Hyosung has been setting the direction and building solid foundations for various industries through countless challenges and innovative technological breakthroughs throughout its 50-year history.
History

2013  Completed the carbon fiber plant in Korea, Started Commercialization of Polyketone
2010  Completed steel cord plant in Vietnam
2009  Completed the aramid fiber plant
1990  Started Spandex business
1989  Started PP and propylene business
1980  Established HYOSUNG BASF (50/50% JV)
1975  Acquired Hanyoung Industry (predecessor of Hyosung Heavy Industry)
1973  Dongyang Polyester and Dongyang Textile established
1971  R&D Center established
1966  Dongyang Nylon established
1957  Hyosung Industry established
Hyosung has become a global leader in innovating textile, industrial materials, chemistry, heavy industry, construction and information communication.

- Spandex
- Tirecode
- Airbag Fabrics
- Polyester Yarn For Seatbelts
Hyosung is the living history and champion of Korea’s economic development which has been overcoming difficulties and obstacles with indomitable spirit at frontlines.
Performances

Total Sales
KRW 126,117 Billion (USD 11.2 Billion)

Operations
KRW 2,776 Billion (USD 250.5 million)

Operating Profit
KRW 1,893 Billion (USD 168 million)

Sales Proportion by Performance Group (million KRW)
- Trading: 24.0% (3,024,342)
- Construction: 5.4% (676,486)
- Power & Industrial Systems: 20.7% (2,614,928)
- Chemicals: 12.2% (1,544,915)
- Etc: 2.7% (334,861)
- Textile: 15.9% (2,004,764)
- Industrial Materials: 19.1% (2,411,454)

- KRW 126,117 Billion (USD 11,191.7 million)
- KRW 113,421 Billion (USD 10,235.6 million)

- '11 '12
Business Areas

Textile
Spandex PU
Nylon Polyester Fiber PU
Fabric : Dyeing PU

Industrial Materials
Tire & Industrial Reinforcements PU
Technical Yarn PU
Global Safety Textiles
Interior PU
Aramid Business Division
Carbon Business Division

Chemicals
PP/DH PU
TPA PU
Film PU
Neochem PU
Packaging PU
Optical Film PU

Power & Industrial Systems
Power Systems PU
Industrial Machinery PU
HYOSUNG GOODSPRINGS PU
Wind Energy Business Division

Construction
Construction PU
Hyosung EBARA Engineering PU
Chinhung International, Inc.

Trading
Steel & Metal Products PU I, II
Chemical Products PU
LED Business Division
Hyosung Trans–World PU

Information & Communication
Nautilus Hyosung PU
Hyosung Information Systems PU
Hyosung ITX Co., Ltd.
Galaxy Electronics Co., Ltd.
Galaxia Communications Co., Ltd.
Galaxia Device Co., Ltd.

Financing & Other Affiliated Companies
Hyosung Capital PU
The Class Hyosung Co., Ltd.
Hyosung Toyota Corporation
The Premium Hyosung Co., Ltd.

With Customers, With the World
Hyosung is your trusted partner
Domestic Business Premises

15 Plants
20 Offices and Sales
5 R&D Labs

Seoul: Mapo (HQ), Cheongdam/Bangbae/Suseo/Banpo Office, Environment R&D Center, Electronic R&D Center

Anyang Plant
Anyang Frozen Storage
R&D Labs
Power & Industrial Systems R&D Center

Oksoo Plant
Sejong Plant

Daejeon Plant

Gumi Plant

Jeonju Plant

Eonyang Plant
Steel Wire Technical Center

Ulsan Plant

Yongyeon Plant

Changwon Plant

Yangsan Plant
Overseas Business Premises

Production Corporations
- 37
- 4 branches of manufacturing sales corporations

Trading Corporations
- 10
- 5 branches of manufacturing sales corporations

Trading Offices
- 19

Locations:
- NORTH AMERICA
- SOUTH AMERICA
- EUROPE
- ASIA
- AFRICA

Countries:
- China (Jiaxing)
- China (Guangdong)
- China (Nantong)
- Vietnam (Dong Nai)
- USA (Dallas)
- Luxembourg (Bissen)
- Turkey (Istanbul)
- USA (Pittsburgh)
- Brazil (Americana)
- USA (Decatur)
- Germany (Maulburg)
Introduction to POLYKETONE

Hyosung R&DB Labs.
【 Contents 】

Ⅰ. Introduction

Ⅱ. Characteristics

Ⅲ. Applications

Ⅳ. Present & Future
I. Introduction

- New Green polymeric material composed of carbon-monoxide and olefin (ethylene, propylene).

