ThirdEye: Materials Toolbox

Here's what you can find out about each material:

- **Thermal Protection**: Can this material withstand heat?
- **Flexibility**: Will this material change its shape if you put a force on it?
- **Density**: What is the weight of this material per unit of volume?
- **Strength**: Can this material perform a task without weakening or breaking?
- **Usefulness as Armor**: Will this material give protection against impact, chemicals, corrosion, cuts, tears, water, and fatigue?
- **Camouflage**: Can this material give you the ability to be invisible?
- **Cost**: Is this material cheap or expensive?

DEFINITIONS

Brittle: When stretched, a brittle material doesn't change its shape (deform) very much before it breaks.

Compression: See: Tension and Compression

Deformation: Elastic Deformation: This is a temporary, reversible change of shape. Plastic Deformation: This is a permanent, irreversible change of shape.

Ductile: When stretched, a ductile material changes its shape (deforms) a lot before it breaks.

Energy Absorption: A material with high "energy absorption" can hold energy from a load and release it later. A material with low "energy absorption" can't hold the energy from a load and reacts right away.

Fatigue: Fatigue is the weakening of a material after a small load is applied on it over and over.

Load: [Noun] A load is a force that an object has to act against. [Verb] To load means to apply a force on an object.

Malleable: When compressed (squeezed), a malleable material has a lot of *plastic deformation* before it breaks.

Stiff: When compressed (squeezed), a stiff material doesn't change its shape (deform) very much.

Strain: Strain is a measure of the change in shape that happens when a force is applied.

Stress: Stress is the amount of force (on a unit of area) that causes a change in shape.

Tension and **Compression**: **Tension** is a force that pulls a material apart. **Compression** is a force that squeezes a material together.

AEROGRAPHITE

Thermal Protection (0/10)

- Aerographite isn't used for thermal protection.

Flexibility (9/10)

- Aerographite is very flexible: It can be squeezed to a 30th of its original size (kind of like squeezing a basketball to the size of a baseball) without being destroyed—and then it can spring back.
- It can be made in different shapes.

Density (2/10)

- Aerographite is one of the lightest materials ever made: it's six times lighter than air.

Strength (8/10)

- Aerographite can carry up to 40,000 times its own weight (that's like a 12-year-old kid carrying a fully loaded space shuttle).
- It gets stronger when it's being squeezed together.

Usefulness as Armor (8/10)

- Same features that are listed for Strength.

Camouflage (0/10)

- Aerographite is not useful as camouflage. It's jet-black and you can't see through it.

Cost (9/10)

- Unknown. But this is a new technology, so the cost could be very high.

Notes and Links

- Aerographite is waterproof.
- Aerographite that is denser than usual can conduct electricity better.

ALUMINUM

Thermal Protection (4/10)

- Aluminum can be heated up to 600°C before it melts.
- BUT… heat also passes easily through aluminum (we say that aluminum "conducts" heat really well). That's not so great for keeping humans protected from heat.

Flexibility (8/10)

- Aluminum is easy to squeeze together and stretch without breaking it.
- Aluminum can be made into thin sheets—and it's easy to fold, roll, and pack.

Density (6/10)

- Aluminum is 2.7 times denser than water.

Strength (6/10)

- Pure aluminum is hard to break compared to many other materials.
- Aluminum gets stronger if it's combined with other materials. These aluminum "alloys" are used to build planes, trucks, and skyscrapers.

FACT: A fully-loaded tractor trailer can hang from a one-square-inch piece of aluminum alloy (if you use the very strongest aluminum alloy).

Usefulness as Armor (6/10)

- Aluminum can absorb a lot of energy (see energy absorption) but it's not bulletproof.

Camouflage (8/10)

- Aluminum is good at reflecting light—which means it's easy for our eyes to see.
- Aluminum can become transparent when it's hit by a very powerful laser (called a "soft X-ray laser").

Cost (1/10)

- Aluminum costs very little: only $1.93 per kilogram. (A kilogram is 2.2 pounds).

