The word material refers to a substance that can be manipulated through numerous industrial processes and procedures, into components, finishes, products, or structures to realize design intent. Whether a doorknob, or a flooring tile, or a movable room divider, every component of the interior space is manufactured involving at least one material, but more commonly a combination of several materials working together to best utilize their performance and aesthetic qualities.

The important question is “why is it crucial to learn about materials?” The design process typically involves developing an initial conceptual idea to an extent that it is ready to be fabricated, manufactured, or built as a useful real-world entity. This “realization” of the design intent requires a knowledge of how various materials are manufactured, processed, combined, and finished. The designer’s career depends on their ability to assess the aesthetic and performance properties of materials while
maintaining an ethical, investigative, and innovative mindset. This is true even when working on purely conceptual works; as soon as the intent needs to be realized, for instance an artistic vision as a conceptual art piece to be exhibited, the designer is required to tap into their knowledge of materials. Among many successful contemporary artists Anish Kapoor has worked with top materials scientists and engineers to realize his art, Richard Serra developed a deep understanding of the materials that he utilized as a medium of expression, or Carl Andre dedicated his art to exploring and understanding what various materials were about.

In summary an ability to creatively and successfully **realize design intent** depends on an extensive knowledge of materials.

Materials can be categorized in various ways. A categorization system that is highly relevant for interior architects and designers is the **MasterFormat®**, the specifications writing standard for most large-scale design and construction projects in North America. Developed and published by the Construction Specifications Institute (CSI), **MasterFormat® is organized around categorizing**
the construction requirements, products, and activities related to various materials, products, components, and systems.

Within the context of interior architecture and design, one can simply classify materials as they relate to flooring, wallcovering, ceilings, and millwork/casework. This is especially useful when trying to specify materials for interior surfaces, every relevant option is categorized together and alternatives can be compared relatively quickly. The downside for this categorization approach is the repetition of each class of materials for each particular interior component.

A more traditional and straightforward categorization of materials would be metals, ceramics, minerals, polymers, composites, plant-based, and animal-based materials. This book is structured around this particular categorization logic. However, some categories such as paint and wallcovering, concrete and natural stone, wood, textiles are separated for clarity and convenience, even though each of these added categories can fit in one of the traditional categories. For example, wood is in fact a polymer composite.

**A BRIEF HISTORY OF MATERIALITY**

As soon a stone fragment is chipped by a human being to create a sharp edge, materiality became relevant. So relevant that there are whole historical eras named based on the impact of a certain material on how historical events unveiled and how people sustained their day-to-day activities. Humanity lived through the stone, copper, bronze, and iron ages; and, maybe in the future the contemporary times will be referred to as the semiconductor or nanomaterial age.

Every material has an association within the collective memory of a society. *Zeitgeist* is a popular term that is often translated as the ghost/spirit of the time/era, which implies that meaning and significance of any notion, including the creative use of materials and manufacturing methods, is a product of their time and they will be engrained in culture accordingly.

The knowledge of the semantic associations of when, why, and in what context a material and manufacturing technology became popular can be utilized to construct meaning and atmosphere, create a sense of place and time, and evoke an emotional response.

For instance, mahogany wall paneling might evoke a feeling of Victorian sophistication, or a glossy, bright and colorful vinyl fabric can be used to set a futuristic atmosphere, or polished white marble can reference neo-classic ideals.

**HUMBLE BEGINNINGS**

Even though there are much earlier examples of straw huts and cave paintings created with prepared pigments, if the manufacturing of an actual building product is considered, it can be said that the humble beginnings of materials coincide with sun-dried bricks around 5300BCE in Mesopotamia. With the integration of plant fibers into a mud mixture,
early bricks became the first composites. In 2006 Litracon®, a translucent concrete building material permitted the passage of light through concrete via latitudinally integrated glass fibers. It presented an impressive marriage of ancient and contemporary materials and techniques to create unexpected effects in a highly traditional material.

**GLAZED TILES** ● Throughout the globe from Africa to North America, pottery is chief among the most common archaeological findings, along with tools and fossils. Pottery is simply formed and fired clay. The firing process helps the material withstand decay over time, early archaeological evidence dating almost 30,000 years back.

