Undergraduate Certificate in Advanced Combustion Engineering

Materials for High-Temperature Environments

Aluminide
Related terms: intermetallic, diffusion coating
Aluminides are intermetallic compounds formed between aluminum and a refractory metal such as nickel, cobalt, or iron. They provide a protective, oxidation-resistant surface that can sustain temperatures above 1200 °C. Common examples include NiAl and FeAl. In turbine blades, aluminide coatings are applied by pack cementation to reduce weight while maintaining high-temperature strength. Challenges include brittleness at low temperatures and the need for precise control of coating thickness to avoid spallation.

Austenitic stainless steel
Related terms: cr-Ni, high-temperature alloy
Austenitic stainless steels contain high levels of chromium and nickel, giving them excellent corrosion resistance and good formability. Grades such as 310 and 321 are used in furnace components that experience temperatures up to 800 °C. Their stability derives from a face-centered cubic crystal structure that remains stable at elevated temperatures. Limitations involve loss of strength above 600 °C and susceptibility to carburization if exposed to carbon-rich gases.

Bond coat
Related terms: thermal barrier, oxidation protection
A bond coat is a metallic layer applied directly to a substrate before the deposition of a ceramic thermal barrier coating (TBC). Typical materials include MCrAlY (where M = Ni, Co) or pure nickel aluminide. The bond coat serves to improve adhesion, accommodate thermal expansion mismatch, and provide oxidation resistance. Over time, bond coat degradation can occur through thermally grown oxide (TGO) thickening, leading to delamination of the TBC.

Carbide-reinforced composite
Related terms: cermet, SiC
Carbide-reinforced composites consist of a metallic matrix (often nickel-based) embedded with hard carbide particles such as silicon carbide (SiC) or tungsten carbide (WC). The carbides improve wear resistance and maintain high strength at temperatures up to 1000 °C. These materials are employed in combustion chamber liners and fuel-nozzle inserts. Manufacturing challenges involve achieving uniform particle distribution and preventing carbide dissolution during high-temperature exposure.

Chromium oxide
Related terms: protective scale, Al_2O_3
Chromium oxide (Cr_2O_3) forms a thin, adherent scale on high-chromium alloys when oxidized at temperatures between 600 °C and 900 °C. The scale provides effective protection against further oxidation and is more volatile than alumina at higher temperatures. It is commonly observed on stainless steels and Fe-Cr alloys used in boiler tubes. The main challenge is scale spallation during rapid temperature cycling,

which can expose the substrate to aggressive combustion gases.

Creep
Related terms: time-dependent deformation, steady-state creep
Creep is the permanent deformation of a material under constant stress at elevated temperature over time. It is characterized by three stages: primary (decelerating), secondary (steady-state), and tertiary (accelerating). In high-temperature components such as turbine blades, creep limits the allowable stress and service life. Materials are selected for low creep rates, often through alloying with refractory elements (e.g., Mo, W) and precipitation strengthening.

Diffusion barrier
Related terms: interdiffusion, substrate protection
A diffusion barrier is a thin layer that prevents the intermixing of elements between a substrate and a coating. Materials such as alumina or yttria-stabilized zirconia (YSZ) are used as barriers in multi-layer coating systems. By limiting diffusion of nickel, cobalt, or chromium into the ceramic layer, the barrier maintains coating integrity at temperatures above 1200 °C. Failure modes include barrier cracking and chemical reaction with adjacent layers.

Duplex stainless steel
Related terms: ferritic-austenitic, high-strength alloy
Duplex stainless steels combine ferritic and austenitic phases, delivering higher strength and better resistance to stress corrosion cracking than standard austenitic grades. Grades such as 2205 are employed in heat exchangers and pressure vessels operating near 500 °C. The dual-phase microstructure provides a balance of toughness and corrosion resistance. However, the presence of ferrite can reduce high-temperature creep resistance, requiring careful design for prolonged service.

Electro-thermal spray
Related terms: plasma spray, thermal barrier coating
Electro-thermal spray (also known as arc spray) uses an electric arc to melt metallic or ceramic feedstock, which is then propelled onto a substrate to form a coating. This technique is suitable for applying bond coats and protective layers on large surfaces like furnace walls. The resulting coatings possess good adhesion and can be deposited at relatively low temperatures, preserving substrate properties. Limitations include porosity and lower coating density compared to plasma spray methods.