Notes and Links

- Aluminum is good at conducting electricity.
- It's safe for aluminum to touch your skin (it's "nontoxic").

DYNEEMA®

Thermal Protection (6/10)

- Dyneema melts at a temperature of 145°C.
- It's hard for heat to pass through Dyneema. (That means Dyneema is much better than aluminum at thermal protection.)

Flexibility (8/10)

- Dyneema is very flexible if you need to bend it.
- But…it can't be stretched very far lengthwise before it breaks.

Density (4/10)

- Dyneema is lighter than water.

Strength (8/10)

- Dyneema might be the strongest fiber in the world: it's 15 times stronger than steel and 1.4 times stronger than Kevlar.
- You can drop a very large load on Dyneema—very suddenly—and it won't break.

Usefulness as Armor (9/10)

- Dyneema is very good at absorbing energy. (See energy absorption.)
- It doesn't wear out when it absorbs water.
- Dyneema is very good at resisting chemicals, fatigue, cuts, and tears.

Camouflage (0/10)

- Dyneema isn't used for camouflage.

Cost (3/10)

- Dyneema's cost is reasonably low at $20 to $50 per kilogram. (A kilogram is 2.2 pounds.)

Notes and Links

- To find out where Dyneema came from, go to: thedyneemaproject.com/en_GB/the-fabrics/dyneema.html

GLASS

Thermal Protection (2/10)

- Glass is not very good at thermal protection.

FACT: Have you heard of "double-glazed" windows? They have two layers of glass panes. They're very good at insulating—which means that houses with double-glazed windows stay toasty warm when it's cold outside. But it's not because of the glass! There's a void between the two panes of glass—and the void is the part of the window that's good at insulating.

Flexibility (5/10)

- At every-day temperatures, glass shatters easily (which you know if you've ever dropped a glass bottle or a cell phone screen).
- New super-thin glass is flexible—and engineers are making glass that will even be foldable.

Density (8/10)

- Glass is 2.5 times denser than water.

Strength (6/10)

- It's hard to squeeze glass together to make it shorter. It's easier to pull it apart (in a laboratory, anyway).
- "Toughened" glass can hold up to more stress than regular glass.

Usefulness as Armor (6/10)

- Same features that are listed for Strength.

Camouflage (0/10)

- Glass is not useful as camouflage.

Cost (1/10)

- Glass costs very little: it's only $1.35 per kilogram (that's 2.2 pounds).
- Read all about using glass to build things in this article about unbreakable glass: https://www.nytimes.com/2009/07/07/science/07glass.html

GLASS FIBER

Thermal Protection (6/10)

- Glass fiber is good at thermal protection: it traps air that prevents heat from being transferred through.
- Glass fiber can be heated up to 850°C to 1050°C before softening. (Wow.)

Flexibility (7/10)

- It's easy to change the shape of glass fiber because it contains so much air.

Density (4/10)

- Glass fiber is very lightweight because it's made of a lot of air.

Strength (8/10)

- Glass fiber is stiff and strong. It takes a lot of force to pull it apart.
- Glass fiber can be made even stiffer and stronger by putting it in crisscrossing layers.

FACT: Glass fiber isn't as strong on humid days. That's because it soaks up water from the air—which makes any cracks and weaknesses in the fibers worse.

Usefulness as Armor (8/10)

- Same features that are listed for Strength.

Camouflage (0/10)

- Glass fiber is not good at camouflage. It can be made transparent or in different colors—but it's still visible to human eyes.

Cost (1/10)

- Glass fiber costs very little: only $1.00 to $4.00 per kilogram. (A kilogram is 2.2 pounds).

Notes and Links

- Fiberglass can irritate your eyes, skin, and respiratory system.

GRAPHENE

Thermal Protection (2/10)

- Graphene has to be heated to a *very* high temperature before it melts.
- BUT…graphene is pretty bad at thermal protection. That's because heat passes through it very easily—more easily than through almost any other material.

