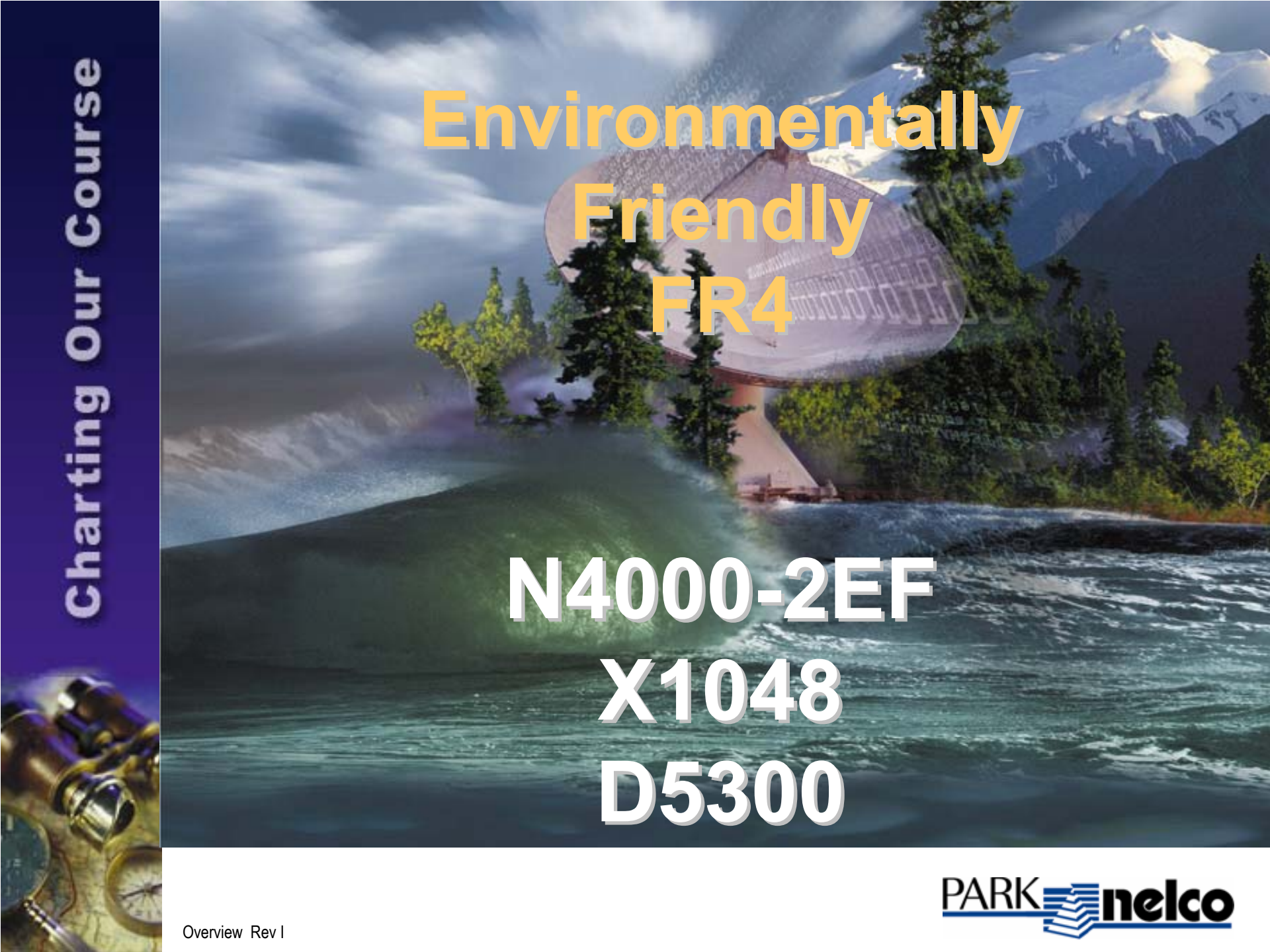
Charting Our Course
Environmentally
Friendly
FR4
N4000-2EF
X1048
D5300



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# Environmentally Friendly FR4

- What is Environmentally Friendly?
- Halogen-free directives
- Lead-free market driver
- N4000-2 EF™
  - Environmentally Friendly FR-4
- X1048
  - High-$T_g$, Environmentally Friendly FR-4
- D5300
  - High-$T_g$, High Speed Environmentally Friendly FR-4
- Green marketing



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# What Is Environmentally Friendly™?

## Nelco's trademark Environmentally Friendly™ material:

- Is halogen-free, and makes use of our proprietary flame retardant
- Continues to meet UL 94V-0 flammability criteria
- Is compatible with lead-free assembly, providing a completely 'green' laminate solution.



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# Bromine Elimination Market Drivers

- Public Opinion: Halogens are Dangerous
  - potential risk of formation of halogenated dioxins (PBB) and furans (PBDE) when burned
- Directive of Waste from Electrical and Electronic Equipment (WEEE) - Effective Jan.2006 if Passed
- Japanese Electronics Recycling Laws
- Marketing - Market Share Increases Shown by OEM's with Lead Free Product Offerings
  - Bromine Elimination is Also Targeted with Lead Free Efforts



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# Halogen-Free Legislation Landscape

- In 1999, TBBA was added to the US EPA's High Production Volume Testing Initiative.1
- Also in 1999, TBBA was added to the US SARA Title 13 list of chemicals requiring annual reporting and environmental releases.1
- A 1998 draft of a proposed EU directive called for a phase out of brominated flame retardants by 2004. While the plan was later amended specifically to polybrominated compounds, TBBA is awaiting formal risk assessment by the EU.
- Japan's Environmentally Preferred Products (EPP) Program calls for reduced lead and bromine free flame retardants.
- "Take Back" recycling programs in Asia and Europe underscore the desire for lead free and halogen free products.