Ferritic stainless steel
Related terms: Cr-Fe alloy, high-temperature oxidation
Ferritic stainless steels contain high chromium and low nickel, resulting in a body-centered cubic structure. Grades such as 430 and 441 are used in exhaust manifolds and boiler tubes where moderate temperatures (up to 600 °C) are encountered. They offer good oxidation resistance but lower ductility than austenitic steels. At temperatures above 700 °C, ferritic steels may experience accelerated oxidation and loss of mechanical strength.

Grain boundary strengthening
Related terms: precipitation hardening, solid solution

Grain boundary strengthening increases a material's yield strength by reducing grain size, thereby impeding dislocation motion. In high-temperature alloys, fine grains can improve creep resistance up to a point, but excessive grain refinement may cause grain growth at elevated temperatures, reducing effectiveness. Thermally stable carbides or nitrides are often introduced to pin grain boundaries and maintain a refined microstructure during service.

High-entropy alloy
Related terms: multi-principal element, refractory HEA
High-entropy alloys (HEAs) consist of five or more principal elements in near-equal proportions, leading to high configurational entropy that stabilizes simple crystal structures. Refractory HEAs containing elements such as Mo, Nb, and Ta can retain strength at temperatures above 1200 °C, making them candidates for next-generation turbine components. Their complex chemistry poses challenges in manufacturing, cost, and understanding of oxidation behavior.

Inconel
Related terms: Ni-Cr alloy, superalloy
Inconel is a family of nickel-based superalloys renowned for excellent high-temperature strength and oxidation resistance. Common grades include Inconel 718 (precipitation-strengthened) and Inconel 625 (solid-solution strengthened). These alloys are used in turbine blades, exhaust manifolds, and heat exchangers operating up to 1000 °C. Limitations involve high density, susceptibility to hot-cracking during welding, and the need for careful heat-treatment to achieve optimal properties.

Intermetallic compound
Related terms: ordered phase, γ-prime
Intermetallic compounds are ordered phases formed between two or more metals, exhibiting distinct crystal structures and often superior high-temperature properties compared to solid solutions. Examples include Ni_3Al (γ-prime) and TiAl. They provide high creep resistance and low density, making them attractive for aerospace engine components. Their brittleness at room temperature and limited ductility pose processing and design challenges.

Jet fuel combustion environment
Related terms: oxidizing atmosphere, thermal gradient
The jet fuel combustion environment is characterized by high temperatures (up to 2000 °C), turbulent flow, and aggressive oxidizing gases such as water vapor and CO_2. Materials exposed to this environment must resist oxidation, thermal fatigue, and creep. Thermal barrier coatings, oxidation-resistant alloys, and cooling schemes are employed to protect turbine blades. Design must also consider hot-section temperature gradients that induce thermal stresses.

Kinetic barrier
Related terms: diffusion control, oxidation rate
A kinetic barrier refers to a material or layer that slows down the rate of a chemical reaction, such as oxidation, by limiting mass transport. In high-temperature applications, a thin alumina scale acts as a kinetic barrier, reducing oxygen diffusion to the underlying metal. The effectiveness of a kinetic barrier depends on its continuity, adherence, and resistance to spallation under cyclic thermal loads.

Lattice distortion
Related terms: solid solution strengthening, misfit strain
Lattice distortion occurs when solute atoms of different size replace host atoms in a crystal lattice, creating strain fields that impede dislocation motion. This mechanism is a key contributor to solid-solution strengthening in high-temperature alloys, such as the addition of Al or Ti to nickel-based superalloys. Excessive distortion can lead to decreased ductility and promote crack initiation under thermal cycling.

Machining tolerance
Related terms: dimensional accuracy, surface finish
Machining tolerance defines the permissible deviation from nominal dimensions after material removal processes. In high-temperature components, tight tolerances are required for features such as cooling hole diameters and blade tip clearances. Achieving these tolerances in refractory alloys is difficult due to tool wear and the material's high strength. Advanced machining techniques, including electrical discharge machining (EDM) and laser machining, are often employed.

Nickel-based superalloy
Related terms: γ-matrix, γ-prime precipitates
Nickel-based superalloys consist of a γ-matrix (Ni-Cr-Co) strengthened by γ-prime ($Ni_3(Al,Ti)$) precipitates, as well as carbides and borides. They retain high strength and creep resistance up to 1050 °C. Widely used in turbine blades, combustor liners, and exhaust systems, these alloys are manufactured via directional solidification or single-crystal growth to minimize grain boundary creep. Their high cost and complex processing are major considerations.

