



ILLUMINA

CINDAS: Thermophysical Properties of Matter Database Guide

2006



Guide to Discovery

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CINDAS: Thermophysical Properties of Matter Database (MPMD)

10 Reasons to Use CINDAS: Thermophysical Properties of Matter Database

1. Access to properties of over 5,000 materials and over 50,000 data curves
2. Identify and assess the appropriateness of materials for engineering and other applications
3. Graph multiple materials and data sets/conditions for comparison
4. Data Visualization (data curves) expedites analysis and materials selection
5. Data is reviewed and processed by Materials experts
6. Updates occur regularly, and coverage dates back to the 1900s
7. Advanced searching capability of 5 indexed fields
8. Ability to cross-search with other CSA Illumina databases including *CINDAS: Microelectronic Packaging Materials Database (MPMD)*
9. Value-added tool streamlines the critical research development process and saves computation time
10. CINDAS is reliable, flexible and critically evaluated

What Is CINDAS: Thermophysical Properties of Matter Database and Why Should I Use It?

The *CINDAS: Thermophysical Properties of Matter Database (TPMD)* contains thermophysical properties of over 5,000 materials with approximately 50,000 data curves that illustrate how various properties of materials behave under different test conditions. The database is searchable by material group, material name, property group, property name and independent variable. For all data curves, the material composition, experimental conditions, raw or smoothed data, and references are given. These references may be to published literature, theses, or technical and laboratory reports. Dynamic graphing capabilities allow users to compare the same property of multiple materials or the same material under different conditions, as well as change the ranges on the graph axes.

The database is produced by CINDAS LLC. For more than 45 years, the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) at Purdue University has managed a comprehensive and systematic research program on the properties and behavior of materials. This research program involves basic and applied research, using both experimental techniques and data from relevant worldwide scientific and technical literature. The end result is the compilation, critical evaluation, correlation, and synthesis of both existing and new experimental data to produce reliable reference data (recommended values), as well as the generation of estimated values to fill data gaps.

CINDAS also produces a "companion" database to TPMD called the *Microelectronics Packaging Materials Database* (MPMD).

On CSA Illumina, TPMD can be searched as a stand alone file or, alternatively, it can be accessed via a search of CSA databases that contain related materials science records, such as the *CINDAS: Microelectronics Packaging Materials Database* (MPMD) and the *CSA Technology Research Database* (TRD).

CINDAS Data Curves

A CINDAS data curve is essentially a graph. It is a visual representation (a plotting) of a table of data illustrating the response of a property with incremental changes – usually with a dependent and independent variable. The line connecting the plotted data points can be curvilinear or rectilinear but most often is curved

The independent variable (e.g. Temperature (deg. K)) is usually plotted on the horizontal "X" axis. The dependent variable (e.g. expansion or contraction of the material being tested) is plotted on the vertical or "Y" axis. A data point is that point in the matrix where a specific temperature gives a specific expansion or contraction.

Dependent and independent variables would be used, for example, in plotting the height of individuals on a crowded bus. The horizontal (X) axis plots the independent variable. In this case, it is height in increments of feet/meters. It is independent because we chose it. The vertical axis (Y) would be the number of individuals that represent that height which meets the parameters given in the horizontal axis.

One curve could represent individuals, or two curves could represent women and men with a third representing children, etc. Multiple data curves are displayed in different colors.

Major Material Groups Covered

- | | |
|--|---|
| <ul style="list-style-type: none">• Aggregate Mixes• Alloy Steels• Aluminum Alloys• Animal and Vegetable Natural Substances• Binary Mixtures of Oxides• Borides• Bromides• Carbides• Carbon Steels and Cast Iron | <ul style="list-style-type: none">• Carbonates• Ceramics and Glasses• Cermets• Chlorides• Chromium Alloys• Coatings, Anodized Conversion• Coatings, Metallic Contact• Coatings, Metallic Pigmented• Coatings, Nonmetallic Inorganic Carbide Contact |
|--|---|