# Problematic Compounds-NEMI

**Regulations or industrial customers have recommended banning these materials for product use in one or more countries:**

- **Cd and compounds**
  - **exempt: Battery applications**
- **Hg and compounds**
  - **exempt: specific safety applications**
- **Ozone Depleting Substances**
  - **exempt: specific safety applications**
- **"Polybrominated aromatic compounds"**
  - **exempt: specific safety applications**
- **Polychlorinated biphenyls / terphenyls**
  - **exempt: specific safety applications**



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# Potential Bromine Replacements

- Red phosphorus
- Organic phosphorus compounds
- Inorganic materials like $Al(OH)_3$, $NH_4H_2PO_4$ or Borates
- Synergistic combination of organo-phosphorus compounds and inorganic fillers



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# Active Lead-Free Initiatives

| Manufacturer | Lead Free Target | Year Implemented | Notes |
|---|---|---|---|
| Sony | All Products Lead Free | 2002 | Except for High Density Packages |
| Toshiba | Mobile Phones | 2001 | |
| Matsushita | Released Compact MD<br>All Product Lines Pb Free | Oct. 1, 1998<br>March 2003 | Major 4 Product Lines<br>All Lead Free |
| Fujitsu | LSI BGA and QFP Pb Free<br>50 % of PWB Assemblies<br>Complete Elimination | June 2001<br>Dec. 2001<br>Dec. 2002 | |
| Mitsubishi | 50% Reduction from 1997<br>Complete Elimination | 2004<br>2005 | Four Major Products |
| NEC | 50 % Reduction in PB Use | 2002 | Sn – Zn Motherboards |



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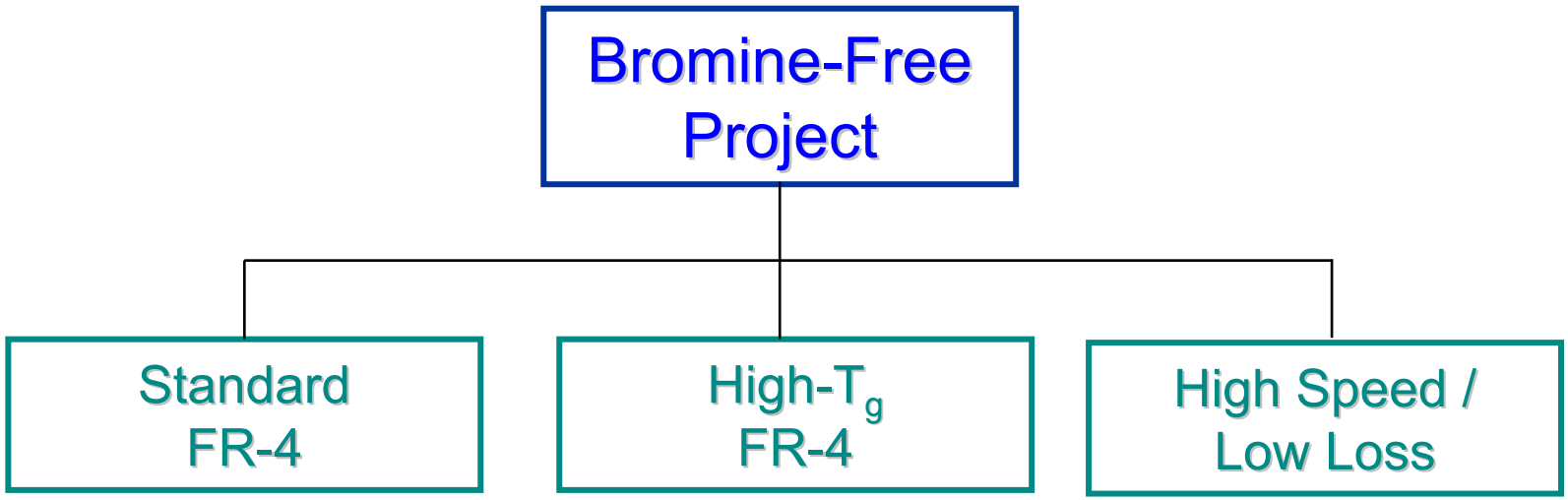
# Corporate R&D Project
# Halogen Free



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# Halogen Free Products Target Properties

| | N4000-2 EF™ | X1048 | D5300 (SI™) |
|---|---|---|---|
| **Thermal** | | | |
| $T_g$ by DSC (°C) | 130-140 | 175 | 180-190 |
| $T_g$ by TMA (°C) | 130-140 | 170 | 170-180 |
| TGA (°C) | 335 | >360 | 397 |
| **Electrical** | | | |
| $D_k$ @1 MHz | 4.5 | 4.3 | 4.2 (3.9) |
| $D_f$ @ 1 MHz | 0.019 | 0.027 | 0.013 (0.011) |
| Surface Resistivity (Megohms) | $10^6$ | $10^7$ | $10^7$ |
| Volume Resistivity (Megohms/cm) | $10^7$ | $10^7$ | $10^7$ |
| **Mechanical** | | | |
| Peel Strength (lb./in.) | 8.0-9.0 | 7.0-8.0 | 9.0-10.0 |
| XY CTE PPM (-40 -125°C) | 12-15 | 12-15 | 10-14 |
| Z CTE % (50-260°C) | 4.2 | 2.9 | 3.2 |
| **General** | | | |
| UL-94 | V-0 | V-0 | V-0 |
| IPC 4101 | Pass | TBD | Pass |



