

Material Design Kit (MDK)

Version 1.0

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Andras Vass-Varnai, Siemens

Andrew Miller, Ansys

BoonChong Ang, Intel

David Ratchkov, Thrace Systems

James Wong, PAe

Justin Bushue, Siemens

Marc Rose, Si2

Michael Durkan, Siemens

Roger Lo, ASE

Rudy Mason, Cadence

Seungmin Woo, Georgia Tech

Tony Mastroianni, Siemens

About Open Compute Foundation

The Open Compute Project (OCP) is a collaborative Community of hyperscale data center operators, telecom, colocation providers and enterprise IT users, working with the product and solution vendor ecosystem to develop open innovations deployable from the cloud to the edge. The OCP Foundation is responsible for fostering and serving the OCP Community to meet the market and shape the future, taking hyperscale-led innovations to everyone. Meeting the market is accomplished by addressing challenging market obstacles with open specifications, designs, and emerging market programs that showcase OCP-recognized IT equipment and data center facility best practices. Shaping the future includes investing in strategic initiatives and programs that prepare the IT ecosystem for major technology changes, such as AI & ML, optics, advanced cooling techniques, composable memory and silicon. OCP Community-developed open innovations strive to benefit all, optimized through the lens of impact, efficiency, scale and sustainability. Learn more at www.opencompute.org

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Compliance with Open Compute Project Tenets

Openness

In this white paper, experts in their fields have contributed their knowledge of chiplet workflows and material data exchanged.

Efficiency

This white paper strives to improve the efficiency of architects, engineers and manufacturers involved in the integration of heterogenous chiplet systems by providing file format to enable the exchange of materials data.

Impact

This white paper is the first to describe a format for exchanging materials data to be used during the integration of heterogeneous chiplet systems.

Sustainability

The contributors hope that this white paper, the first of its kind, will benefit anyone interested in growing the Open Chiplet Economy.

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Executive Summary

The Chiplet Material Design Kit (MDK) aims to standardize and streamline the integration of chiplet-based designs, addressing the growing need for modularity and scalability in semiconductor technologies. It is a collaborative effort under the Open Compute Project (OCP) and includes contributions from leading organizations.

The MDK provides a comprehensive framework for defining, evaluating, and validating the material properties and design parameters required for chiplet-based systems. It focuses on critical elements such as substrates, interposers, redistribution layers (RDL), and 3D integration technologies. The kit emphasizes the importance of material properties, such as dielectric constants, thermal conductivity, and mechanical strength, to optimize performance, reliability, and cost-efficiency.

Key components include:

- Standardized Material Properties: Definitions for electrical, thermal, structural, and optical properties.
- Design and Simulation Frameworks: Guidelines for assembly, testing, and mechanical analysis of chiplets.
- Application Scenarios: Examples of material and package design for real-world implementation.

The MDK promotes innovation in chiplet design by fostering collaboration and openness, ensuring broad accessibility, and supporting rapid adoption across the semiconductor industry.

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Introduction

The Chiplet Material Design Kit (MDK) is a pivotal resource developed to support the integration and advancement of chiplet-based technologies. With the increasing demand for modular semiconductor designs that optimize performance, cost, and scalability, the MDK provides a standardized framework for evaluating, selecting, and implementing materials and design parameters critical to these systems.

Chiplets represent a paradigm shift in semiconductor manufacturing, enabling the creation of high-performance systems by assembling smaller, specialized components. The MDK addresses the unique challenges of chiplet integration, such as material compatibility, thermal management, and electrical connectivity, by providing detailed specifications and guidelines.