- Composition
  - ENPLA Ter-Polymer (carbon-monoxide + ethylene + propylene)
  - Super FiberCo-Polymer (carbon-monoxide + ethylene)
I. Introduction

II. Characteristics

III. Applications

IV. Present & Future
Ⅱ. Characteristics

1. **Characteristics – “New Green Polymeric Material”**

- New green polymeric material made of CO, one of major air-pollution source.

*Major 6 Air Pollution Source: CO, NOx, SOx, NH3, VOC, PM*

- **Polyketone 50,000MT**
- CO Consumption 25,000MT.

Total Emission of Air pollution source in Korea: 3.68 mil. MT

- NOx 28.8%  *Nitrogen Oxide*
- VOC 23.5%  *Volatile Organic Compounds*
- CO 20.9%  *Carbon Monoxide*
- SOx 10.9%  *Sulfur Oxide*
- NH3 7.9%  *Ammonia Emission*
- TSP 4.8%  *Total Suspended Particulate*
- PM10 3.2%  *Particle Matter in Diameter 10㎛*

Same as 3.80 mil. Pine Tree
(30yr. Pine tree purify 6.6 Kg/yr CO2)

Source: National Institute of Environmental Research (Korea)
### II. Characteristics

**Characteristic— “High Impact Strength”**

- More than 230% higher impact strength compared to Nylon, PBT.
- No deterioration due to good hydrolysis resistance.

<table>
<thead>
<tr>
<th>Items</th>
<th>Unit</th>
<th>POK</th>
<th>PA6</th>
<th>PA66</th>
<th>PBT</th>
<th>POM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>g/cm³</td>
<td>1.24</td>
<td>1.14</td>
<td>1.14</td>
<td>1.30</td>
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<td>°C</td>
<td>220</td>
<td>220</td>
<td>260</td>
<td>220</td>
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<td>Impact Strength</td>
<td>KJ/m²</td>
<td>12</td>
<td>5.2</td>
<td>4.1</td>
<td>5.0</td>
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<tr>
<td>Tensile Strength</td>
<td>MPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Dry</td>
<td>70</td>
<td>80</td>
<td>80</td>
<td>55</td>
<td>65</td>
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<tr>
<td></td>
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<td>70</td>
<td>55</td>
<td>70</td>
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<tr>
<td></td>
<td>Wet</td>
<td>60</td>
<td>35</td>
<td>50</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Elongation at Break</td>
<td>%</td>
<td>270</td>
<td>17</td>
<td>19</td>
<td>16</td>
<td>35</td>
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<tr>
<td></td>
<td>Dry</td>
<td></td>
<td>270</td>
<td>17</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Conditioned</td>
<td></td>
<td>40</td>
<td>19</td>
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<tr>
<td></td>
<td>Wet</td>
<td></td>
<td>390</td>
<td>360</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td>370</td>
<td>370</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>MPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dry</td>
<td>1,800</td>
<td>2,600</td>
<td>2,900</td>
<td>2,400</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>Conditioned</td>
<td>1,800</td>
<td>1,200</td>
<td>2,200</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>1,450</td>
<td>600</td>
<td>1,100</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Dry: 23°C, 50% RH, 24hrs  Conditioned: 23°C, 50% RH, 60days  Wet: 23°C, 90% RH, 60days
** POK : Hyosung M330A properties.
Generally PA6, P66 has high tensile property but impact strength and elongation is low. Polyketone have good impact strength and elongation with enough tensile property.