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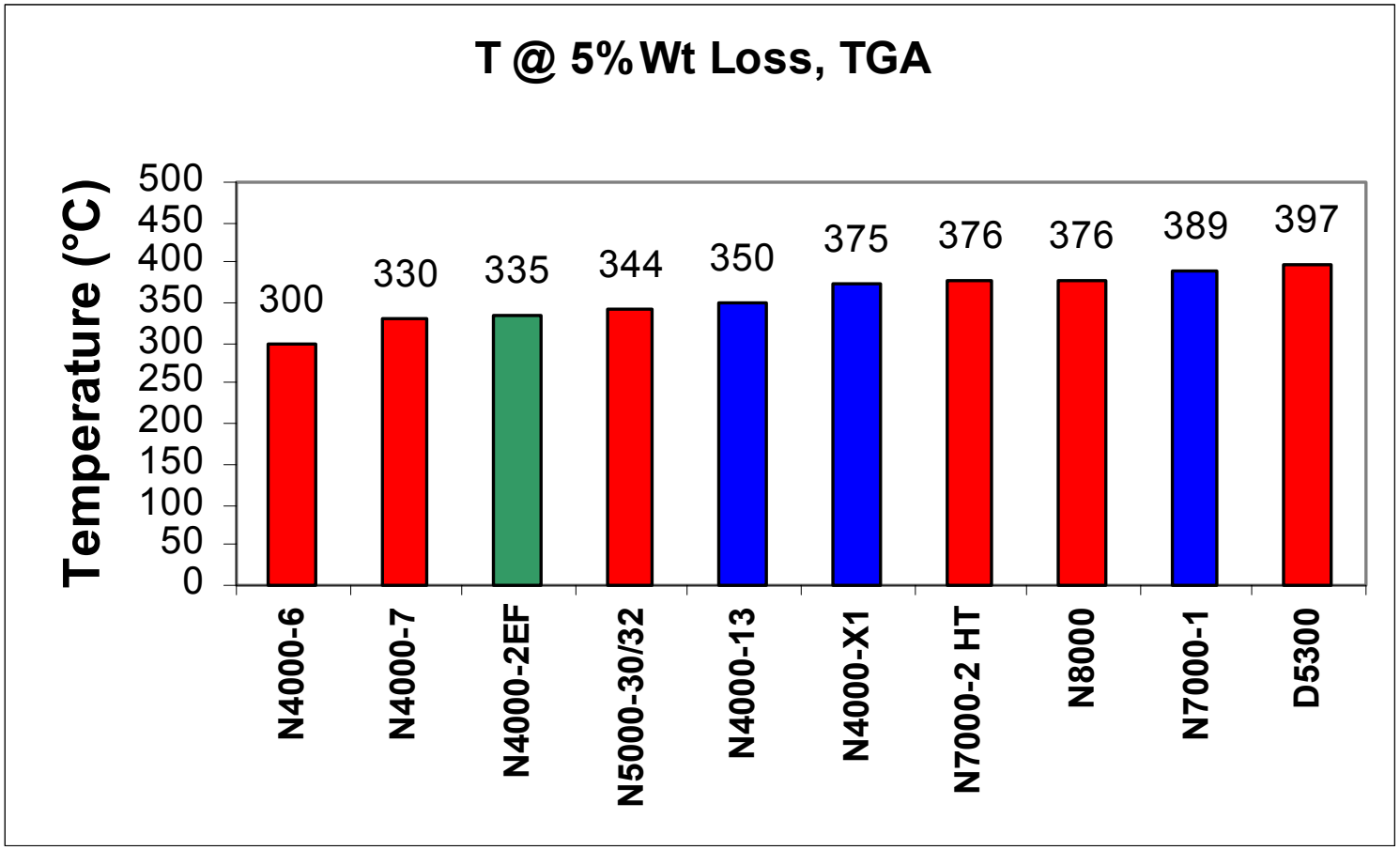
# Thermogravimetric (TGA) Data



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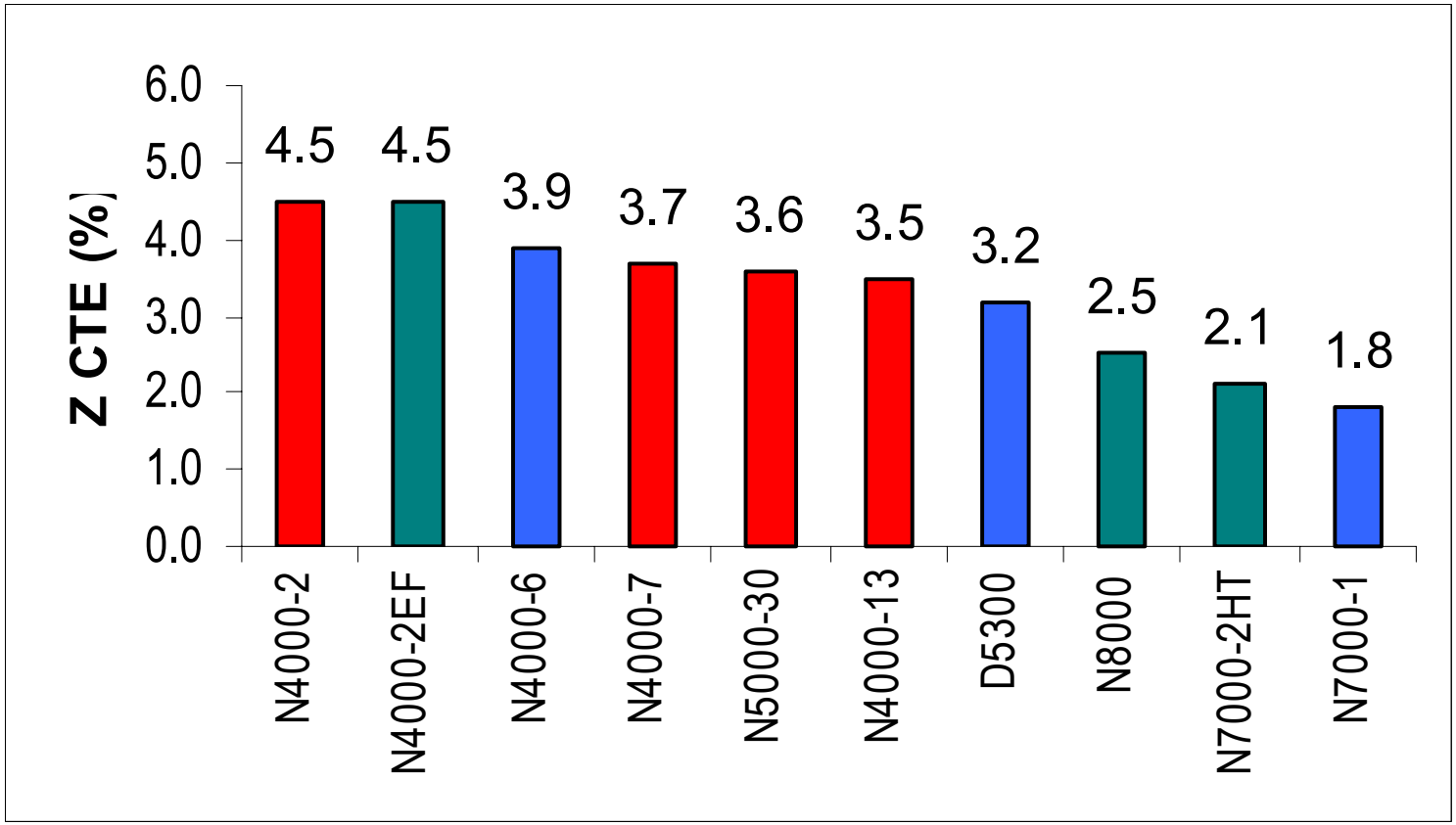
# Z-Axis CTE Comparison