Oxidation resistance
Related terms: protective scale, chromium content
Oxidation resistance describes a material's ability to form a stable, adherent oxide layer that protects the substrate from further attack. Alloys with high Cr, Al, or Si contents develop protective Cr_2O_3, Al_2O_3, or SiO_2 scales. In combustion environments, maintaining oxidation resistance is critical to prevent rapid material loss. Challenges include scale spallation during thermal cycling and volatility of certain oxides at very high temperatures.

Phase stability
Related terms: γ-prime dissolution, solid solution
Phase stability refers to the ability of an alloy's microstructure to retain its beneficial phases (e.g., γ-prime, carbides) during prolonged exposure to high temperatures. Unstable phases may coarsen or dissolve, reducing strength. Alloy design focuses on selecting elements that form thermally stable compounds and controlling heat-treatment schedules to preserve phase distribution. Monitoring phase stability is essential for predicting component life.

Powder metallurgy
Related terms: HIP, additive manufacturing
Powder metallurgy (PM) involves consolidating metal powders into dense components through pressing and sintering, often followed by hot isostatic pressing (HIP) to eliminate porosity. PM enables the production of complex shapes and the incorporation of hard particles (e.g., carbides) uniformly throughout

a matrix. It is used for manufacturing turbine blades, combustor inserts, and wear-resistant coatings. Limitations include residual porosity, anisotropic properties, and the need for precise powder control.

Quench cracking
Related terms: thermal shock, residual stress
Quench cracking occurs when a material experiences rapid temperature changes, leading to high thermal gradients and the development of tensile stresses that exceed fracture toughness. In high-temperature components, sudden cooling (e.g., after shutdown) can induce quench cracks, especially in brittle intermetallics or ceramics. Design strategies include using materials with low thermal expansion coefficients and incorporating gradual cooling procedures.

Refractory metal
Related terms: W, Mo, Nb, high-melting point
Refractory metals possess melting points above 2500 °C and retain strength at extreme temperatures. Tungsten (W), molybdenum (Mo), and niobium (Nb) are common refractory metals used in high-temperature applications such as rocket nozzles and furnace elements. Their high density and susceptibility to oxidation limit widespread use; protective coatings or inert atmospheres are required to prevent rapid degradation.

Silicon carbide
Related terms: SiC, ceramic reinforcement
Silicon carbide (SiC) is a hard, high-temperature ceramic with excellent thermal conductivity and oxidation resistance up to 1500 °C. It is used as a reinforcement phase in metal-matrix composites, as a coating for turbine blades, and as a structural material for combustion chambers. SiC's low fracture toughness and tendency to develop a silica layer that may volatilize at very high temperatures are key challenges.

Solid solution strengthening
Related terms: alloying elements, lattice distortion
Solid solution strengthening occurs when alloying atoms dissolve uniformly in the host lattice, creating distortion fields that hinder dislocation movement. Elements such as Al, Ti, and Cr are added to nickel-based superalloys to increase high-temperature strength. The effectiveness depends on solubility limits and the size mismatch between solute and solvent atoms. Excessive solute can lead to precipitation of brittle phases.

Thermal gradient
Related terms: temperature differential, thermal stress
A thermal gradient is the spatial variation of temperature within a component. In turbine blades, steep gradients between the hot gas path and cooled interior generate thermal stresses that can cause fatigue cracking. Managing gradients involves internal cooling passages, thermal barrier coatings, and material selection with low thermal expansion coefficients. Accurate prediction of gradients is essential for reliable life assessment.

Thermal barrier coating
Related terms: TBC, YSZ

Thermal barrier coatings (TBCs) are ceramic layers, typically yttria-stabilized zirconia (YSZ), applied to metallic substrates to insulate them from high-temperature gases. They reduce the substrate temperature by up to 1000 °C, extending component life. TBCs are deposited by plasma spray, EB-PVD, or air plasma spray. Failure mechanisms include TGO growth, thermally induced cracking, and delamination due to mismatched expansion. Proper surface preparation and bond coat selection are critical for durability.

Udimet
Related terms: Nickel superalloy, single crystal
Udimet is a family of single-crystal nickel-based superalloys developed for high-pressure turbine blades. Grades such as Udimet-720 and Udimet-720Li incorporate high levels of refractory elements and low-density additions to achieve superior creep resistance at 1050 °C. Their directional solidification eliminates grain boundaries, minimizing creep pathways. Manufacturing complexity, high cost, and sensitivity to processing defects are major considerations.