Glazing, the fused glassy coating on fired clay products, came much later. First glazed tiles were used as a building material on the Ishtar Gate around 575BCE. Kiln-dried bricks were applied with a coating and through exposure to intense heat, various vivid colors, as well as protection, was achieved. This ended up being the precursor of the modern ceramic tile.

**OPUS CAEMENTICIUM** ● Concrete is part of virtually every contemporary construction, whether it is used to set a foundation or to create a tube structure for a high-rise building, board-formed for decorative finishing interiors or poured over to create a durable substrate. Ancient Romans were the first to successfully implement concrete on an industrial scale. Cement, a mixture of calcium carbonate and limestone, enabled Romans to develop concrete and build the 142 feet wide dome of Pantheon in 126 CE. After the fall of the Roman Empire, the technology was almost lost until the end of the 18th century.
Glassmaking requires very high temperatures, mainly to melt and purify silica, the major raw constituent of glass. Human-kind did not achieve the required technology until medieval times. The naturally occurring volcanic glass, which is known as obsidian, or glass formed after a meteoric impact such as Moldavite were the first glass materials to be used since Stone Age. Around the 12th century, the Romanesque stained glass expressing religious themes, became a precursor to the large stained glass windows that were later associated with Gothic cathedrals. Glass became part of the architectural language with the mass manufacture of broad sheet glass in 1226, in Sussex, UK. Today, manufacturing became so reliable and feasible that whole skyscrapers can be enveloped with glass.

**LETTING LIGHT IN**

**AUTOMATION REPLACING JOBS**

The industrial revolution enabled the manufacture and widespread use of some known materials in extraordinary quantities, chiefly among them, iron and later steel, replacing the traditional wood, brick, and stone. Entire buildings were made from iron, one of the most famous being the Eiffel Tower, still standing in Paris, France. As the Industrial Revolution ensued, textile manufacturing technology also advanced. In 1784 Edward Cartwright invented the first mechanized loom speeding textile production, enabling cheap access to a variety of textile products, but also impacting a whole branch of skilled labor by automating a process ultimately catalyzing civil unrest and social change.

**NATURAL VS. SYNTHESIZED**

Rubber as a naturally occurring polymer has been known since 1300BC, however, following the industrial revolution, new venues of use for this flexible and resilient material were discovered, such as transmission belts and pneumatic tires, which

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**Fig.01/04** Stained glass windows often depicted religious stories or figures in vivid colors.

**Fig.01/05** Latex being extracted from a rubber tree.
Skyrocketed demand. Rubber plantations in various regions with tropical climates became widespread around the late 19th century. In addition to intense deforestation, some of the plantations, such as those in Congo, were associated with deep human drama. Starting from the 1910s until the 1940s synthesized rubber was perfected to become a feasible alternative, not completely replacing but greatly reducing dependency on natural rubber.

**Better Living Through Chemistry**

The first example of synthesized polymers started appearing as early as the 1830s. Like many other early polymers, formaldehyde was discovered in 1859, while attempting to synthesize something else. The commercial production of formaldehyde took off towards the end of the 19th century. Phenol-formaldehyde resin became an important component for Bakelite manufacturing, the world’s first totally synthetic thermosetting plastic invented in 1907. Bakelite was advertised as a “material with a thousand uses”, with only two colors available at first, brown and darker brown. In the 1930s melamine based on melamine-formaldehyde, became a replacement for Bakelite enabling vivid colors and a smooth finish. It is somewhat ironic that plastics replaced completely unsustainable and at times cruel rubber, ivory, silk, etc. manufacturing, however, today they became a sustainability problem due to overproduction and their persistence in nature.

**Manipulating Wood**

Even though it was possible to cut and carve wood into any desired shape, it was time-consuming manual labor and required skilled craftsmanship. The Thonet Chair introduced by Michael Thonet in 1859 utilized steam to bend wood pieces, achieving components with an organic and flowing quality. More importantly, it was possible to mass-produce these components. Millions of Thonet chairs were produced in the subsequent years. Similar bending and molding methods were successfully applied by many designers including Alvar Aalto, Eero Saarinen, and more famously by Charles and Ray Eames. Steam bent plywood is an important aspect of the Eames Chair and Ottoman, which is still a valued addition to high-end offices and living rooms.