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# Product Development Phases

| Status | Level | Description |
|---|---|---|
| X | 1 | Key Characteristics/Screening/Research Tests |
| | 2 | Research Tests/IPC 4101/Initial Manufacturability |
| | 3 | Materials Engineering Tests |
| | 4 | Alpha Site Testing |
| D | 5 | Beta Site Testing |
| | 6 | Final Manufacturability |
| | 7 | Accelerated Life Testing |
| N | 8 | Full Product Release |



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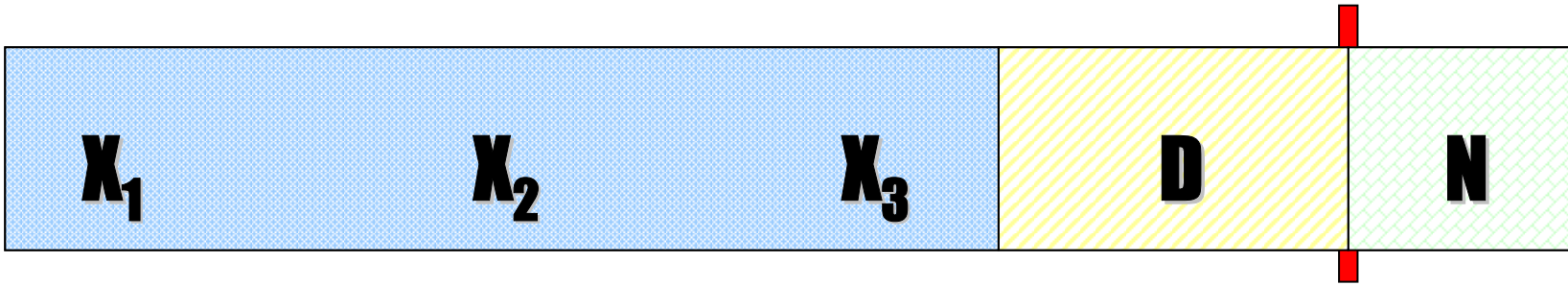
# N4000-2 EF Status

## *Bromine-Free FR-4*




- Completed application engineering testing
- Data sheet and processing guide available at www.parknelco.com
- Material supplied to 28 different customers
- Preliminary qualification with 2 large OEM's
- Final UL approval received May 2001
- Currently in production at three European PWB fabricators


# N4000-2 EF™ Product Summary

- Halogen-free
  - Passes JCPA-ES-01 test method for halogen-free materials
- Compatible with lead-free assembly
- Compatible with standard FR-4 processing