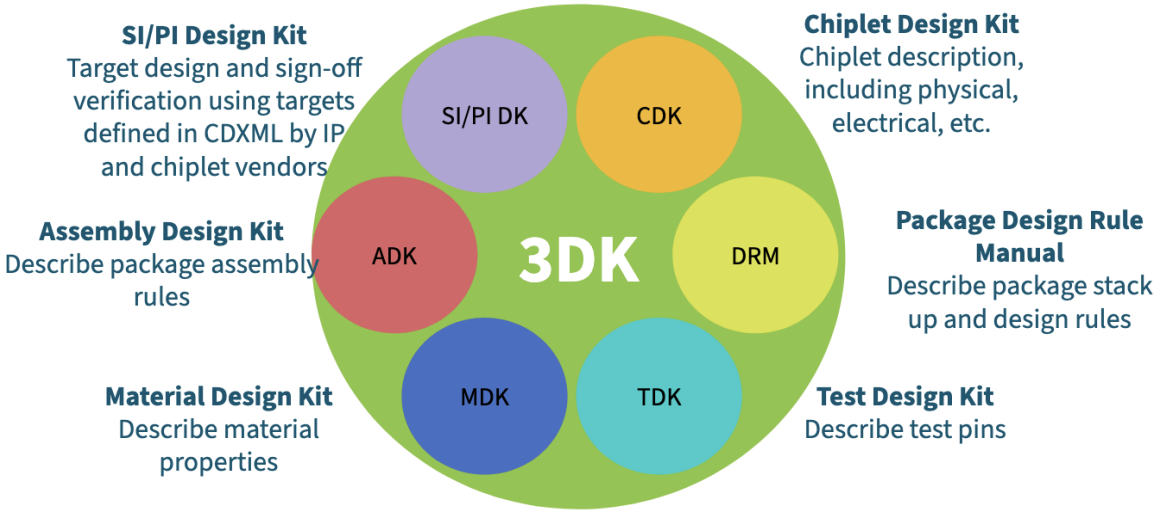
The core components of the MDK include:

- Die: The foundation of chiplets, determining size, complexity, and functionality.
- Package: Encapsulation that ensures mechanical support, thermal management, and electrical interfacing.
- Interposer: A substrate enabling high-density connections and efficient data exchange between chiplets.
- Redistribution Layer (RDL): Routing solutions for electrical connections between chiplets and package interconnects.
- 3D Integration: Techniques for stacking chiplets to enhance performance and reduce form factors.

By standardizing material properties and design practices, the MDK aims to simplify development processes, improve system reliability, and accelerate time-to-market for chiplet-based products. It is a collaborative effort under the Open Compute Project (OCP), bringing together contributions from industry leaders to advance open hardware innovation.

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3D-IC Design Kits (3DK)



Architecture	Chiplet selection	CDK for choosing chiplets ADK for chiplet compatibility DRM for package technology
	Package planing	DRM for choosing a technology MDK for material properties
	System planning	ADK for physical floorplan CDK for netlist creation
	Performance analysis	SI/PI Design Kit MDK for thermal
Design	DFT	TDK for test connectivity
	Package routing	DRM for design rules
Sign-off	SI/PI analysis	SI/PI Design Kit for sign-off targets MDK for material properties
	Thermal and mechanical analysis	MDK for material properties

Components

Die: A chiplet's electronic circuits are made on a single silicon substrate called the die. Using methods specific to the production of semiconductors, each chiplet is made as an individual die. The needs of the component they stand for dictate the size, complexity, and functionality of the chiplet dies. Performance, power consumption, and cost are all affected by important aspects such die size and technology node selection.

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Package: The package encases the chiplets, shielding them from physical harm while also managing their temperature and electrical connections. Multiple varieties of chiplet packaging exist, including flip-chip, ball grid array (BGA), and multi-chip module (MCM) formats. Some of the things that go into choosing a package are the form factor, thermal limitations, manufacturing costs, and concerns about signal integrity.

Interposer: To enable communication and data exchange across chiplets, an intermediary substrate layer called an interposer is used. This layer also allows high-density connections. Silicon or glass layers with embedded vias and traces make up an interposer. Critical to the operation of high-speed signaling protocols like UCIe, HBM (High Bandwidth Memory), and high-speed SerDes interfaces are interposers, which allow for fine-pitch, high-bandwidth connections between chiplets.