Vanadium carbide
Related terms: VC, hardening phase
Vanadium carbide (VC) is a hard ceramic particle used to strengthen metal matrices, particularly in nickel-based alloys. VC particles impede dislocation motion and improve wear resistance at temperatures up to 900 °C. They are often introduced via powder metallurgy or in-situ precipitation. Challenges include controlling particle size to avoid brittleness and ensuring stability of VC in oxidizing environments, where it may oxidize to V_2O_5.

Weldability
Related terms: fusion joining, heat affected zone
Weldability describes how easily a material can be joined by welding without compromising mechanical properties. High-temperature alloys often contain elements that form brittle phases in the heat-affected zone (HAZ), reducing weldability. Techniques such as electron beam welding, laser welding, and friction welding are employed to minimize HAZ width. Pre- and post-weld heat treatments are essential to restore microstructure and prevent cracking.

X-ray diffraction
Related terms: phase identification, crystallography
X-ray diffraction (XRD) is an analytical technique used to identify crystalline phases, measure lattice parameters, and assess texture in high-temperature alloys. It helps verify the presence of γ-prime, carbides, and oxide scales after service exposure. Quantitative XRD can be used to monitor phase coarsening or dissolution, informing maintenance schedules. Sample preparation must avoid altering the microstructure, especially for temperature-sensitive phases.

Yttria-stabilized zirconia
Related terms: YSZ, thermal barrier
Yttria-stabilized zirconia (YSZ) is a ceramic material containing 8–10 wt % yttria, which stabilizes the cubic zirconia phase and provides high ionic conductivity. It is the primary material for thermal barrier coatings due to its low thermal conductivity and high coefficient of thermal expansion, matching that of nickel alloys. At temperatures above 1200 °C, YSZ may undergo phase transformation to tetragonal or monoclinic forms,

leading to coating spallation.

Zirconium diboride
Related terms: ZrB_2, ultra-high temperature ceramic
Zirconium diboride (ZrB_2) is an ultra-high temperature ceramic (UHTC) with a melting point near 3245 °C and excellent thermal conductivity. It is investigated for use in leading edges of hypersonic vehicles and rocket nozzles. ZrB_2 can be reinforced with SiC to improve oxidation resistance, forming a protective SiO_2 layer. Manufacturing challenges include achieving dense, defect-free components and managing oxidation in air at temperatures above 1500 °C.

Aluminum-rich coating
Related terms: Aluminizing, oxidation barrier
Aluminum-rich coatings are applied to steels and nickel alloys to form a surface layer with high Al content, which subsequently develops an Al_2O_3 scale during service. Techniques include pack cementation, chemical vapor deposition (CVD), and flame spraying. These coatings enable operation in oxidizing environments up to 1200 °C. Potential issues involve coating adhesion, thickness control, and the formation of brittle intermetallics at the coating-substrate interface.

Beta phase
Related terms: β-NiAl, ordered structure
The beta phase in Ni-Al systems refers to the ordered β-NiAl intermetallic with a B2 crystal structure. It offers good oxidation resistance and high temperature strength, making it suitable for diffusion coatings and as a constituent in some superalloys. However, the β-phase is brittle at room temperature and may transform to γ-prime at elevated temperatures, affecting mechanical performance.

Chromium carbide
Related terms: Cr_3C_2, wear resistance
Chromium carbide (Cr_3C_2) particles are incorporated into metal-matrix composites to improve hardness and wear resistance. They retain stability up to 900 °C and are commonly used in turbine blade leading edges. The carbide particles act as obstacles to dislocation motion and improve erosion resistance. Excessive carbide content can reduce ductility and promote crack initiation under thermal cycling.

Diffusion coating
Related terms: pack cementation, chemical vapor deposition
Diffusion coating involves the migration of alloying elements (e.g., Al, Cr) into the substrate surface, forming a graded compositional layer. Pack cementation and CVD are typical methods. The resulting coating provides oxidation resistance and can be tailored for thickness and composition. Controlling diffusion depth and avoiding the formation of brittle intermetallic layers are critical for coating performance.

Electron beam physical vapor deposition
Related terms: EB-PVD, thermal barrier coating
EB-PVD uses an electron beam to vaporize a target material, which then condenses onto a substrate under vacuum. This method produces columnar, low-stress TBCs with excellent adherence. EB-PVD coatings often exhibit superior strain tolerance compared to plasma-sprayed coatings, making them suitable for

high-stress turbine sections. The process is expensive and requires precise control of deposition parameters.