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# N4000-2 EF™ Properties

| Property / Condition | Value (U.S. Units) | | Value (Metric Units) | | Test Method |
|---|---|---|---|---|---|
| **Mechanical** | | | | | |
| Peel Strength - 1 oz. (35μm) Cu | | | | | |
| After Solder Float | 9.6 | lb / inch | 1.7 | N / mm | IPC-TM-650.2.4.8 |
| At Elevated Temperature | 8.5 | lb / inch | 1.5 | N / mm | IPC-TM-650.2.4.8.2a |
| After Exposure to Process Solutions | 9.0 | lb / inch | 1.6 | N / mm | IPC-TM-650.2.4.8 |
| X / Y CTE [-40°C to +125°C] | 12 - 15 | ppm / °C | 12 - 15 | ppm / °C | IPC-TM-650.2.4.41 |
| Z Axis Expansion [50°C to 260°C] | 4.2 | % | 4.2 | % | IPC-TM-650.2.4.41 |
| Young's Modulus (X / Y) | 4.7 / 3.4 | psi x $10^6$ | 31.9 / 23.1 | kN / $m^2$ | ASTM D3039 |
| Poisson's Ratios (X / Y) | 0.17 / 0.16 | | 0.17 / 0.16 | | ASTM D3039 |
| Thermal Conductivity [150°C] | 0.3 - 0.4 | W / mK | 0.3 - 0.4 | W / mK | ASTM E1461 |
| Specific Heat | TBD | J / gK | TBD | J / gK | ASTM E1461 |
| **Electrical** | | | | | |
| Dielectric Constant (50% resin content) | | | | | |
| @ 1 MHz (TFC / LCR Meter) | 4.5 | | 4.5 | | IPC-TM-650.2.5.5.3 |
| @ 1 GHz (RF Impedance) | 4.2 | | 4.2 | | IPC-TM-650.2.5.5.9 |
| Dissipation Factor (50% resin content) | | | | | |
| @ 1 MHz (TFC / LCR Meter) | 0.019 | | 0.019 | | IPC-TM-650.2.5.5.3 |
| @ 1 GHz (RF Impedance) | TBD | | TBD | | IPC-TM-650.2.5.5.9 |
| Volume Resistivity | | | | | |
| C - 96 / 35 / 90 | $10^7$ | MΩ - cm | $10^7$ | MΩ - cm | IPC-TM-650.2.5.17.1 |
| E - 24 / 125 | $10^7$ | MΩ - cm | $10^7$ | MΩ - cm | IPC-TM-650.2.5.17.1 |
| Surface Resistivity | | | | | |
| C - 96 / 35 / 90 | $10^6$ | MΩ | $10^6$ | MΩ | IPC-TM-650.2.5.17.1 |
| E - 24 / 125 | $10^6$ | MΩ | $10^6$ | MΩ | IPC-TM-650.2.5.17.1 |
| Electric Strength | 800 | V / mil | $3.1 \times 10^4$ | V / mm | IPC-TM-650.2.5.6.2 |
| Dielectric Breakdown | >50 | kV | >50 | kV | IPC-TM-650.2.5.6 |
| Arc Resistance | 124 | seconds | 124 | seconds | IPC-TM-650.2.5.1 |
| **Thermal** | | | | | |
| Glass Transition Temperature ($T_g$) | | | | | |
| DSC (°C) | 130 | °C | 130 | °C | IPC-TM-650.2.4.25c |
| TMA (°C) | 130 | °C | 130 | °C | IPC-TM-650.2.4.24c |
| Degradation Temp (TGA) (5% wt. loss) | 335 | °C | 335 | °C | IPC-TM-650.2.3.40 |
| Pressure Cooker | Pass | | Pass | | IPC-TM-650.2.6.16 |
| $T_{260}$ | >10 | minutes | >10 | minutes | IPC-TM-650.2.4.24.1 |
| **Chemical / Physical** | | | | | |
| Moisture Absorption | 0.12 | wt. % | 0.12 | wt. % | IPC-TM-650.2.6.2c |
| Methylene Chloride Resistance | 0.13 | % wt. chg. | 0.13 | % wt. chg. | IPC-TM-650.2.3.4.3 |
| Density [50% resin content] | 2.07 | g / $cm^3$ | 2.07 | g / $cm^3$ | Internal Method |

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# N4000-2 EF™ Market Status

- Product has full commercial status globally
- Three fabricators consuming material for production part numbers
- Numerous evaluations underway in Asia and North America
- North American production targeted for late 2002
- Total customers sampled= 28
- Material has exhibited a wide processing latitude and good thermal performance



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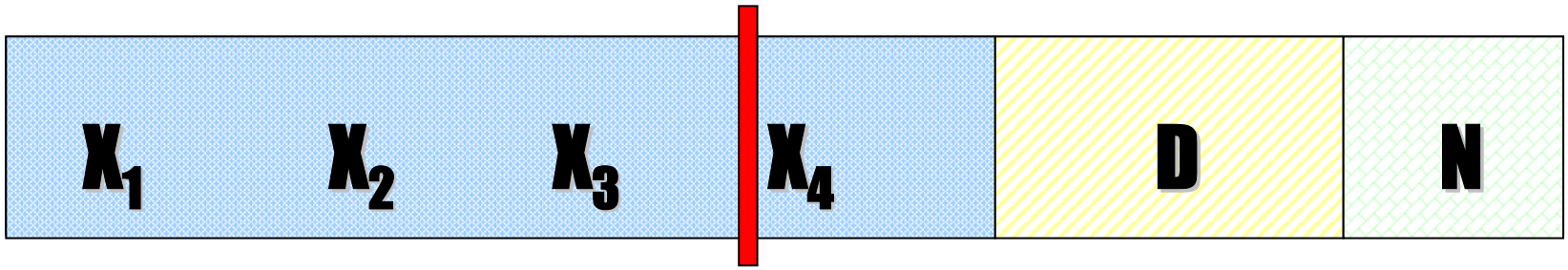
# X1048 Product Development Status




- R&D evaluations complete
  - Characterization of thermal, electrical, and mechanical properties
  - Preliminary applications testing
  - Pilot production runs
- Published preliminary processing guidelines
- Full production runs and alpha site testing pending



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# X1048 Product Summary

- Halogen-free
  - Passes JCPA-ES-01 test method for halogen-free materials
- Lead-free compatible
- Superior thermal performance
- Compatible with standard FR-4 processing
- Leads the market in high-$T_g$, halogen free
  - Tg > 170°C by DSC



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# X1048 Key Attributes

| Property | X1048 | -2EF | -6 | X1027 |
|---|---|---|---|---|
| Tg I/U °C (DSC) | 173/183 | 130 | 175 | 170 |
| T260 (min) | 30+ | 10+ | 4 | 25 |
| Pressure Cook / Solder Dip (sec) | 900+ | | 120 | 450 |
| Solder Float (sec) | 900+ | | 250 | 450 |
| ILBS (lb/in) | 5.6 | | 7.5 | 5.4 |
| Cu Peel (lb/in) | 5.03 | 9.6 | 8 | 6 |
| Total burn (sec) | 20 | | 31 | 12 |
| Halogen Free | Yes | Yes | No | No |