Substrate: The substrate is the base upon which the chiplets are mounted and connected within the package. It allows the chiplets to be mechanically supported, electrically connected, and thermally dissipated. Common examples of substrate materials are ceramics, organic laminate, and glass epoxy composite. A chiplet package's electrical performance, signal integrity, and thermal characteristics are all affected by the design of the substrate.

RDL: The Redistribution Layer is a patterned metal layer on the substrate or interposer that redistributes the electrical connections between the chiplets and the package pins. RDL provides the necessary routing and fan-out for connecting the fine-pitch bond pads of the chiplets to the package interconnects. RDL design considerations include signal routing density, impedance matching, power delivery, and thermal management.

3D Integration: The term "3D integration" describes the practice of vertically stacking several chiplets or dies to increase integration, performance, and functionality. Stacking using an interposer, die-to-die stacking, and through-silicon vias (TSVs) are all examples of 3D integration technology. System performance, power consumption, and form factor can all be enhanced with 3D integration, which allows for tighter coupling between chiplets, shorter interconnect lengths and higher bandwidth communication.

List of Properties

Physics	Subtype	Material Properties	Conditions*	Units (SI)	Units (Metric)	Comments
Electrical	High Frequency (HF)	Dielectric constant (Dk)	Frequency, Temperature	<unitless>	<unitless>	
		Dissipation factor (Df)	Frequency, Temperature	<unitless>	<unitless>	
		Bulk conductivity	Temperature	S/m	S/m	
		Bulk resistivity	Temperature	ohm.m	ohm.m	Resistivity = 1/Conductivity

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		Permeability	Frequency, Temperature	H/m N/A^2		
Thermal	Steady state	Thermal conductivity	Temperature, Orientation	W/m.K	W/m.K	Andrew to update K to Celsius
	Transient	Specific Heat	Temperature	J/kg.°C	J/kg.°C	
		Density	Temperature	kg/m^3	kg/m^3	
Structural	Linear elastic	Young's modulus	Temperature, Orientation	Pa	GPa	
		Poisson's ratio	Temperature, Orientation	<unitless>	<unitless>	
	Failure	Yield strength	Temperature, Orientation	Pa	MPa	
		Failure strength	Temperature, Orientation	Pa	MPa	
	Thermo-mechanical	Coefficient of Thermal Expansion	Temperature, Orientation	/°C	ppm/°C	
Optical		Refractive Index	Wavelength	<unitless>	<unitless>	
		Reflectance	Wavelength	<unitless>	<unitless>	
		Transmission	Wavelength	<unitless>	<unitless>	

Structure

CDXML

Materail Design Kit

Conditions

Material (list)

Properties (list): See table above

Units and conversions

Values

<cdxml>

<materials>

…conditions…

<material>

<name>Material 1</name>

…properties…

</material>

</material>

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</cdxml>

Units and linear conversions

This document defines units to be applied to the various values where applicable. The general definition of units follows the following convention:

- Default unit (required and immutable): The description requires a default unit. CDXML developers are required to follow the default unit exactly without any modifications.
- User-defined unit (optional) - a user-defined unit that includes conversion to the default unit. Conversion is defined by two values: factor and offset, as is user as follows:

  ```
  default_unit = factor * user_unit + offset
  ```

  For example, someone wishing to use Fahrenheit units will use a factor of 1.8 and an offset of - 57.6 because:

  ```
  degree C = degree F * 1.8 - 57.6
  ```

Each section below will specify how units are defined as applicable.

Conditions

Typically, material properties depend on the external environment or simulation conditions. The following are the conditions supported for material properties. These conditions and the default units are immutable and defined by the format and must appear in the file as-is. However, developers can add any number of optional units as needed.