Fretting corrosion
Related terms: contact wear, oscillatory motion
Fretting corrosion occurs at contact interfaces subject to small-amplitude oscillatory motion, leading to surface damage and accelerated corrosion. In turbine engines, fretting can develop at blade-disk interfaces and seal joints. Mitigation strategies include using compliant coatings, surface treatments, and lubricants designed for high-temperature operation. Monitoring is essential because fretting damage can propagate into cracks under cyclic loading.

Graded material
Related terms: functionally graded, composition gradient
A graded material exhibits a gradual variation in composition or microstructure across its thickness. This design reduces thermal mismatch between a metal substrate and a ceramic coating, improving adhesion and reducing stress. Examples include graded Al_2O_3/NiAl layers used as bond coats. Manufacturing methods such as plasma spraying with controlled feed rates or additive manufacturing enable precise gradient control. Challenges involve ensuring continuity and preventing delamination at intermediate layers.

Hot corrosion
Related terms: sulphate attack, Na_2SO_4
Hot corrosion is a severe form of degradation that occurs when molten salts (e.g., Na_2SO_4, V_2O_5) deposit on a metal surface at temperatures above 600 °C, accelerating oxidation and causing rapid material loss. It is common in marine and desert environments where salt-laden combustion gases are present. Alloying with high Al and Cr, applying protective aluminide coatings, and using ceramic barriers are typical countermeasures.

Inconel 625
Related terms: solid solution, corrosion resistant
Inconel 625 is a nickel-chromium-molybdenum alloy that relies on solid-solution strengthening rather than precipitation. It offers excellent resistance to oxidation, pitting, and stress corrosion cracking up to 700 °C. The alloy is widely used in heat exchangers, furnace components, and marine applications. Its high nickel content contributes to cost, and welding requires careful control to avoid sensitization.

Jahn-Teller distortion
Related terms: crystal field, electronic degeneracy
Jahn-Teller distortion describes the geometric deformation of a coordination complex to remove electronic degeneracy, thereby lowering energy. In high-temperature alloys, certain transition metal oxides may undergo Jahn-Teller distortions, influencing oxide scale morphology and adherence. Understanding this effect helps in tailoring alloy composition to promote stable oxide scales.

Kinetic alloying
Related terms: diffusion-controlled, interdiffusion
Kinetic alloying refers to the formation of alloy phases through diffusion processes rather than equilibrium solidification. In coating systems, kinetic alloying can produce graded intermetallic layers during

high-temperature exposure, enhancing adhesion between substrate and ceramic coating. Control of temperature and time is essential to avoid excessive intermetallic growth that may embrittle the interface.

Laser cladding
Related terms: directed energy deposition, surface modification
Laser cladding uses a high-power laser to melt powder feedstock onto a substrate, creating a metallurgically bonded coating. It enables precise deposition of wear- and oxidation-resistant layers such as Ni-Cr-Al alloys on turbine components. The rapid solidification rates can produce fine microstructures, improving hardness. Limitations include residual stresses, potential cracking, and the need for post-cladding heat treatment.

Microstructural stability
Related terms: coarsening, precipitate dissolution
Microstructural stability is the ability of an alloy's microstructure to retain its advantageous features (e.g., fine γ-prime precipitates, stable carbides) during prolonged high-temperature exposure. Instability leads to coarsening, loss of strength, and reduced creep resistance. Alloy design incorporates elements like Ta and Hf to slow diffusion and maintain precipitate size. Monitoring microstructure through microscopy and XRD is vital for life prediction.

Nickel aluminide
Related terms: NiAl, beta phase
Nickel aluminide (NiAl) is an intermetallic compound with a high melting point (~1650 °C) and excellent oxidation resistance due to the formation of Al_2O_3. It is used as a bond coat in high-temperature turbine applications and as a lightweight structural material in engine components. NiAl's brittleness at low temperatures and limited ductility under impact loading are significant challenges.

Oxidative wear
Related terms: abrasive oxidation, scale spallation
Oxidative wear combines mechanical abrasion with concurrent oxidation, leading to accelerated material loss. In turbine engines, particles entrained in the hot gas stream can erode coating surfaces while the high temperature promotes oxide formation. Materials with hard, oxidation-resistant surfaces such as SiC-reinforced composites are preferred. Design must consider particle size distribution and flow velocity to mitigate damage.