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# X1048 Property Comparison

| TEST | N4000-6FC | N4000-7 | D1028 | X1048 |
|---|---|---|---|---|
| Tg (DSC) | 175? C. | 155? C. | 175°C. | 172 °C |
| Tg (TMA) | 170? C. | 150? C. | 165°C. | 161 °C |
| Tg (DMA) | 180°C | 160? C. | 195°C | 195 °C |
| X axis CTE (-40 to +125? C.) | 14.0 ppm/°C | 15.5ppm/? C. | 14.0ppm/°C | 17.1 ppm/°C |
| Y axis CTE (-40 to +125? C.) | 12.0 ppm/°C | 12.5ppm/? C. | 12.0ppm/°C | 11.6 ppm/°C |
| Z axis CTE (below Tg) | 70ppm/? C. | 55ppm/? C. | 65ppm/°C. | 67 ppm/°C |
| Z axis CTE (above Tg) | 320ppm/C. | 250ppm/? C. | 265ppm/°C. | 248 ppm/°C |
| Z axis expansion (50 to 260? C.) | 3.70% | 3.80% | 3.20% | 3.20% |
| Z axis expansion (50 to 288? C.) | 5.90% | 4.60% | 4.20% | 3.91% |
| Moisture Resistance (24 hr. immersion) | 0.15% | 0.07% | 0.15% | 0.15% |
| $T_{260}$ | 7 min. | 16 min. | 30 min. | > 120 min |
| $T_{288}$ | 1.4 min. | 1.4 min. | 5 min. | >30 min |
| Solder Float (4"x4" Cu Clad) | 230 sec. | 263 sec. | 550+ sec. | >900 sec |



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# Competitive Data

| Property | X1048 | Sample A | Sample B | Sample C | Typical FR-4 (high Tg) |
|---|---|---|---|---|---|
| Tg°C | 173/183(DSC) | 140-150(TMA) | 175(DMA) [162.5-our result via DSC] | 155* | 170 |
| Dk | 4.6 (2 GHz) | 4.8-5.0(1MHz) | | 4.6-4.9(1MHz) | 4.3 |
| Df (1MHz) | .021(2 GHz) | .006-.007(1MHz) | | 0.02(1MHz) | 0.023 |
| CTE (z axis <Tg) | 60 | 40-50 | | 60* | 70 |
| *Reported only for .78mm or greater | | | | | |



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# Why X1048?

- Upgrade in thermal performance from N4000-2 EF™ and competitors at standard FR-4 costs
- High-$T_g$ FR-4 performance brought to halogen-free arena
- Standard high $T_g$ FR-4 users can now offer ‘green’ products without compromise in price or performance



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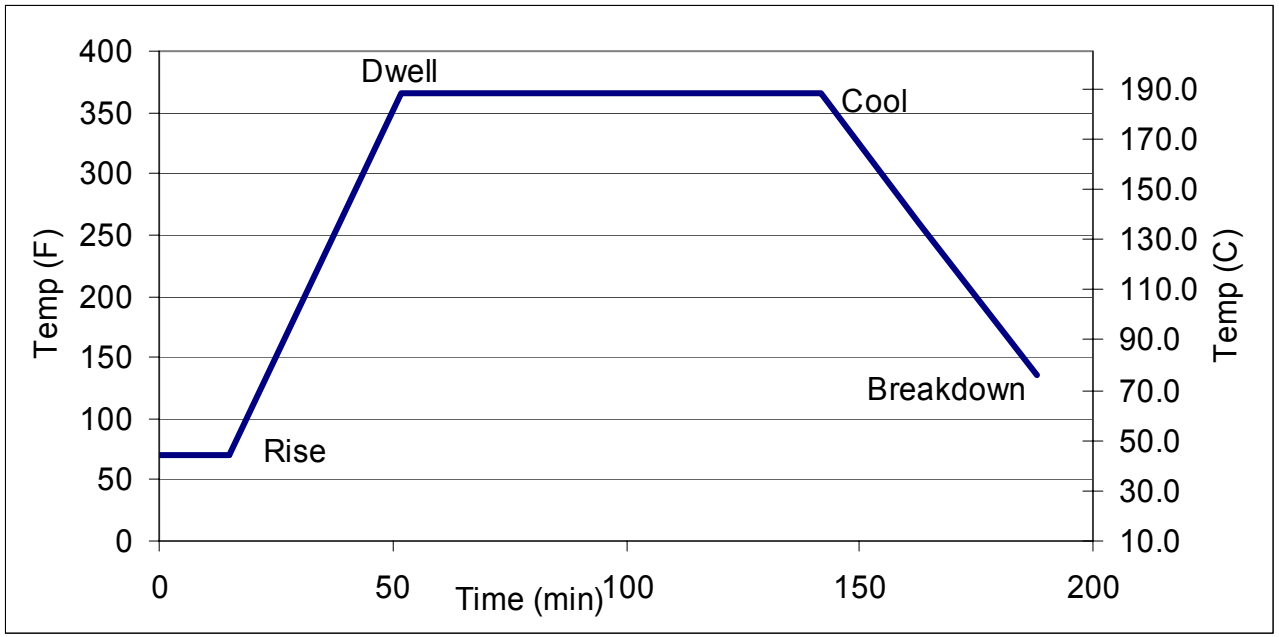
# Press Cycle




- Vacuum : 28.5" Hg 15 min
- Heat Up Rate : 6 - 10° C / minute
- Pressure : 100 –200 psi
- Cure Time 90 minutes at 185°C
- Cool Down Rate : 5°C / minute or less



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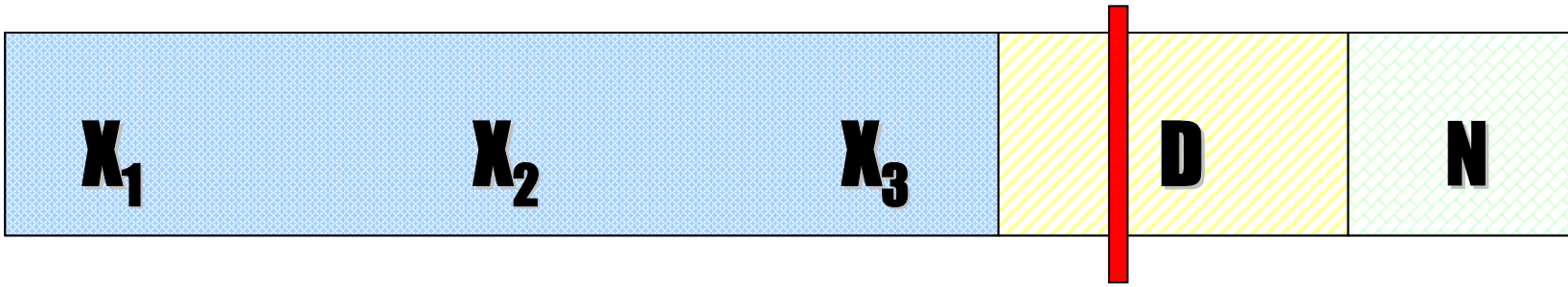
# D5300 (SI™) Status
# High Speed / Low Loss