Temperature

```
<condition type=”temperature”>
      <unit name=”C” description=”Celcius” defaultUnit/>
      <unit name=”F” description=”Fahrenheit” conversionFactor=”1.8”
conversionOffset=”-57.6”/>
      <unit name=”K” description=”Kelvin” conversionFactor=”1”
conversionOffset=”-273.15”/>
</condition>
```

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Frequency

```
<condition type="frequency">
      <unit name="Hz" description="Hertz" defaultUnit/>
      <unit name="KHz" description="Kilo Hertz" conversionFactor="1e3"/>
      <unit name="MHz" description="Mega Hertz" conversionFactor="1e6"/>
      <unit name="GHz" description="Giga Hertz" conversionFactor="1e9"/>
</condition>
```

Pressure

```
<condition type="pressure">
      <unit name="Pa" description="Pascal" defaultUnit/>
      <unit name="KPa" description="Kilo Pascal" conversionFactor="1e3"/>
      <unit name="MPa" description="Mega Pascal" conversionFactor="1e6"/>
      <unit name="GPa" description="Giga Pascal" conversionFactor="1e9"/>
</condition>
```

Values

Values for material properties can be derived by measurement, simulation, or estimation. As a result, there isn't one singular value for a given material property. This necessitates providing the user with additional information about the value, such as whether it is a typical, min, or max value or has a statistical distribution. For statistical distributions specifically, the provided data must be a pair of values—the distribution mean and 1-sgima.

Additionally, a value may specify external environmental conditions, such as temperature or pressure, at which it was obtained.

```
<property_value>
      <condition type="temperature" value="25" units="C"/>
      <condition type="frequency" value="2" units="MHz"/>
```