**Steel Replacing Style**

The very durable Damascus steel was being manufactured a thousand years before the industrial revolution and used
for building swords and armor. However, it took a technological breakthrough to manufacture steel, namely the Bessemer Conversion, enabled its feasible production in industrial quantities. Cheap steel ended up transforming architecture by successfully replacing masonry and timber. With the advent of International Style, steel along with glass and concrete became an expression of material potential, replacing previous stylistic conventions, at least for a while. Furniture design was also being transformed by reliable and cheap steel. Wassily Chair (Model B3), designed by Marcel Breuer in 1926 employed steel tubing in furniture first time.

**WEAVING CARBON** In 1940, the development of the combination of polymer resin and glass fibers resulted in Glass Reinforced Plastic (GRP), a lightweight and high-performance material to be used in structural applications. The aeronautical industry pushed the development of different types of composites, including high-performance metals in the equation. Carbon-fiber, which is essentially a carbon lattice set in resin, is one of the most widely known composites, partly due to its unique look, outperforming many metal alloys in terms of stiffness and strength-to-weight. Even though it started out as a very expensive material, carbon fiber is much more affordable today due to the demand developed over the years and refined manufacturing techniques.

**LIGHT EMITTING DEVICE** In 1977 electrically conducting organic polymers were discovered which were developed into semiconductor light sources, widely known as light-emitting devices or LED – formerly known as light-emitting diode. These tiny light sources enabled surfaces and textiles to be lit and even to form screens, in a wide range of colors. Their high efficiency enabled large architectural surfaces as well as thin reveals to be illuminated, transforming the look of contemporary architecture. Recent examples of material integration include LED woven into a metal fabric, such as in GKD’s MediaMesh®, or set in resin such as in Sensitile’s Lumina®.

**COMMITMENT TO SUSTAINABILITY** From the 1950s to the end of the 20th century, the consumption of finite resources, pollution caused by manufacturing and transportation practices, the persistence of waste in landfills, and the overall negative impact on the environment and diversity of life created a growing awareness that a prevalent sustainable mindset is needed. In 1993 the first international conference on “green goods” was held at The Hague, Netherlands, one of the first steps for a sustainable and green future for the next generation. Today sustainable thinking is an integral part of the design process, and many leading manufacturers are committing to sustainable practices; this

*Fig.01/08 Charles and Ray Eames deeply explored Glass Reinforced Plastic (GRP) in furniture design.*

*Fig.01/09 Today, Light Emitting Devices (LED) are a common source of artificial illumination.*
ultimately transformed how materiality is understood and applied.

SMART AND RESPONSIVE • Today, new materials are continuously being introduced featuring nanotechnology, programmability, light-mapping, phase changing, etc. Designers have more options to explore and are given more capability to increase the quality of life, create unique experiences for users, and ensure sustainability. Many of these materials are in daily use; electrochromic glass can convert from transparent to translucent instantly with the flick of a switch, thermochromic coating on a mug can change appearance when heated by the hot liquid in it, or photochromic lenses develop a dark tint with exposure to UV light. Similar to composites, it is not hard to imagine that smart and responsive materials will be further enmeshed into daily life in the future.

MATERIAL PERFORMANCE

Material performance refers to various physical and chemical properties of a material that determines the behavior of a material under various conditions. Understanding performance parameters is key for determining the best material for a particular surface, design detail, or finish. The performance properties of materials are systematically investigated by the field of Materials Science. A piece of metal feels cold to the touch due to its high thermal conductivity, or the injection molding success of a thermoplastic resin is determined by its melt flow index. Materials science employs an engineering mindset to solve manufacturing issues. On the other hand, an interior architect or designer is more involved with aesthetic implications, psychological impact, sustainability concerns, maintenance and life cycle costs, and end-of-life processes of materials. Therefore, a basic understanding of the foundational terminology and related performance parameters is important to make sense of materials, but more often than not, designers don’t have to understand the exact physics and chemistry behind the parameters.

A material’s performance, visual quality, and workability is determined by the specific arrangement of its molecular structure. For example, steel has a homogeneous distribution (isotropic) and wood has a heterogeneous distribution (orthotropic). Based on its molecular structure, a material can be porous/impervious, transparent/opaque, conductive/insulative, flammable/fire retardant etc. In general, a combination of multiple properties determine the performance of a material.