- Coatings, Nonmetallic Inorganic Other Contact
- Coatings, Nonmetallic Inorganic Oxide Contact
- Coatings, Nonmetallic Inorganic Silicate or Titanate Contact
- Coatings, Nonmetallic Pigmented, Other Binders
- Coatings, Nonmetallic Pigmented, Others
- Coatings, Nonmetallic Pigmented, Potassium Silicate Binder
- Coatings, Nonmetallic Pigmented, Silicone Binder
- Coatings, Other Contact
- Coatings, Other Pigmented
- Coatings, Oxidized and Others Conversion
- Coatings, Pigmented, Trade Name
- Coatings, Resin Contact
- Cobalt Alloys
- Composites
- Copper Alloys
- Elements
- Elements: Carbon, Graphite
- Fabrics, Yarns, And Hairs
- Fluorides and Their Mixtures
- Foods & Biological Materials
- Gas Mixture, Monatomic Systems
- Gas Mixture, Monatomic and Polyatomic Systems
- Gas Mixture, Polyatomic Systems
- Hydrides
- Intermetallic Compounds, Mixtures
- Intermetallics, Aluminides
- Intermetallics, Beryllides
- Intermetallics, Miscellaneous

- Intermetallics, Silicides
- Iodides
- Magnesium, Manganese, Molybdenum and Niobium Alloys
- Minerals, Rocks and Processed Mineral Substances
- Miscellaneous Alloys And Mixtures
- Miscellaneous Refractory Materials
- Mixtures of Oxide and Nonoxide
- Multiple Mixtures of Oxides
- Nickel Alloys
- Nitrates, Nitrides and Nitrites
- Nonoxide Inorganic Mixtures
- Organic Compounds
- Other Nonferrous Binary Alloys
- Other Nonferrous Multiple Alloys
- Other Nonoxide Inorganic Compounds
- Oxide Compounds: Calcium, Magnesium, Sodium Oxides
- Oxide Compounds: Others
- Phosphates
- Polymers
- Residues, Slags and Scales
- Salts
- Selenides and Tellurides
- Semiconductors
- Silicides
- Single Oxides: Aluminum, Beryllium and Silicon Oxide
- Single Oxides: Others
- Stainless Steel
- Sulfates
- Sulfides and their Mixtures
- Systems & Structures
- Titanium Alloys
- Zirconium Alloys

Properties Covered

Thermophysical Properties:

- | | |
|---|---|
| <ul style="list-style-type: none">• Coefficient of Thermal Expansion• Density• Glass Transition Temperature• Lattice Parameter• Moisture Linear Expansion | <ul style="list-style-type: none">• Specific Heat Capacity• Specific Heat (at constant pressure)• Thermal Conductivity• Thermal Linear Expansion• Viscosity |
|---|---|

Thermoradiative Properties:

- | | |
|--|--|
| <ul style="list-style-type: none">• Absorptance To Emittance Ratio• Angular Integrated Reflectance• Angular Solar Absorptance• Angular Solar Transmittance• Angular Spectral Absorptance• Angular Spectral Emittance• Angular Spectral Reflectance• Angular Spectral Transmittance• Angular Total Emittance• Carrier Concentration• Change in Normal Solar Absorptance• Change in Normal Spectral Absorptance• Change in Normal Spectral Reflectance• Hemispherical Integrated Absorptance• Hemispherical Integrated Reflectance | <ul style="list-style-type: none">• Hemispherical Solar Absorptance• Hemispherical Spectral Emittance• Hemispherical Spectral Reflectance• Hemispherical Spectral Transmittance• Hemispherical Total Emittance• Normal Integrated Absorptance• Normal Integrated Reflectance• Normal Integrated Transmittance• Normal Solar Absorptance• Normal Solar Reflectance• Normal Solar Transmittance• Normal Spectral Absorptance• Normal Spectral Emittance• Normal Spectral Reflectance• Normal Spectral Transmittance• Normal Total Emittance• Reflectance |
|--|--|

Optical Properties:

- Absorption Coefficient
- Absorptive Index
- Refractive Index

Other Properties:

- | | |
|--|--|
| <ul style="list-style-type: none">• Ablation Temperature• Apparent Heat of Ablation | <ul style="list-style-type: none">• Coupling Coefficient Impulse• Grain Size• Heat of Fusion |
|--|--|

- | | |
|---|---|
| <ul style="list-style-type: none"> • Mass Loss • Mass Loss, Derivative • Melting Threshold • Pore Size • Surface Energy for Cleavage • Weight Change (per Area) | <ul style="list-style-type: none"> • Coefficient of Thermal Expansion • Coefficient of Thermal Expansion (Z) • Contact Angle |
|---|---|

Searchable Field Codes Available in CINDAS: Thermophysical Properties of Matter Database

Field Name	Label	Search Examples
Independent Variable	IA=	Nitrogen gas pressure
Material Group	MG=	Alloy steels
Material	ML=	Titanium
Property	PP=	Angular Total Emittance
Property Group	PG=	Thermophysical properties

Boolean Operators and Other Search Tools supported by CSA Illumina

Boolean operators help define the relationships between words or groups of words.