FACT: The longer a piece of graphene is, the better it is at conducting heat.

Flexibility (6/10)

- Graphene can be stretched until it's 20% longer.
- But it also breaks fairly easily if you bend it. (In other words, it's brittle.)

Density (2/10)

- Graphene is very lightweight.

Strength (10/10)

- Graphene is the *strongest material ever tested*—over 100 times stronger than the strongest steel.

FACT: A graphene hammock that weighs only as much as a cat's whisker could support the weight of an entire cat.

Usefulness as Armor (10/10)

- Same features that are listed for Strength.
- Graphene stands up to impacts *better than any other material*. (Graphene is 10 times better at it than steel.)

Camouflage (2/10)

- Graphene is almost transparent, so it's not good at camouflage.

Cost (10/10)

- Graphene is super expensive: around $100,000 per kilogram. (A kilogram is 2.2 pounds.)

Notes and Links

- Graphene is used to make touch screens, light panels, and solar cells.
- Graphene can conduct electricity better than copper.
- What is graphene's story? How was it discovered? Find out: https://www.graphene.manchester.ac.uk/site-map/

KEVLAR

Thermal Protection (6/10)

- Kevlar can stand up to temperatures as high as 450°C and as low as -196°
- Kevlar shrinks when it's heated.

FACT: If Kevlar catches fire, it can actually put the fire out itself.

Flexibility (6/10)

- Kevlar isn't very flexible on its own. But some types of Kevlar can be made into fibers that have more flexibility.

Density (7/10)

- Kevlar is lightweight.

Strength (8/10)

- Kevlar is five times stronger than steel of the same weight.
- Kevlar is stiff—so it's difficult to drill and cut it.
- It's harder to pull Kevlar apart than to squeeze it together.
- The higher the temperature, the easier it is to pull Kevlar apart.

FACT: Kevlar's strength goes down by 50% after 70 hours at 260°C.

Usefulness as Armor (8/10)

- You've probably heard of Kevlar being used in sports, in the military, and in personal safety equipment like helmets, bulletproof vests, and body armor. That's because it's very good at resisting impacts, scratches, and gashes.

Camouflage (0/10)

- Kevlar isn't used as camouflage.
- Kevlar's original color was yellow, but now it's available in other colors too.

Cost (4/10)

- Kevlar costs between $50 and $200 per kilogram (that's 2.2 pounds).

M5 FIBER

Thermal Protection (6/10)

- M5 Fiber is good at resisting high temperatures.

Flexibility (4/10)

- M5 Fiber is not very flexible. It breaks quickly when it's stretched even a little bit (by 1.4%).

Density (4/10)

- A protective system made from M5 fiber can be 40% to 60% lighter than one made from Kevlar.

Strength (8/10)

- M5 Fiber is stronger than Dyneema, Kevlar, and Spectra.

Usefulness as Armor (10/10)

- M5 Fiber is often used in lightweight armor.
- It's excellent at resisting damage and fire.

FACT: M5 fiber is better at resisting fire than any other organic fiber made by humans.

Camouflage (0/10)

- M5 Fiber is not used as camouflage.

Cost (5/10)

- The cost is unknown, but it will probably be more expensive than Kevlar.

METALLIC GLASS (AMORPHOUS METAL)

Thermal Protection (2/10)

- Metallic glass is good at keeping heat from passing through it.
- It exists only in thin layers.

Flexibility (5/10)

- If metallic glass is stretched lengthwise, it tends to come apart suddenly. But a processed form of metallic glass can be stretched to 1.2 times its original length.
- Metallic glass is not very stiff. If you heat it up, you can change its shape. When you cool it down, it gets its strength back.

Density (6/10)

- There are different kinds of metallic glass, each with a different density.

Strength (8/10)

- Metallic glass is very hard—and stronger than stainless steel.
- Because it's strong but not stiff, metallic glass can stand up to a lot of use and wear.

Usefulness as Armor (6/10)

- Metallic glass is good at resisting wear and corrosion.
- Metallic glass is *not* good at absorbing the energy of impacts—like from a bullet. (See energy absorption.)