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```
      <value min="1" typical="2" max="3" mean="2.5" sigma="0.01"/>
</property_value>
```

Properties

Electrical Properties

Property	Definition	Units	Conditions
Dielectric Constant (Dk)	Ability of a material to store electrical energy in an electric field.	Unitless	Frequency, Temperature
Dissipation Factor (Df)	Rate of energy loss in dielectric materials.	Unitless	Frequency, Temperature
Resistivity	Resistance to electrical flow; resistance per unit length and area.	Ohm-meter (Ω·m)	Temperature
Conductivity	Ease of electrical flow; inverse of resistivity.	Siemens per meter (S/m)	Temperature
Relative Permeability	Ratio of a material's magnetic permeability to that of free space.	Unitless	Frequency, Temperature

Dielectric constant (Dk)

The dielectric constant, typically denoted as Dk, is the ratio of the capacitance of a capacitor filled with the given material to the capacitance of an identical capacitor in a vacuum without the dielectric material. This property is unitless.

<Dk>

...property values…

</Dk>

Dissipation factor (Df)

The dissipation factor, tyopically denoted as Df, is the loss-rate of of electrical potential energy in dielectric materials. This property is unitless.

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<Df>

. .property values…

</Df>

Resistivity

Resistivity measures how strongly a material opposes the flow of electric current. It is the electrical resistance of a unit length and unit cross-sectional area of the material. For further details, may refer to IEEE std 100-2000. The default unit for this property is ohm.m (“Ohm meters”).

<resistivity>

<unit name=”ohm.m” default/>

…property values…

</resistivity>

Conductivity

This is the inverse of resistivity. The default unit for this property is S/m (“Siemens per meter”).

<conductivity>

<unit name=”S/m” default/>

…property values…

</conductivity>

Relative Permeability

Permeability is the measure of magnetization produced in a material due to applying a magnetic field. Relative permeability is commonly used and is the ratio of the material’s permeability to that of free space, which has a permeability of 4pi*1e-7. This property is unitless.

<relativePermeability>

…property values…

</relativePermeability>

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Thermal Properties

Property	Definition	Units	Conditions
Thermal Conductivity	Ability of a material to conduct heat.	Watts per meter Kelvin (W/m·K)	Temperature, Orientation
Specific Heat	Heat required to raise the temperature of unit mass by one degree Celsius.	Joules per kilogram-degree Celsius (J/kg·°C)	Temperature
Density	Mass per unit volume of a material.	Kilograms per cubic meter (kg/m^3)	Temperature

Thermal conductivity

The property of a material to conduct heat. It quantifies the ability of the material to transfer heat through it by conduction, as defined by IEEE std 100-2000. The default unit for this property is W/mK (“Watts per meter Kelvin”).

<thermalConductivity>
    <unit name=”W/mK” default/>
    <unit “name=”W/mK” conversionFactor=”1”/>
    …property values…
</thermalConductivity>

Specific heat

Specific heat is the amount of heat per unit mass required to raise the temperature of a substance by one degree Celsius. The default unit for this property is J/kgm^3 (“Joules per kilogram cubic meters”).

<specificHeat>
    <unit name=”J/kgm^3” default/>
    …property values…
</specificHeat>

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Density

The mass per unit volume of a material. It is a measure of how much matter is packed into a given volume. The default unit for this property is kg/m^3 (“kilograms per cubic meter”).

<density>
    <unit name=”kg/m^3” default/>
    …property values…
</density>

Structure Properties

Property	Definition	Units	Conditions
Young’s Modulus	Stiffness of a material; stress-strain relationship.	GigaPascal (GPa)	Temperature, Orientation
Poisson’s Ratio	The ratio of transverse to axial strain.	Unitless	Temperature, Orientation

Young’s modulus

A measure of the stiffness of a solid material. It defines the relationship between stress (force per unit area) and strain (proportional deformation) in a material. The default unit for this property is GPa (“Giga Pascals”).

<YoungModulus>
    <unit name=”GPa” default/>
    <unit name=”Pa” conversionFactor=”1e9”/>
    …property values…
</YoungModulus>

Poisson’s ratio

The ratio of the transverse strain to the axial strain in a material subjected to axial stress. It describes how the material deforms in directions perpendicular to the direction of loading. This property is unitless.

<PoissonRatio>
    …property values…
</PoissonRatio>

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Failure Properties

Property	Definition	Units	Conditions
Yield Strength	Stress at which a material starts to deform plastically.	MegaPascal (MPa)	Temperature, Orientation
Failure Strength	Maximum stress a material can handle before breaking.	MegaPascal (MPa)	Temperature, Orientation

Yield Strength

<yieldStrenght>

<unit name=”MPa” default/>

<unit name=”Pa” conversionFactor=”1e6”/>

…property values…

</yieldStrenght>

Failure Strength

<failureStrenght>

<unit name=”MPa” default/>

<unit name=”Pa” conversionFactor=”1e6”/>

…property values…

</failureStrenght>

Thermal-Mechanical Properties

Property	Definition	Units	Conditions
Coefficient of Thermal Expansion (CTE)	Change in material size with temperature variation.	ppm/°C	Temperature, Orientation

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Coefficient of Thermal Expansion (CTE)

The measure of the change in size of a material in response to a change in temperature. It is usually expressed as a fractional change in length or volume per degree of temperature change. The default unit for this property is ppm/C, (“parts per million per degree C”).

Optical Properties

Property	Definition	Units	Conditions
Refractive Index	Measure of light bending as it passes through a material.	Unitless	Wavelength
Reflectance	Proportion of light reflected from the surface.	Unitless	Wavelength
Transmission	Proportion of light transmitted through the material.	Unitless	Wavelength

Surface and Mechanical Properties

Property	Definition	Units	Conditions
Surface Roughness	Variability in surface texture of a material.	Nanometers (nm)	-
Tensile Strength	Resistance to breaking under tension.	MegaPascal (MPa)	-
Transition Temperature	Temperature at which material transitions between phases.	Degrees Celsius (°C)	-

Surface roughness

For the purposes of this Material Design Kit, surface roughness is limited in scope to define the variability of surface in a given material used in the manufacturing of integrated circuits (IC). The default unit for this property is nm (“nanometers”).

Tensile strength

Related to tension, it refers to the resistance of a material to breaking under tension. Tensile strength is the maximum stress that a material can withstand while being stretched or pulled before breaking.

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Transition Temperature

The temperature at which a material changes from one phase to another, such as solid to liquid (melting point) or liquid to gas (boiling point).

XML Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">

  <!-- Root element -->
  <xs:element name="MaterialProperties">
    <xs:complexType>
      <xs:sequence>

        <!-- Electrical Properties -->
        <xs:element name="ElectricalProperties">
          <xs:complexType>
            <xs:sequence>
              <xs:element name="Property" maxOccurs="unbounded">
                <xs:complexType>
                  <xs:sequence>
                    <xs:element name="PropertyName" type="xs:string"/>
                    <xs:element name="Definition" type="xs:string"/>
                    <xs:element name="Units" type="xs:string"/>
                    <xs:element name="Conditions" type="xs:string"/>
                  </xs:sequence>
                </xs:complexType>
              </xs:element>
            </xs:sequence>
          </xs:complexType>
        </xs:element>

        <!-- Thermal Properties -->
        <xs:element name="ThermalProperties">
          <xs:complexType>
            <xs:sequence>
              <xs:element name="Property" maxOccurs="unbounded">
                <xs:complexType>
                  <xs:sequence>
                    <xs:element name="PropertyName" type="xs:string"/>
                    <xs:element name="Definition" type="xs:string"/>
                    <xs:element name="Units" type="xs:string"/>
                    <xs:element name="Conditions" type="xs:string"/>
                  </xs:sequence>
                </xs:complexType>
              </xs:element>
            </xs:sequence>
```