- Excellent choice for halogen-free, high-speed applications
- Treater runs completed in France, California, Arizona
- Alpha site evaluations complete
- Material evaluation in progress for major OEM
- Excellent performance in ITRI Bromine-Free Task Group
- Potential target product introduction during 1Q CY'03



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# D5300 Product Summary

- Halogen-free
  - Passes JCPA-ES-01 test method for halogen-free materials
- Lead-free compatible
- Superior thermal performance
- Compatible with standard FR-4 processing
- High $T_g$
- Low $D_k$ / $D_f$



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# Applications For X5300

- Telecommunications (wireless base stations) - SI™ Version
- Military
- Aerospace
- Automotive
- Commercial
  - Burn-in boards
  - Chip packaging
  - “Down Hole” drilling



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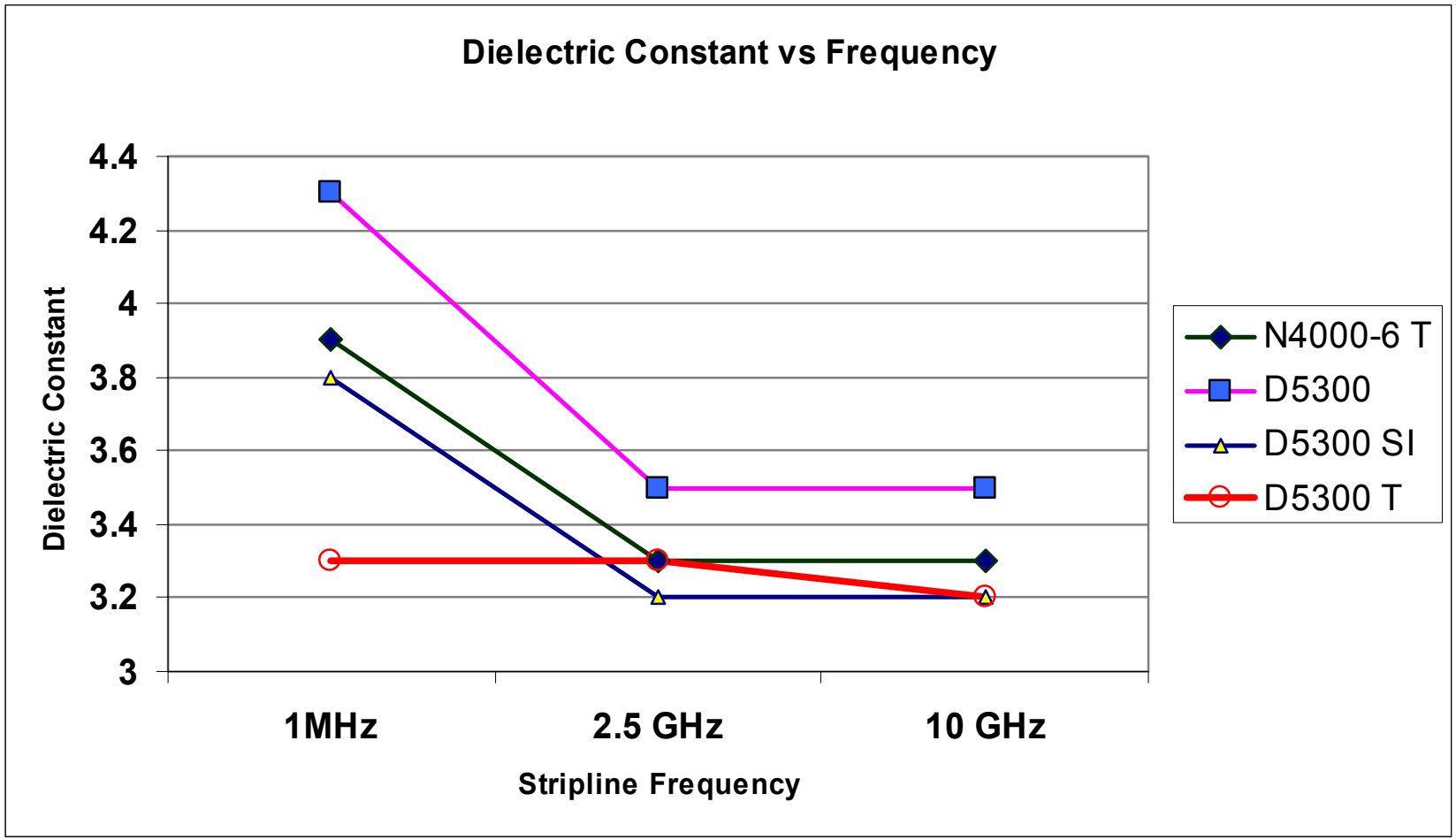
# D5300 Dielectric Constant