- **Density**
- **Tensile Strength (Dry)**
- **Tensile Strength (Cond.)**
- **Tensile Strength (Wet)**
- **Impact Strength**
- **Elongation**
- **Flexural Modulus (Dry)**
- **Flexural Modulus (Cond.)**
- **Flexural Modulus (Wet)**

* Dry: 23°C, 50% RH, 24hrs  Conditioned: 23°C, 50% RH, 60days  Wet: 23°C, 90% RH, 60days

** POK : Hyosung M330A properties.

1 : Inferior  3 : Normal  5 : Superior
II. Characteristics

Tensile Properties

Tensile Strength at Yield (MPa)

Elongation at Yield (%)
II. Characteristics

Characteristic – “Excellent Chemical Resistance”

- PK’s chemical resistance is the top level among the plastics.
- No drops in properties due to the resistance to acidic/basic solutions.
## Chemical Resistance

<table>
<thead>
<tr>
<th></th>
<th>Semi-crystalline</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Amorphous</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>PK</td>
<td>PA66</td>
<td>PA12</td>
<td>POM</td>
<td>PBT</td>
<td>PPS</td>
<td>PVDF</td>
<td>PPO</td>
<td>PSU</td>
<td>PC</td>
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<tr>
<td>Hydrocarbons</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<td>aromatic</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<td>halogenated</td>
<td>+</td>
<td>+</td>
<td>⊗</td>
<td>+</td>
<td>⊗</td>
<td>+</td>
<td>+</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
</tr>
<tr>
<td>Ketones</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
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<tr>
<td>Esters/ethers</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
</tr>
<tr>
<td>Aldehydes</td>
<td>+</td>
<td>⊗</td>
<td>⊗</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
</tr>
<tr>
<td>Aqueous</td>
<td>+</td>
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<td>+</td>
<td>⊗</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>water</td>
<td>+</td>
<td>⊗</td>
<td>⊗</td>
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<td>+</td>
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<td>+</td>
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<td>weak acids</td>
<td>+</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>weak bases</td>
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<td>⊗</td>
<td>⊗</td>
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<td>+</td>
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<td>+</td>
<td>⊗</td>
<td>+</td>
</tr>
<tr>
<td>strong acids</td>
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<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
<td>+</td>
<td>+</td>
<td>⊗</td>
<td>+</td>
</tr>
<tr>
<td>strong bases</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
<td>⊗</td>
<td>+</td>
<td>+</td>
<td>⊗</td>
<td>+</td>
</tr>
</tbody>
</table>

+ Resistant  ⊗ Not Resistant

Note: Relative ranking including temperature effects
II. Characteristics

- **Excellent fuel resistance, small change after 3,000 hrs test.**

- **2 times superior to the PA12, current material for automotive tube.**
**Characteristic – “Excellent Tribological Property”**

- Polyketone has 14 times higher anti-abrasion property than that of POM, currently most stiff material. It helps almost permanent use without change.

* POK base resin > POM base resin  →  14 times higher.
* POK base resin > POM with 1% additive →  1.7 times higher.
* POK with 1% additive > POM with 3% additive →  10 times higher.

![Graph showing Abrasion Loss and Squeak Noise](image)
Characteristics – “High Barrier Property” : Gas Barrier

- Same level of EVOH, top class of food packaging material due to the gas barrier property.
  (EVOH : multi-layer, Polyketone : mono-layer)
Ⅱ. Characteristics

*Characteristic – “High Barrier Property” : Hydrocarbon*

- Polyketone has excellent barrier property to the hydrocarbon, with good chemical resistance.
II. Characteristics

Permeability to unleaded Gasoline at 93°C

- Weight Change, g
- Exposure, days

*Measured according to GM SPEC 9061-P*
Characteristic – “Excellent Flame Retardant”

- Polyketone makes water, reacted ketone (C=O) group with hydrogen during burning and Char layer covered surface not to contact to oxygen and heat. ⇒ 50% dose of flame retardant additive compared to Nylon (UL-V0 rate).