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```
    </xs:complexType>
  </xs:element>

  <!-- Structural Properties -->
  <xs:element name="StructuralProperties">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="Property" maxOccurs="unbounded">
          <xs:complexType>
            <xs:sequence>
              <xs:element name="PropertyName" type="xs:string"/>
              <xs:element name="Definition" type="xs:string"/>
              <xs:element name="Units" type="xs:string"/>
              <xs:element name="Conditions" type="xs:string"/>
            </xs:sequence>
          </xs:complexType>
        </xs:element>
      </xs:sequence>
    </xs:complexType>
  </xs:element>

  <!-- Failure Properties -->
  <xs:element name="FailureProperties">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="Property" maxOccurs="unbounded">
          <xs:complexType>
            <xs:sequence>
              <xs:element name="PropertyName" type="xs:string"/>
              <xs:element name="Definition" type="xs:string"/>
              <xs:element name="Units" type="xs:string"/>
              <xs:element name="Conditions" type="xs:string"/>
            </xs:sequence>
          </xs:complexType>
        </xs:element>
      </xs:sequence>
    </xs:complexType>
  </xs:element>

  <!-- Thermo-Mechanical Properties -->
  <xs:element name="ThermoMechanicalProperties">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="Property" maxOccurs="unbounded">
          <xs:complexType>
            <xs:sequence>
              <xs:element name="PropertyName" type="xs:string"/>
              <xs:element name="Definition" type="xs:string"/>
              <xs:element name="Units" type="xs:string"/>
```

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```
            <xs:element name="Conditions" type="xs:string"/>
          </xs:sequence>
        </xs:complexType>
      </xs:element>
    </xs:sequence>
  </xs:complexType>
</xs:element>

<!-- Optical Properties -->
<xs:element name="OpticalProperties">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Property" maxOccurs="unbounded">
        <xs:complexType>
          <xs:sequence>
            <xs:element name="PropertyName" type="xs:string"/>
            <xs:element name="Definition" type="xs:string"/>
            <xs:element name="Units" type="xs:string"/>
            <xs:element name="Conditions" type="xs:string"/>
          </xs:sequence>
        </xs:complexType>
      </xs:element>
    </xs:sequence>
  </xs:complexType>
</xs:element>

<!-- Surface and Mechanical Properties -->
<xs:element name="SurfaceAndMechanicalProperties">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="Property" maxOccurs="unbounded">
        <xs:complexType>
          <xs:sequence>
            <xs:element name="PropertyName" type="xs:string"/>
            <xs:element name="Definition" type="xs:string"/>
            <xs:element name="Units" type="xs:string"/>
            <xs:element name="Conditions" type="xs:string"/>
          </xs:sequence>
        </xs:complexType>
      </xs:element>
    </xs:sequence>
  </xs:complexType>
</xs:element>

  </xs:sequence>
 </xs:complexType>
</xs:element>

</xs:schema>
```

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OCP Demo Example

Example materials from the OCP demo project.