- AND Use to narrow a search and retrieve records containing all of the words it separates

- OR Use to broaden a search and retrieve records containing any of the words it separates

- NOT Use to narrow a search and retrieve records that do not contain the term following it.

- () Use to group words or phrases when combining Boolean phrases and to show the order in which relationships should be considered.

Proximity operators identify the number of words to come between the search terms.

- WITHIN Use to narrow a search by specifying a proximity relationship of "X" fewer than "X" words between search terms.

- NEAR Use to narrow a search by specifying a proximity relationship of fewer than 10 words between search terms.

Special symbols can expand the scope of your search.

- * Truncate using the wild card symbol. This expands a search term to include forms of a root word (e.g. epox* retrieves epoxy, epoxies, etc.)
- * Find an unlimited number of characters within a word (e.g. col*r retrieves color, colour, etc.)
- ? Find alternative spellings. The ? represents any single character; ?? represents two characters and so on. Use within or at the end of a word (e.g. gr?y finds grey as well as gray).

Note: Search queries containing several operators search in the following order: (), NEAR, NOT, AND, OR

Ready, Set, Search! Using the CSA Illumina Platform to Search CINDAS: Thermophysical Properties of Matter Database

Now that you have an understanding of what the *CINDAS: Thermophysical Properties of Matter Database* is about and how the searchable field codes and search tools function, you are ready to search the database using the CSA Illumina platform.

Clicking on 'Help & Support' at any time will direct you to a context-specific Help page.

QUICK, ADVANCED, OR COMMAND SEARCHING

On CSA Illumina, search strategies can be applied using one of three approaches.

- **Quick Search** restricts your search to anywhere (AY=). An anywhere search searches across all of the available fields in a record. Multiple words entered into the search field, will be treated as a phrase.
 - **Advanced Search** gives you the advantage of being able to select any of the 5 field codes from a pull-down menu. The separate search boxes are formatted to include the Boolean Operators to help guide you in formatting your search.
 - **Command Search** or **Professional Search** may be preferred by advanced users who are comfortable with entering search strategies without aid of a template.
-

SORTING FEATURES

The sorting features give you the opportunity to order your results based on the most relevant field code.

- *Independent Variable*
 - *Material*
 - *Material Group*
 - *Property*
 - *Property Group*
-

RECORD VIEW

Select how many records to display from the 'Results per Page' pull-down menu: 10, 25 or 50.

PRINT, SAVE AND E-MAIL

Add records to your Marked Records list by clicking 'Mark' all on page, or check the boxes next to individual records and click 'Update Marked List.' Printing, saving, and e-mailing records can be done by using the 'Save, Print, E-mail' function.

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Logout Quick Search Advanced Search Search Tools Browse 0 Marked Records | Search History | Alerts

Save, Print, Email Return to Results Help & Support

Use 16 records from the current results list of All Publication Types
From record 1 to 16 of 16 Published Works (maximum 500 at a time)

Short format

Comments: Hello Bob, Please take a look at these CINDAS records. They will be beneficial to our research. Thanks, Sally

New! Create a bibliography with QuikBib (Only records for Published Works will be processed.)
Choose a document format:
 HTML Text RTF MS Word

Choose a bibliographic style:
APA - American Psychological Association, 5th Edition

To: bob@domain.com From: sally@domain.edu
optional

File format: PC Macintosh Unix

(Only records for Published Works will be processed.)

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Note: The 'QuikBib' and 'Export to RefWorks' features only function with records for Published Works, and are not available for records in the CINDAS databases.

The CINDAS: Thermophysical Properties of Matter Database Research Process

There are 2 primary ways to search the *CINDAS: Thermophysical Properties of Matter Database*. A database user can perform a search for key terms or phrases on the CSA Illumina platform, or browse the database directly on the CINDAS platform.