<table>
<thead>
<tr>
<th>Char 형성 : “Carbon Rich Aromatic Polymer”</th>
</tr>
</thead>
</table>

* Phosphorous flame retardant (Metal Phosphinate) test result for UL-V0 rate

<table>
<thead>
<tr>
<th></th>
<th>PK</th>
<th>NY66</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contents(%)</td>
<td>8</td>
<td>17</td>
</tr>
</tbody>
</table>
II. Characteristics

Characteristic – “High Productivity”

- High crystallinity of Polyketone helps to shorten cycle time. 
  → Improve productivity

<table>
<thead>
<tr>
<th>Injection molding cycle times (seconds)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
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</thead>
<tbody>
<tr>
<td>Relay box</td>
<td>PA 66</td>
<td>48%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiator endtank</td>
<td>PA 66</td>
<td>31%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheelcover</td>
<td>PA 66</td>
<td>12%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fender</td>
<td>PA/PPO</td>
<td>20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gears</td>
<td>POM</td>
<td>25%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conveyor links</td>
<td>POM</td>
<td>26%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Valve cover</td>
<td>PET</td>
<td>19%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geophone housing</td>
<td>PC</td>
<td>50%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### Summary

- Polyketone is a new green polymeric material, made of carbon-monoxide. It has excellent "Impact strength", "Chemical Resistance", "Anti-abrasion", "Gas barrier", "Flame retardant", superior to current engineering plastic.
II. Characteristics

Polyketone Positioning

- High Performance Polymers
  - (Super ENPLA)
  - PBT
  - Engineering Plastics
  - HIPS, LDPE, LLDPE, TPE, PET
  - Continuous-Use Temperature
    - 150°C
    - 90°C
  - Cost Driven
    - Five ENPLAs
      - Tensile str > 500Kg/cm²
        - PA, PBT/PET
      - POM, PC, m-PPO
    - Semi-ENPLA
      - Tensile str < 500Kg/cm²
        - ABS, PP compound
    - Five Commodities
      - Tensile str < 300Kg/cm²
        - HDPE, LDPE, PP
        - PVC, PS (GPPS, HIPS)
- Performance Driven
  - POK
  - Amorphous
  - Crystalline
Ⅰ. What is Polyketone

Ⅱ. Characteristic

Ⅲ. Applications

Ⅳ. Present & Future
Ⅲ. Applications

Automotive Fuel Systems and under the Hood Applications

- Very Good Chemical Resistance
- High Permeation Resistance
- Superior Impact Strength
- Good High Temperature Performance

* Under Developing with Hyosung’s Polyketone.
Automotive Outer Component Applications

Ⅲ. Applications

Characteristics

- Superior Impact Strength
- Very Good Chemical Resistance
- Very Good Hydrolytic Stability
- Outstanding Stiffness/Toughness Balance

* Under Developing with Hyosung’s Polyketone.
Electrical Applications: Connector & Plug, Switch, Socket, etc.

Characteristics

- Halogen and Red Phosphorus Free Fire Retardant
- Good Toughness
- Good Tracking Resistance
- High Resilience
- Good Processability

* Under Developing with Hyosung’s Polyketone.
Ⅲ. Applications

Gears: ATM, Office Automation (OA), Automotive, etc.

Characteristics

- Superior Wear & Abrasion Resistance
- High Creep Resistance
- Very Good Hydrolytic Stability
- Outstanding Stiffness/Toughness Balance

Gears of ATM, OA Machines

* Under Developing with Hyosung’s Polyketone.
III. Applications

Barrier Pipe & Packaging Applications

Characteristics

- Chemicals & Hydrocarbons Barrier
- Oxygen Barrier: Food
- Aroma/Flavor Barrier: Personal Care Products

Pipe & Tube
Pipe Cap
Packaging Bottles
Personal Care Products
Food Packaging

* Under Developing with Hyosung’s Polyketone.
IV. Present & Future

**Development History**

- 2004  Start Lab. Scale Development.
- 2006  Bench scale Polymerization Equipment set-up (Capa. : 10 MT/Y, Anyang R&DB Labs.)
- 2008  Start ENPLA development.
- 2011  Start Fiber Development.
- 2012  Pilot Polymerization Plant set-up. (Capa. : 1,000 MT/Y, Ulsan Plant)
- 2013  Finish engineering for Commercial Plant.
- 2015  Commercial Plant start. (Capa. : 50,000 MT/Y, Ulsan Plant)

Hyosung developed basic material technology and engineering design was finished.