Precipitation hardening
Related terms: ageing, γ-prime
Precipitation hardening strengthens alloys by forming fine, coherent precipitates (e.g., γ-prime, carbides) during a controlled ageing heat treatment. These precipitates impede dislocation motion, enhancing yield strength and creep resistance at high temperatures. The process requires precise temperature control to achieve the desired precipitate size and distribution. Over-aging can cause coarsening, reducing strength.

Quaternary alloy
Related terms: four-component system, complex composition
A quaternary alloy contains four principal elements, allowing tailored combinations of high-temperature

strength, oxidation resistance, and low density. An example is a Ni-Cr-Co-Al alloy designed for turbine blade applications. The increased compositional complexity demands careful thermodynamic modeling to predict phase stability and avoid detrimental intermetallic formation.

Recrystallization
Related terms: grain growth, annealing
Recrystallization is a process where deformed grains are replaced by new, strain-free grains during annealing at elevated temperatures. In high-temperature alloys, controlled recrystallization can restore ductility after cold working. However, excessive recrystallization may lead to grain coarsening, reducing creep resistance. Heat-treatment schedules are optimized to balance hardness and toughness.

Superalloy
Related terms: high-temperature alloy, γ-matrix
A superalloy is a metallic alloy engineered to retain mechanical strength and resist oxidation at temperatures approaching its melting point. Nickel-based superalloys dominate turbine applications due to their superior creep resistance, while cobalt-based and iron-based superalloys serve niche roles. They often employ directional solidification, single-crystal growth, and advanced coating systems. Their production is costly, and alloy selection must consider operating temperature, stress, and environmental conditions.

Thermal fatigue
Related terms: cyclic heating, crack initiation
Thermal fatigue results from repeated heating and cooling cycles that generate cyclic thermal stresses, leading to crack initiation and propagation. In turbine components, thermal fatigue can limit service life, especially in regions with steep temperature gradients. Mitigation strategies include using materials with low coefficient of thermal expansion, applying thermal barrier coatings, and designing for gradual temperature changes.

Ultra-high temperature ceramic
Related terms: UHTC, ZrB_2
Ultra-high temperature ceramics (UHTCs) are a class of refractory materials capable of withstanding temperatures above 2000 °C in oxidative environments. Common UHTCs include zirconium diboride (ZrB_2) and hafnium carbide (HfC). They are investigated for hypersonic vehicle leading edges and rocket nozzles. Manufacturing challenges involve achieving dense, crack-free components and protecting against oxidation, often by adding SiC to form a protective SiO_2 layer.

Vapor deposition
Related terms: PVD, CVD
Vapor deposition encompasses techniques where material is transferred from a vapor phase to a solid surface, forming thin films. Physical vapor deposition (PVD) includes sputtering and EB-PVD, while chemical vapor deposition (CVD) relies on chemical reactions of gaseous precursors. These methods produce uniform, adherent coatings such as Al_2O_3, TiN, and YSZ for high-temperature protection. Process parameters must be tightly controlled to avoid defects and ensure coating stoichiometry.

Wear-resistant alloy

Related terms: hardfacing, carbide reinforcement
Wear-resistant alloys are formulated to resist abrasive and erosive wear in high-temperature environments. They often contain high concentrations of carbides (e.g., WC, TiC) and strong solid-solution elements (e.g., Mo, Cr). Applications include turbine blade leading edges, combustor liners, and nozzle inserts. Balancing hardness with toughness is essential to prevent brittle fracture under impact loading.

Yield strength
Related terms: stress at 0.2% offset, high-temperature behavior
Yield strength is the stress at which a material begins to deform plastically. At elevated temperatures, yield strength decreases, influencing design limits for turbine components. High-temperature alloys achieve higher yield strength through precipitation strengthening, solid-solution strengthening, and grain boundary engineering. Accurate measurement at service temperatures is critical for reliable component design.

Zirconia
Related terms: ZrO_2, thermal barrier
Zirconia (ZrO_2) is a ceramic material with high fracture toughness and low thermal conductivity when stabilized with yttria. It forms the basis of many thermal barrier coatings, providing insulation for metal substrates in turbine engines. Stabilization prevents the monoclinic phase transformation that would cause volume expansion and cracking. At temperatures above 1200 °C, zirconia may undergo phase changes that degrade coating performance; appropriate yttria content mitigates this risk.