In order to assess the behavior of a material under stress, it is important to understand the various forces that can act on the material. Compression, tension, and shear are the most prominent three of such forces. Compression refers to pushing onto the material. On the other hand, tension refers to pulling the material apart. Lastly, shear refers to applying opposite forces on the same body.
As opposed to an isotropic material such as steel, porcelain, or acrylic, the properties of a wood piece are not homogeneous in all directions, conversely, being an orthotropic material the mechanical properties are distinct and independent on each axis. Imagine a piece of wood with a prominent and fairly parallel grain structure; considering that wood is highly sensitive towards the directionality of the applied force, it can relatively easily split along the grain. Now, compression applied across the grain (tangential) might create failure, as opposed to compression applied along the grain (longitudinal). On the other hand, tension applied along the grain is tolerated much better than across the grain as it would split the material at the weakest grain. Some sources mention up to 20 times the difference in resistance. Lastly, shear strength will be higher against the grain than along the grain. Grain direction is one among many properties when considering the strength of wood, along with wood species, density, drying method, or the presence of knots. **Ductility** is a material’s ability to withstand tensile stress. Ductal®, the ultra-high performance concrete (UHPC) material manufactured by Knauf is one example used in demanding structural applications. Ductility also determines impact strength in materials, ability to deflect instantaneous loads.

*Materials can display improved performance when they are combined to work together.* For instance, concrete is a material that performs well under compression but poorly under tension. In order to augment the performance of concrete, a material with good tensile strength is needed and steel possesses the necessary properties. Reinforced concrete is developed with this principle in mind, so as many other composite materials. Aside from acquiring a strength and stability benefit, the specific pH of the concrete wrapping the steel reinforcement keeps it from corroding. Together these materials achieve substantially better performance.

**Density** is simply the amount of mass of a material relative to its volume. It should be noted that high density does not always mean high stability or durability. For instance, gold has very high density but it is so soft that pure gold can be bent and scratched with bare hands.
Low-density materials are often ideal for thermal insulation; even some highly conductive metals such as aluminum can be highly insulative when foamed. **R-value** indicates a material’s capability for resisting the flow of heat. **Hardness** refers to the ability of the surface, not the totality, of a material to withstand scuffing, scraping, scratching, denting, and various other physical abuse. Porcelain has a higher degree of hardness compared to ceramics which makes them appropriate for areas with high traffic. **Stability** is a term that identifies the ability of a material to remain inert against the changes in its environment, including but not limited to moisture, temperature, or UV exposure. Compared to medium density fiberboard (MDF), chipboard is far less stable as it will quickly deform and deteriorate when exposed to moisture. **Durability** is similar to stability, but focuses on the longevity of resisting change. As an example, introducing fly ash to a concrete mix will increase its durability as well as cold weather resistance, cracking problems, and permeability. **Elasticity** refers to the ability of a material to completely recover from deformations produced by physical exertion after the load is removed. Rubber is highly elastic and resists denting and deforming when heavy equipment is placed or dropped on it, making it a great choice for gym flooring.

**Workability** refers to a material’s tendency to resist being physically shaped and processed, being cut, folded, hammered, drilled, milled, welded, planed, sanded. It is an important concern when specifying materials as it will impact workmanship costs and product success. **Malleability** is one aspect of workability that is defined by the material’s ability to be permanently and predictably deformed under compressive stress. For instance, sterling silver is highly malleable, it can be manipulated easily and predictably so that it is commonly used for handmade jewelry. On the other side of the spectrum, glass after it is tempered cannot be drilled or cut as it will simply shatter. Marble is especially fragile along its veins and prone to failing under shear forces. It is difficult to weld copper as the heat output will also substantially distorts the workpiece. Workability is a serious issue for anisotropic and orthotropic materials, those that don’t have homogeneous properties on different axes. For instance, cherry wood, despite its desirable grain patterns, often has directional changes in its wood grain, making it somewhat difficult to work, plane, and join.

**SURFACE ATTRIBUTES**

Within an interior space, the user primarily experiences the surface features of materials. Beyond their immediate visual qualities, surfaces can be felt through skin, soak up or exude various odors, absorb or reflect sound in unique ways, determined by their make-up and finish. Surfaces will require cleaning, conditioning, sealing, protection, and maintenance. Most surfaces will weather, wear, abrade, and fade.
Moisture needs to be carefully calculated and controlled throughout a building, including within the envelope: the boiling water on a range, a hot shower in a small bathroom, splashes from a powder room sink, leakage from a water tank, the water smeared on baseboards when mopping, or seeping through old grout. After it is absorbed, water will easily diffuse through materials, and vapor in the environment can condense at cold spots, creating opportunity for mold growth.