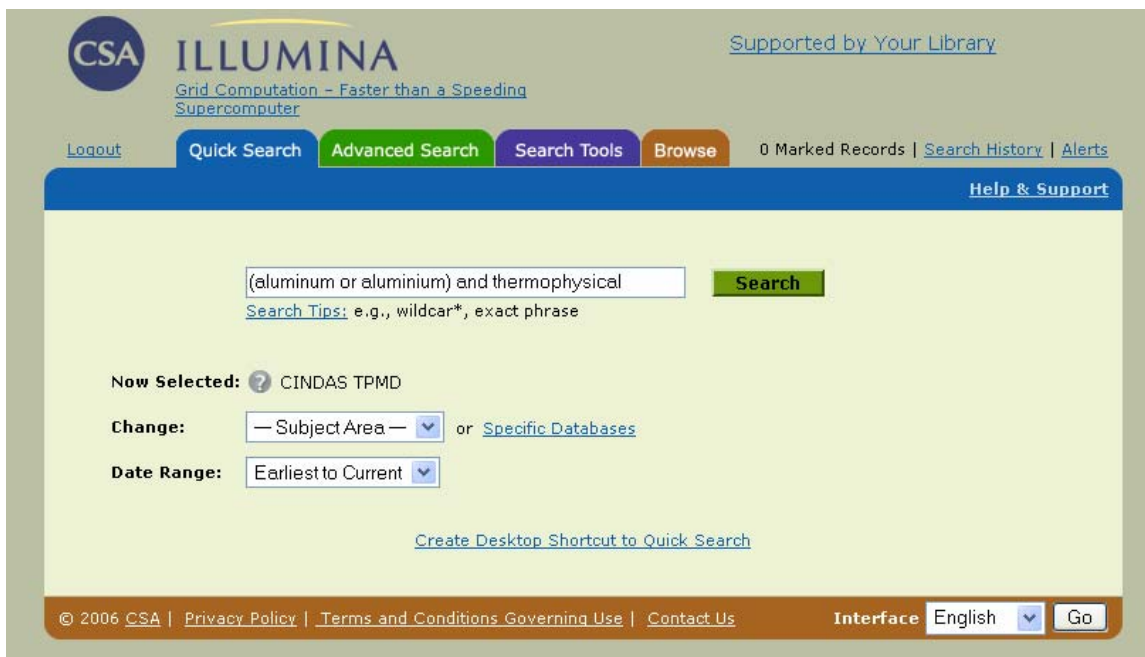
Search CINDAS: Thermophysical Properties of Matter Database on the CSA Illumina platform

I) Begin the Research Process

- A. Determine your goals:
1. State your research question:
“How can the service life of gas turbine engine components be extended without compromising performance?”
 2. Set parameters for your search
“What specific materials are relevant?”
“What specific properties or test conditions are relevant?”
- B. Identify general concepts:
1. What is the area of research?
“Improve existing but aging gas turbine engines; Turbine compressor disks replacements; Matrix composites, Aluminum stator vane”
 2. What is the premise for this research?
“By replacing the turbine compressor disks and stators with an aluminum matrix composite that operates at high temperatures and resists fatigue, engines can be upgraded to maintain capability at a lesser cost than purchasing new engines. Will the components fabricated from aluminum matrix composites durable resist foreign object damage and accelerated erosion under these conditions?”
 3. Which general terms relate to your search?
“aluminum alloys; thermophysical properties; thermal linear expansion”
- C. Choose the appropriate database
1. Is the *CINDAS: Thermophysical Properties of Matter Database* a relevant source of information for this research question?
Yes, the data on thermophysical properties of materials in the *CINDAS: Thermophysical Properties of Matter Database* can be used to compare different aluminum matrices and determine what the best material is for fabricating components designed to withstand damage and erosion.

II) Build your Search Strategy

- A. Quick Search:
1. Enter phrase or multiple search terms separated by Boolean operators AND to link terms, OR to link similar words or synonyms, in the Quick Search box:
“(aluminum or aluminium) and thermophysical”
 2. Note: Consult the **Major Material Groups Covered** and **Properties Covered** sections of this *CINDAS: Thermophysical Properties of Matter Database* Guide or the Database Factsheet for relevant search terms.