Camouflage (2/10)

- Metallic glass is visible and has a shiny color—so it's *not* great at camouflage.

Cost (2/10)

- Metallic glass is easy to produce, so it tends to be low cost.

Notes and Links

- Metallic glass is good at conducting electricity.

MICROLATTICE

Thermal Protection (6/10)

- Microlattice is good at keeping heat from passing through it.

Flexibility (9/10)

- Microlattice is very flexible. It can be squeezed to 50% of its original size without being destroyed—and then it can spring back.

Density (2/10)

- Microlattice is made of 99.99% air.
- Microlattice is one of the lightest materials used in structures. It's only a bit heavier than air—and 100 times lighter than styrofoam.

Strength (9/10)

- Microlattice can carry about 1,000 times its own weight. That's like a 12-year-old kid carrying ten full-grown elephants!

Usefulness as Armor (8/10)

- Microlattice is extremely good at absorbing energy (See energy absorption.) which makes it very useful as armor.

Camouflage (0/10)

- Microlattice is not used as camouflage.

Cost (9/10)

- Microlattice is a new technology, so it could be very expensive.

NANOCELLULOSE

Thermal Protection (0/10)

- Nanocellulose is not used for thermal protection.

Flexibility (8/10)

- Nanocellulose can be stretched until it's 14% longer (and then it breaks).
- It can be used to make bendable batteries, super-flexible screens, and incredibly fine fibers.

Density (2/10)

- Nanocellulose is extremely light.

Strength (9/10)

- Nanocellulose is one of the strongest materials and as stiff as Kevlar.
- It can support 10,000 times its own weight. What does that look like? Imagine a 12-year-old kid carrying the world's largest passenger plane!
- It stays strong even when it's wet.

Usefulness as Armor (8/10)

- Nanocellulose is incredibly tough—and can even be bullet-proof.

Camouflage (0/10)

- Nanocellulose has a thick consistency—kind of like honey (we say it's "viscous").
- It's also transparent and is not used for camouflage.

Cost (2/10)

- Because there's plenty of nanocellulose around, it doesn't cost much—only $4 to $10 per kilogram (that's 2.2 pounds).

Notes and Links

- Read about making stronger armor and faster cars: techradar.com/news/world-of-tech/future-tech/the-amazing-material-that-promises-flexible-displays-faster-cars-and-bullet-proof-suits-1150030#article-body
- Nanocellulose can be made into foam.
- It can conduct electricity.

NYLON

Thermal Protection (5/10)

- Nylon is good at withstanding sunlight—but will easily catch fire if it's exposed to an open flame.
- Nylon will melt instead of burn at high temperatures.

Flexibility (8/10)

- Nylon is very flexible. It can be stretched lengthwise by 20% to 40% before it breaks.

Density (6/10)

- Nylon's density can vary, depending on how it's made.

Strength (6/10)

- Nylon is very tough and long lasting.
- It's used for things like seat belts and tire reinforcements.

Usefulness as Armor (8/10)

- Nylon is very resistant to wear and tear.
- Nylon is resistant to many chemicals—and other things like insects, fungi, animals, molds, mildew, and rot.
- It's waterproof and fast-drying.
- Nylon has low friction (meaning it's easy to slide on a nylon surface).

Camouflage (6/10)

- Nylon can be either shiny or dull.
- Nylon is transparent under infrared light.

Cost (1/10)

- Nylon costs very little at $2.5 to $3.5 per kilogram. (A kilogram is 2.2 pounds.)

Notes and Links

- Nylon is a good electrical insulator (meaning electricity doesn't go through it easily).

POLYCARBONATE

Thermal Protection (5/10)

- Polycarbonate is heat resistant. It can slow down the spread of fire.
- Polycarbonate starts to soften slowly at about 147°C degrees. (That's about 1.5 times hotter than boiling water.)