Dimensions and Material Properties of Glass

	Glass
# Metal Layer	3
Metal thickness	4um
Dielectric thickness	15um
Dielectric constant	3.3
Minimum Wire W/S	2um/2um
Via size	22um
Bump size	16um
Die-to-Die spacing	100um
Micro-bump pitch	35um
C4 bump pitch	650um

		Glass
Substrate	Material	AGC EN-A1
	Permittivity (Dk)	4.9
	Loss tangent (Df) @ 1GHz	0.0056
	Young's mod (GPa)	74.8

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	CTE (ppm/K)	3.2
Dielectric	Material	ABF GL102
	Permittivity (Dk)	3.3
	Loss tangent (Df) @ 1GHz	0.0044
	Young's mod (GPa)	13
	CTE (ppm/K)	13

```
<?xml version="1.0" encoding="UTF-8"?>
<MaterialProperties>
  <ElectricalProperties>
    <Property>
      <PropertyName>Permittivity (Dk) - Glass Substrate</PropertyName>
      <Definition>Dielectric constant of AGC EN-A1 glass substrate</Definition>
      <Units>dimensionless</Units>
      <Conditions>AGC EN-A1</Conditions>
    </Property>
    <Property>
      <PropertyName>Loss Tangent (Df) - Glass Substrate</PropertyName>
      <Definition>Dielectric loss factor of AGC EN-A1 glass substrate</Definition>
      <Units>dimensionless</Units>
      <Conditions>@ 1GHz, AGC EN-A1</Conditions>
    </Property>
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      <PropertyName>Permittivity (Dk) - Dielectric Material</PropertyName>
      <Definition>Dielectric constant of ABF GL102</Definition>
      <Units>dimensionless</Units>
      <Conditions>ABF GL102</Conditions>
    </Property>
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      <Definition>Dielectric loss factor of ABF GL102</Definition>
      <Units>dimensionless</Units>
      <Conditions>@ 1GHz, ABF GL102</Conditions>
    </Property>
  </ElectricalProperties>

  <ThermalProperties>
    <Property>
      <PropertyName>CTE - Glass Substrate</PropertyName>
```

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      <Definition>Coefficient of Thermal Expansion for AGC EN-A1</Definition>
      <Units>ppm/K</Units>
      <Conditions>AGC EN-A1</Conditions>
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    <Property>
      <PropertyName>CTE - Dielectric Material</PropertyName>
      <Definition>Coefficient of Thermal Expansion for ABF GL102</Definition>
      <Units>ppm/K</Units>
      <Conditions>ABF GL102</Conditions>
    </Property>
  </ThermalProperties>