B. Advanced Search:

1. The Field Code drop-down boxes in the Advanced Search screen allow you to limit the search by any of the searchable field codes: Independent Variable (IA=), Material Group (MG=), Material (ML=), Property (PP=), and Property Group (PG=).
2. Enter phrase or multiple search terms separated by the Boolean operators AND to link terms, OR to link similar words or synonyms, provided in the Advanced Search screen:
MG= (Aluminum Alloys) and PP= (Coefficient of Thermal Linear Expansion or Thermal Linear Expansion)
3. Note: Consult the **Major Material Groups Covered** and **Properties Covered** sections of this *CINDAS: Thermophysical Properties of Matter Database* Guide or the Database Factsheet for relevant search terms.

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[Add Row](#) | [Remove Row](#)

	(Aluminum Alloys	or		or)	Material Group, MG=	▼
and	▼	(or		or)	Property, PP=	▼
and	▼	(or		or)	Anywhere	▼

[Search Tips](#): e.g., wildcard*, exact phrase; use Keywords for a single search of Title, Abstract, Descriptors

Search **Clear**

Now Selected: [CINDAS TPMD](#)

Change: — Subject Area — or [Specific Databases](#)

Limited to:

Independent Variable	Unlimited ▲ Aging Time Air Pressure ▼
Material Group	Unlimited ▲ Aggregate Mixes Alloy Steels ▼
Property	Unlimited ▲ Ablation Temperature Absorptance To Emittance Ratio ▼
Property Group	Unlimited ▲ Optical Properties Other Properties ▼
Material	Unlimited ▲ 1,1,1-Trichloro-2,2,2-Trifluoroethane, CF(3)CCl(3) 1,1,1-Trichloroethane, CH(3)CCl(3) ▼

III) Analyze Results

A. Relevant results:

1. Review the retrieved results and determine whether they are satisfactory:

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Results Edit Search Help & Support

102 results found for: MG=(aluminum alloys) and PP=((coefficient of thermal linear expansion ... in ? CINDAS TPMD

Data Curves 102

Data Curves from CINDAS, LLC

Mark or Clear all on page | Update Marked List | Save, Print, Email | RefWorks Sort by: Material Go

◀ Previous 1 2 3 4 5 Next ▶ Record # Go

<input type="checkbox"/>	<p>1. Material: Aluminum + Beryllium + .. Alloys, Al + Be + .. Material Group: <i>Aluminum Alloys</i> Property Group: Thermophysical Properties Property: <i>Coeff. of Thermal Linear Expansion</i> Independent Variable: Temperature View Data Curves</p>	Database: CINDAS TPMD
<input type="checkbox"/>	<p>2. Material: Aluminum + Beryllium + .. Alloys, Al + Be + .. Material Group: <i>Aluminum Alloys</i> Property Group: Thermophysical Properties Property: <i>Thermal Linear Expansion</i> Independent Variable: Temperature View Data Curves</p>	Database: CINDAS TPMD
<input type="checkbox"/>	<p>3. Material: Aluminum + Beryllium Alloys, Al + Be Material Group: <i>Aluminum Alloys</i> Property Group: Thermophysical Properties Property: <i>Coeff. of Thermal Linear Expansion</i> Independent Variable: Temperature View Data Curves</p>	Database: CINDAS TPMD
<input type="checkbox"/>	<p>4. Material: Aluminum + Beryllium Alloys, Al + Be Material Group: <i>Aluminum Alloys</i> Property Group: Thermophysical Properties Property: <i>Thermal Linear Expansion</i> Independent Variable: Temperature View Data Curves</p>	Database: CINDAS TPMD

2. If they are satisfactory, click on the “View Data Curves” link to view the appropriate data curve on the CINDAS platform:

In this case, the results are relevant. One data curve in particular helps you identify an aluminum alloy that can be used to fabricate robust, discontinuously reinforced aluminum stator vanes withstand high temperature under the specified conditions. This material can be used to extend the service life of turbine engine components without compromising performance.