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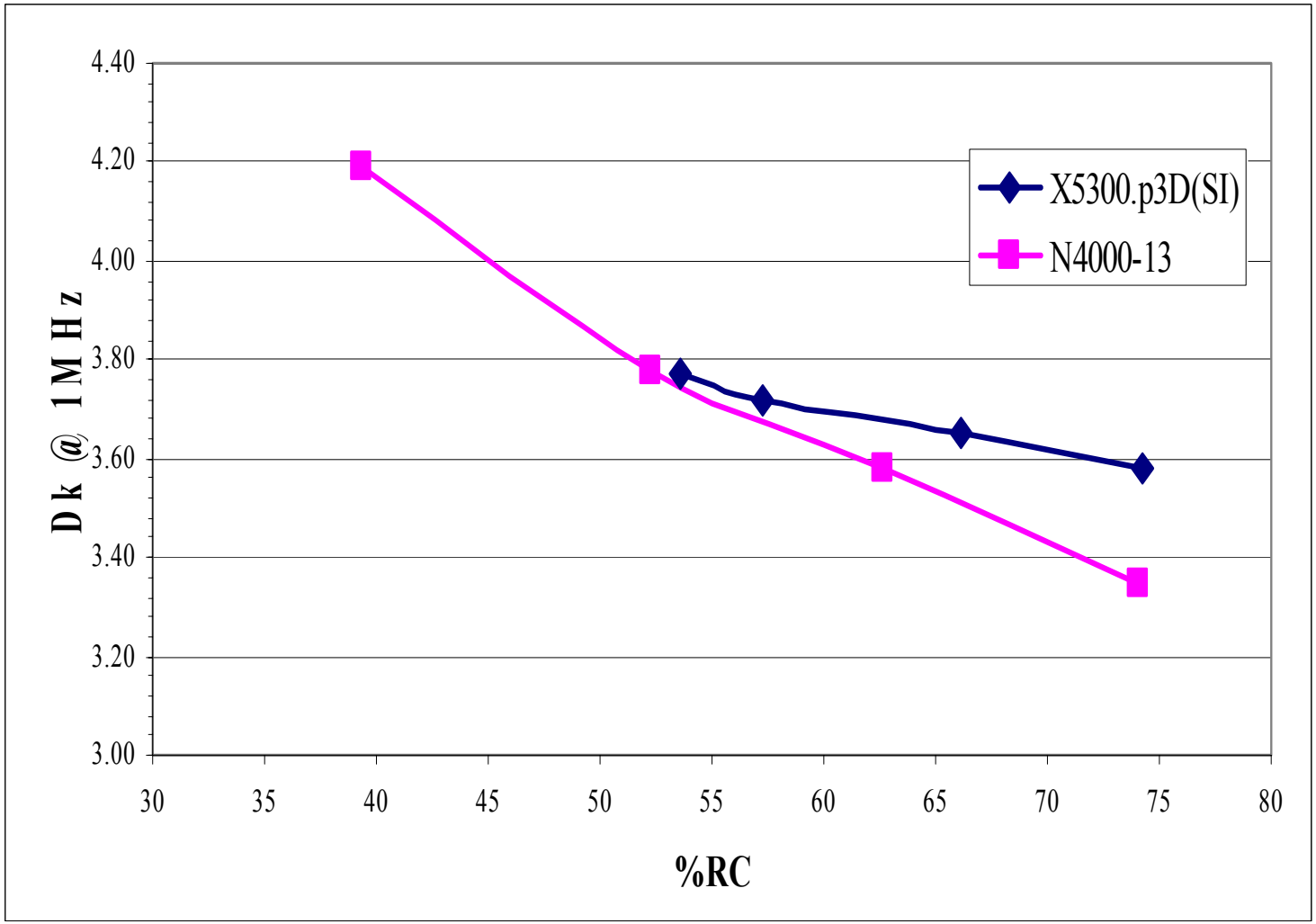
# X5300-SI Electricals



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# Typical Engineering Values

| Mechanical | X5300 | X5300 SI |
|---|---|---|
| X/Y CTE (ppm/°C) [-40°C to 125°C] | 10-14 | 9-13 |
| Z-CTE (%) [50°C to 260°C] | 3.2 | 3.2 |
| **Electrical** | | |
| Dielectric Constant ($D_k$) | | |
| $D_k$ at 1 MHz | 4.3 | 4.4 |
| $D_k$ at 10 GHz | 3.5 | 3.3 |
| Dissipation Factor ($D_f$) | | |
| $D_f$ at 1 MHz | 0 .013 | 0 .014 |
| $D_f$ at 10 GHz | 0.013 | 0 .015 |
| **Thermal** | | |
| $T_g$ by DSC (°C | 180 | 180 |
| TGA (°C 5% wt. loss) | 397 | 397 |
| Time to Delamination- $T_{260°C}$ (minutes) | 240+ | 240+ |



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# D5300 and D5300 SI™ Property Comparison

| Test Properties | N4000-6 Hi Tg Epoxy | D5300 E-Glass | D5300 SI |
|---|---|---|---|
| **Thermal** | | | |
| Tg by DSC (°C) | 180 | 185 | 185 |
| Tg by TMA (°C) | 170 | 175 | 175 |
| TGA (°C) | 297 | 397 | 397 |
| **Electrical** | | | |
| $D_k$ at 1 MHz | 4.5 | 4.2 | 3.9 |
| $D_f$ at 1 MHz | 0.025 | 0.013 | 0.013 |
| **Mechanical** | | | |
| Peel Strength (Kg/cm) | 1.7 | 1.7 | 1.7 |
| XY-CTE ppm (-40 - 125°C | 12-15 | 10-14 | 9-13 |
| Z axis expansion % (50-260°C) | 4.5 | 3.2 | 3.2 |
| **General** | | | |
| UL-94 | V0 | V0* | V0* |
| IPC 4101 | Pass | Pass | Pass |



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# D5300 (SI) Alpha Test

- Fabricator report:
  - Desmear weight-loss good
  - UV blocking good
  - Some resin recession
  - Alternative oxide preferred
- 3 X5300-SI™ boards shipped
- OEM's $D_k$ target = 3.5 @ 200 MHz



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# Marketing

- Japan's "Environmentally Preferred Products" in production for Japanese market:
  - Reduced Pb
  - No Bromine flame retardant
  - Increased recyclable content
  - Reduced energy use
- Japan is pushing EPPs in Europe as well

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# In addition to environmental concerns, green marketing has a strong image component

## European ‘eco-labels’




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