **Hardness** | **Nominal Value** | **Unit** | **Test Method** |
| Rockwell Hardness (M-Scale) | 114 | | ASTM D785 |
| **Thermal** | **Nominal Value** | **Unit** | **Test Method** |
| Deflection Temperature Under Load (66 psi, Unannealed, 0.125 in) | 418 | °F | ASTM D648 |
| Deflection Temperature Under Load (264 psi, Unannealed, 0.125 in) | 413 | °F | ASTM D648 |
| Vicat Softening Temperature | 450 | °F | ASTM D1525 [2] |
| CLTE - Flow (-4 to 302°F) | 8.0E-6 | in/in/°F | ASTM E831 |
| RTI Elec | | | UL 746 |
| 0.06 in | 221 | °F | |
| 0.12 in | 221 | °F | |
| RTI Imp | | | UL 746 |
| 0.06 in | 221 | °F | |
| 0.12 in | 221 | °F | |
| RTI Str | | | UL 746 |
| 0.06 in | 221 | °F | |
| 0.12 in | 221 | °F | |

| Electrical | Nominal Value | Unit | Test Method |
|---|---|---|---|
| Volume Resistivity | 1.5E+16 | ohms·cm | ASTM D257 |
| Dielectric Strength (0.0625 in, in Oil) | 600 | V/mil | ASTM D149 |
| Dielectric Constant (1 kHz) | 3.70 | | ASTM D150 |
| Dissipation Factor (1 kHz) | 2.0E-3 | | ASTM D150 |
| **Flammability** | **Nominal Value** | **Unit** | **Test Method** |
| Flame Rating | | | UL 94 |
| 0.06 in | V-0 | | |
| 0.12 in | V-0 | | |

**Processing Information**

| Injection | Nominal Value | Unit |
|---|---|---|
| Drying Temperature | 290 to 300 | °F |
| Drying Time | 4.0 to 6.0 | hr |
| Drying Time, Maximum | 8.0 | hr |
| Rear Temperature | 630 to 750 | °F |
| Middle Temperature | 640 to 750 | °F |
| Front Temperature | 650 to 750 | °F |
| Processing (Melt) Temp | 640 to 750 | °F |
| Mold Temperature | 225 to 350 | °F |

**Notes**

[1] Typical properties: these are not to be construed as specifications.

[2] Rate B (120°C/h), Loading 2 (50 N)

Esempio di scelta delle materie prime

Ensinger: azienda europea, fornisce già il prodotto stampato (plates)

PRL-PEIG40: azienda Nord-America fornisce il pellet che va estruso o stampato

## Conclusioni:

- ❖ I primi risultati della FASE#3 possono non essere soddisfacenti
- ❖ Può essere pertanto necessario reiterare il processo di selezione fino ad arrivare ad un risultato soddisfacente
- ❖ La selezione parte dalla definizione dei vincoli e degli obiettivi: l'analisi approfondita dei vincoli rappresenta la parte essenziale del processo di selezione
- ❖ L'Analisi di EcoAudit, per prodotti che non hanno una funzionalità specifica (ad esempio non prevedono il consumo di corrente elettrica), si concentra sull'impatto delle materie prime, trasporto e processo di produzione.
- ❖ Un'analisi accurata delle materie prime può potenzialmente modificare l'output dell'EcoAudit.