CINDAS Databases | Thermophysical Properties of Matter Database [Start Over](#)

TPMD (data version 4.0) [View Theories and Measurements](#)

Material Group: Aluminum Alloys
Property: Coeff. of Thermal Linear Expansion
Independent Variable: Temperature [Edit Selection](#) [Show Text](#)

Step 1. Select Materials
Select one or more materials from the list below. Hold the control key to select multiple materials. Available data curves will be displayed on the right. Then proceed to Step 2.

Material 1: Aluminum + Silicon + .. Alloys, Al + Si + ..

(Listing 1 materials)

Step 2. Select Data Curves/Test Conditions
Select between one and twenty data curve descriptions from the list below to view graphs. Hold the Control key to select multiple data curves.
Key: Selected Material: (Set, Curve) - Remarks

1. Material 1 (1, 1) - Al + 1.0 Si + 0.8 Others, Provisional Values from CINDAS
2. Material 1 (1, 2) - Al + 12.5 Si + 1.2 Mg + Others, Provisional Values from CINDAS
3. Material 1 (1, 3) - Al + 45 Si + Others, Provisional Values from CINDAS

Coeff. of Thermal Linear Expansion of Aluminum + Silicon + .. Alloys... vs. Temperature

Temperature (K)	Material 1 (1, 1) (10 ⁻⁶ /K)	Material 1 (1, 2) (10 ⁻⁶ /K)	Material 1 (1, 3) (10 ⁻⁶ /K)
100	12.5	11.5	10.5
200	16.5	14.5	13.5
300	20.5	18.5	16.5
400	24.5	21.5	19.5
500	28.5	23.5	21.5
600	31.5	24.5	23.5
700	34.5	24.5	25.5
800	37.5	24.5	27.5

Graph Parameters

	Min	Max
X-Axis	75.0	775.0
Y-Axis	11.3	32.5

[Change Range](#)
Show Gridlines

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B. If results are not relevant:

1. Check spelling of search terms, and drop unnecessary or misleading terms.
2. Increase precision: An excellent source for search terms is the **Major Material Groups Covered** and **Properties Covered** sections of this *CINDAS: Thermophysical Properties of Matter Database* Guide or the Database Factsheet. (To access the Database Factsheet, click on the “?” icon next to the database name, CINDAS TPMD, at the top of your results list.) Utilizing these materials groups and properties as search terms will increase the effectiveness of the search, and increase the number of relevant results retrieved.
3. Finally, you may need to rethink whether the database you selected is appropriate for your search.

C. Too few/too many results:

1. Increase retrieval by using fewer ANDs and more ORs
2. Increase precision by using additional ANDs and fewer ORs (NOT can be used to exclude some terms)

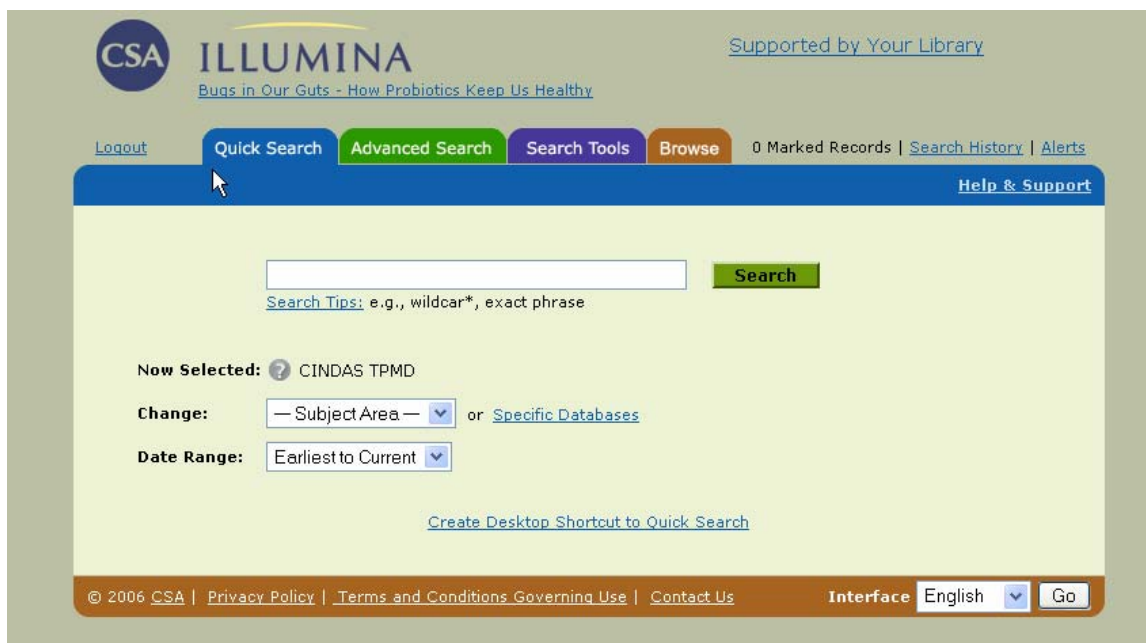
IV) Search Multiple Databases Simultaneously