  <StructuralProperties>
    <Property>
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      <Definition>Elastic modulus of AGC EN-A1 glass substrate</Definition>
      <Units>GPa</Units>
      <Conditions>AGC EN-A1</Conditions>
    </Property>
    <Property>
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      <Definition>Elastic modulus of ABF GL102</Definition>
      <Units>GPa</Units>
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  <FailureProperties>
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  <ThermoMechanicalProperties>
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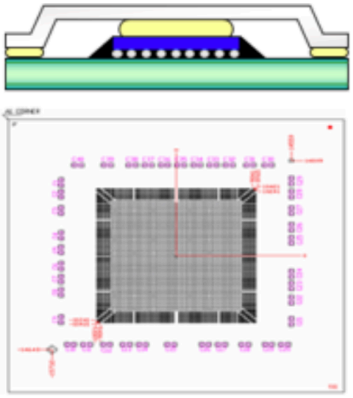
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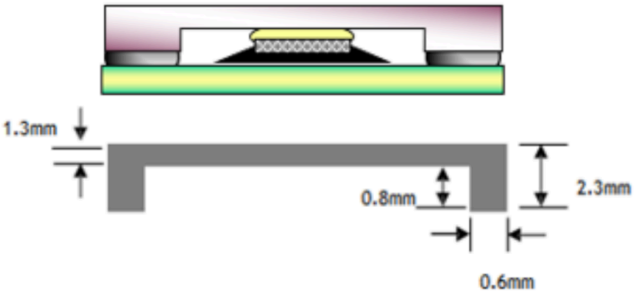
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</MaterialProperties>
```

ASE Example

ASE PKG_MTL requirement information for simulation

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Components	Type	Modulus (GPa) @ 25 ºC/260 ºC	CTE (ppm/ºC) @ 25 ºC/260 ºC	Tg (ºC)
Die	Silicon	131	2.8	-
Lid	Copper	117	16.9	-
Copper	Copper	117	16.9	-
Substrate core	MCL-E-705G	26/17	5.6/1.5	260
ABF	ABF-GX13	4.0/0.059	46/120	156
Solder mask	AUS703	2.6/0.1	55/140	102
Underfill	XXX	XXX	XXX	XXX
Adhesive	XXX	XXX	XXX	XXX
Solder bump	SnAg	42.5/36.3	23.5	-
TIM	XXX	XXX	XXX	XXX
EMC	XXX	XXX	XXX	XXX
...				
...				

Grade	Material properties	
Filler content	wt%	90
Filler sieving size	um	20
Fine filler variation	-	B imp2+C imp2
Epoxy	-	MF
Hardener	-	MF
Catalyst	-	Decreased
<General Properties>		
Spiral Flow	cm	86
Gel time	sec	65
Alpha1	ppm	8
Alpha2	ppm	25
Tg(TMA)	degC	170
Flexural strength @25	MPa	179
Flexural Modulus @25	MPa	23900
Specific gravity	-	2.04
Water absorption	%	0.20
Shrinkage	%	0.05

Metal Layer Thickness: 4 µm

Dielectric Thickness: 15 µm

Dielectric Constant (Dk): 3.3

Minimum Wire Width/Spacing: 2 µm / 2 µm

Via Size: 22 µm

Bump Size: 16 µm

Die-to-Die Spacing: 100 µm

Micro-Bump Pitch: 35 µm

C4 Bump Pitch: 650 µm

```
<?xml version="1.0" encoding="UTF-8"?>
<ChipMaterialProperties>
  <MetalLayer>
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  </MetalLayer>
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  <MicroBumpPitch unit="µm">35</MicroBumpPitch>
  <C4BumpPitch unit="µm">650</C4BumpPitch>
</ChipMaterialProperties>
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References

1. Github: https://github.com/opencomputeproject/OCP-SVR-ODSA-3DK-MDK
2. DAC 23 (Pruek) - https://drive.google.com/file/d/1KKz17b9oA2q7M6NCurAxTezW5455kF2j/view?usp=sharing
3. TCPMT 20 (PRC) - https://drive.google.com/file/d/11OlvCtnhIEBYBoiRAG8nCNmse7xt-t7h/view?usp=sharing
4. ECTC 20 (PRC) - https://drive.google.com/file/d/1uaglTOom8-wg6_6oHKswZSfmOhbL4JPu/view?usp=sharing
5. ISOM 13 - https://drive.google.com/file/d/1TYhd0kmbWrC9KUW0UrWwrExXfFPP4NAx/view?usp=sharing
6. JMEP_19 - https://drive.google.com/file/d/1jHYmBEXIulsYfLWUd3PebDMp6xuCobVn/view?usp=sharing

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