“June `2015, Commercial plant will be started”

- Patent : Total 160 (Domestic 133, World-wide 27)
### Portfolio

- **5 Base resin (M230A~M640A)** and 27 compounding recipes
- **Melt Index 6~200, Melting Temp. 220~240℃ for Injection Molding and Extrusion.**

### POK Grade

<table>
<thead>
<tr>
<th>Name</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>M230A</td>
<td>High Flow</td>
</tr>
<tr>
<td>M330A</td>
<td>Medium Flow Injection Molding</td>
</tr>
<tr>
<td>M340A</td>
<td>High Temp.</td>
</tr>
<tr>
<td>M630A</td>
<td>High Impact Injection</td>
</tr>
<tr>
<td>M640A</td>
<td>High Impact at low temp.</td>
</tr>
</tbody>
</table>

- **M230A**: High Flow Injection Molding For High Filling
- **M330A**: Medium Flow For general/thin wall injection
- **M340A**: High Temp. For high temperature use
- **M630A**: High Impact Extrusion/Injection For Pipe Extrusion For high impact injection molding
- **M640A**: High Impact at low temp For high impact at low temperature

<table>
<thead>
<tr>
<th>Item</th>
<th>Method</th>
<th>Unit</th>
<th>M230A</th>
<th>M330A</th>
<th>M630A</th>
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</thead>
<tbody>
<tr>
<td><strong>Physical</strong></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Density</td>
<td>ASTM D792</td>
<td>g/cm³</td>
<td>1.24</td>
<td>1.24</td>
<td>1.24</td>
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<tr>
<td>Water Content (23°C, 60% RH, Eq.)</td>
<td>ASTM D570</td>
<td>%</td>
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<td>0.5</td>
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<tr>
<td><strong>Thermal</strong></td>
<td></td>
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</tr>
<tr>
<td>Melting Temperature</td>
<td>ASTM D1525</td>
<td>°C</td>
<td>220</td>
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</tr>
<tr>
<td>Melt Flow Rate (240°C, 2.16kg)</td>
<td>ASTM D1238</td>
<td>g/10min</td>
<td>150</td>
<td>60</td>
<td>6</td>
</tr>
<tr>
<td>Deflection Temperature</td>
<td>ASTM D648</td>
<td>°C</td>
<td>205</td>
<td>210</td>
<td>210</td>
</tr>
<tr>
<td>: HDT 0.45MPa(4.6 kg/cm²)</td>
<td></td>
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</tr>
<tr>
<td><strong>Mechanical</strong></td>
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</tr>
<tr>
<td>Tensile Strength</td>
<td>ASTM D638</td>
<td>Kg/cm²</td>
<td>500</td>
<td>600</td>
<td>620</td>
</tr>
<tr>
<td>Nominal Strain at Break</td>
<td>ASTM D638</td>
<td>%</td>
<td>&gt;25</td>
<td>&gt;250</td>
<td>&gt;300</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>ASTM D790</td>
<td>Kg/cm²</td>
<td>500</td>
<td>600</td>
<td>620</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>ASTM D790</td>
<td>Kg/cm²</td>
<td>13,000</td>
<td>18,000</td>
<td>18,000</td>
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<tr>
<td>Charpy Notched Impact Strength</td>
<td>ASTM D256</td>
<td>Kg · cm/cm</td>
<td>5</td>
<td>12</td>
<td>18</td>
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<tr>
<td><strong>Electrical</strong></td>
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<tr>
<td>Volume Resistivity</td>
<td>ASTM D257</td>
<td>Ω·cm</td>
<td>$10^{15}$</td>
<td>$10^{15}$</td>
<td>$10^{15}$</td>
</tr>
<tr>
<td>Dielectric Strength</td>
<td>ASTM D149</td>
<td>KV/mm</td>
<td>20</td>
<td>17</td>
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</tbody>
</table>
Thank you very much.