You can also cross-search multiple CSA Illumina databases simultaneously to expand your search process and identify other sources of information. On CSA Illumina, the *CINDAS: Thermophysical Properties of Matter Database* (TPMD) can be searched as a stand alone file or, alternatively, it can be accessed via a search of CSA databases that contain related materials science records, such as the *CINDAS: Microelectronics*

Packaging Materials Database (MPMD) and the CSA Technology Research Database (TRD).

Browse CINDAS: Thermophysical Properties of Matter Database on the CINDAS platform

You can also browse the *CINDAS: Thermophysical Properties of Matter Database* directly on the CINDAS platform. From the Quick Search or Advanced Search screen on the CSA Illumina platform, click on the “Specific Databases” link.



Then click on the “Browse CINDAS TPMD” link to begin.

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Select Databases Help & Support

Change Subject Area: — All Subject Areas — Go

Select the Database(s) you would like to search. [Mark](#) or [Clear](#) all on page

[Continue to Search](#)

- ? CINDAS MPMD [Browse CINDAS MPMD](#)
Microelectronics Packaging Materials Database
- ? CINDAS MPMD Demo [Browse CINDAS MPMD Demo](#)
Demo version of Microelectronics Packaging Materials Database
- ? CINDAS TPMD [Browse CINDAS TPMD](#)
Thermophysical Properties of Matter Database
- ? CINDAS TPMD Demo [Browse CINDAS TPMD Demo](#)
Demo version of Thermophysical Properties of Matter Database

[Continue to Search](#)

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For more information on how to use the specific Browse and Search features on the CINDAS platform, refer to the **Search Examples: Step by Step Guide** for the *CINDAS: Microelectronics Packaging Materials Database* available in the Quick Links section of the Database Factsheet. To access the Database Factsheet, click on the “?” icon next to the database name, CINDAS TPMD, on the CSA Illumina platform.

CSA Guide to Discovery

CINDAS: Thermophysical Properties of Matter Database Materials
Search Examples: Step-by-Step
Version: 09-September-2006

- I. [Search by Material Group](#)
- II. [Features of the database dynamic graphing](#)
- III. [Search by Property Group](#)
- IV. [Search material by string \(partial name\)](#)
- V. [Search property by string \(partial name\)](#)

I. Search by Material Group

a) On the main CINDAS TPMD search screen **select Stainless Steel** from the **Material Group** dropdown menu. There are a total of 78 entries for Material Group for you to choose from.

CSA Guide to Discovery
Materials Properties Data Provided by CINDAS, LLC

CINDAS Databases | Thermophysical Properties of Matter Database

TPMD (data version 4.0)

Browse By:

Material Group (Help)

- Stainless Steel
- Other Nonferrous Binary Alloys
- Other Nonferrous Multiple Alloys
- Other Nonoxide Inorganic Compounds
- Oxide Compounds: Calcium, Magnesium, Sodium Oxides
- Oxide Compounds: Others
- Phosphates
- Polymers
- Perovskites, Slags and Scales
- Salts
- Selenides and Tellurides
- Semiconductors
- Silicides
- Single Oxides: Aluminum, Beryllium and Silicon Oxide
- Single Oxides: Others
- Stainless Steel
- Sulfates

Search By:

Material

or

Property

Contact CSA:

For Technical Support: support@csa.com

For Training Requests: training@csa.com

For Training Materials: <http://www.csa.com/support/trainingmaterial.php>

For Sales Inquiries: sales@csa.com

For a complete list of CSA Illumina databases and other CSA products: http://www.csa.com/e_products/databases-collections.php