**Absorption coefficient** is an important property determining the ability of a material to absorb liquids and vapors when it is exposed. Absorption coefficient has a significant influence on the possible uses of a material and the various ways it can be treated, sealed, and finished. For instance, wood is a porous material with an ability to retain moisture and react by deforming or it can simply rot. Sealing the wood with a coating of varnish would extend the life expectancy of the material significantly. One should also consider that absorption levels substantially differ between wood species. For instance, due to its naturally oily constitution teak repels water and is a popular material for high-end shipbuilding. Untreated fabrics not only absorb vapors, organic compounds, and odor from the environment, they tend to emit them back, sometimes over many years. Another important example is granite, the surface of which appears impermeable to the naked eye, however, it harbors microscopic pores as well and a yearly sealant application is required to prevent bacterial growth. For this reason, granite countertops cannot be used in commercial kitchens as they cannot satisfy the National Health and Safety Foundation’s NSF/ANSI Standards developed for food contact materials, unlike stainless steel, quartz, and some other resin bonded countertops such as terrazzo. Metals are non-absorptive, however, their surface chemically reacts to the environment often eventuating in tarnishing, staining, oxidation, and corrosion. Therefore, they need to be alloyed with more resistant metals, or a protective surface finish is required, however, their non-absorptive nature may dictate an alternative paint finish such as powder coating.

**WEATHERING AND AGING**

Extended exposure to various environmental conditions, such as humidity, pollution, sunlight exposure, abrasive contact, cleaning agents, etc. causes materials to weather and age. Inappropriately specified materials with poor protection and maintenance measures can age very quickly and badly. On the other hand, with proper surface treatment and appropriate care they can age in a very desirable manner.

When specifying materials, the designer should consider how the material will transform due to environmental conditions in the next 2, 5, and 10 years from the installation date.

**Patina** refers to the transforming surface condition of a material, that develops over time as it is exposed to physical or chemical actors whether through natural or artificial means, until an equilibrium is reached. Some of these actors are moisture, UV light, caustic or alkaline chemicals, surface abrasion, etc. Patina development is closely tied to the specific environmental conditions, for instance, the same copper roofing can develop a slightly different color and texture in
a seaside city where the air is more acidic and corrosive compared to an industrial inland city where the air is pollutes. Pre-patination and pre-weathering are common among construction materials, enabling visually consistent weathering effect without the time commitment. Nevertheless, the unique visual signature of a building’s site cannot be attained through artificial means.

Many materials are sensitive to daylight, or sometimes even artificial lights such as Xenon. Light exposure causes materials to deteriorate, some lose color and vibrancy, others lose flexibility, and some simply disintegrate. The effects of UV light on wood components are well known. Wood slowly darkens and grays out as it is exposed to UV light, sometimes creating an uneven and undesirable look if the exposure is irregular. Careful specification, UV inhibiting finishes, a deeper stain finish, or installing low-E glass on openings can help control the effect; simply sanding and refinishing wood after several years of use might be another answer, depending on the species of wood. Other materials such as high-density polyethylene become brittle with extended sunlight exposure and starts to crumble; on the other hand, some plastics, such as acrylic, largely stays unchanged.

Dimensional movement is another significant consideration when specifying materials. Materials deform over time as the environmental moisture level changes, building settles, temperature fluctuates, or continuous weight, force, or vibrations are applied. For instance, expansion joints in cast-in-place concrete finish are utilized to mitigate cracks due to dimensional movement; a shiplap or tongue and groove joint work in a similar way especially useful when a species of wood, highly susceptible to warping, is used, such as Douglas fir before it is stabilized in its environment. Creep is the permanent deformation of a material due to the exertion of a constant force over time. If a material is expected to support constant loads over long periods, the designer should make sure that it is ductile enough and properly supported. One serious issue regarding dimensional movement is the degree of compatibility between different materials that are specified to interface together. It may be necessary to allow for the relative movement of different components that are expected to respond to environmental conditions differently. For instance, if relative movement is expected when attaching wood to a metal frame, washers can be utilized to screw the wood piece through larger holes on the metal frame. This will allow for some movement, minimizing the chance of damage over time.