Flexibility (8/10)

- Polycarbonate can be stretched a lot before it breaks.
- It's easier to change the shape of polycarbonate when you heat it up.

Density (6/10)

- Polycarbonate is lightweight.

Strength (6/10)

- Polycarbonate is strong and tough, and it can stand up to impacts.
- It stays rigid (keeps its shape) at temperatures up to 140°C, and it stays tough at temperatures down to -20°C.

Usefulness as Armor (6/10)

- It can be used to make bullet-proof glass—and astronaut helmets!
- It's not good at resisting scratches.

Camouflage (0/10)

- Polycarbonate is transparent and not used for camouflage.

Cost (1/10)

- Polycarbonate is low-cost at $4.90 per kilogram. (A kilogram is 2.2 pounds.)

Notes and Links

- Polycarbonate absorbs very little water.
- Polycarbonate is a good electrical insulator (meaning electricity doesn't go through it easily).

POLYSTYRENE

Thermal Protection (7/10)

- Polystyrene is very flammable…BUT it doesn't let heat pass through it easily, so it's good for thermal protection.
- Polystyrene foam is often used to insulate buildings.

Flexibility (2/10)

- Polystyrene breaks easily—after being stretched only 3% to 4%.

Density (6/10)

- Polystyrene is lightweight.

Strength (2/10)

- Polystyrene is not very strong; it can't stand up to much force.

Usefulness as Armor (2/10)

- Same features that are listed for Strength.

Camouflage (0/10)

- Polystyrene is not used as camouflage.
- It's transparent—although colors can be added.

Cost (1/10)

- Polystyrene costs only $1.40 to $1.80 per kilogram (that's 2.2 pounds).

Notes and Links

- Polystyrene biodegrades slowly—so it stays around as litter for a long time.
- Polystyrene has some potential health risks (for example, it can harm the human nervous system).

RUBBER

Thermal protection (2/10)

- Rubber is not good for thermal protection because it's easy to heat it up and melt it.

Flexibility (10/10)

- Rubber is so flexible that we call it "hyperelastic."
- It can be stretched up to 700% before it breaks. That's like stretching a five-foot kid to the height of a telephone pole!
- Rubber is even easier to stretch at higher temperatures.
- As you decrease the temperature, rubber keeps getting harder and stiffer—until finally it turns into glass.

Density (6/10)

- Rubber is in the middle of all the materials in the toolbox: not very light but not very heavy.

Strength (4/10)

- Different kinds of rubber have different strengths.
- Rubber is a lot weaker when at high temperatures.

Usefulness as Armor (4/10)

- Same features that are listed for Strength.

Camouflage (0/10)

- Polystyrene is not used for camouflage.

Cost (1/10)

- Rubber is low-cost at $1.40 to $1.90 per kilogram. (A kilogram is 2.2 pounds.)

Notes and Links

- Rubber is waterproof.
- Rubber is good at keeping vibrations from passing through it.
- Rubber is a good electrical insulator (meaning electricity doesn't go through it easily).

SPIDER SILK

Thermal Protection (6/10)

- Spider silk fibers known as "dragline silks" can hold their strength at temperatures as high as 220°C and as low as -40°C.

Flexibility (8/10)

- Some spider silks can stretch up to five times their original length without breaking.
- In water, spider silk can shrink to 50% of its original length (we call that supercontraction).

Density (2/10)

- A strand of spider silk that's long enough to go around the earth would weigh less than 500 grams. (That's only a bit over one pound!)

Strength (7/10)

- Pound for pound, spider silk is about five times stronger than steel.
- It's about half as strong as Kevlar.

Usefulness as Armor (8/10)

- Spider silk is extremely tough and resistant to heat.

Camouflage (3/10)

- Spider silk is not invisible—but its silvery white color can be missed by human eyes.

Cost (8/10)

- Spider silk is very expensive. It costs about $37,500 to produce one kilogram (2.2 pounds) of spider silk.

Notes and Links

- Some spider silk strands can absorb three times more energy than Kevlar on a weight-to-weight basis. (See energy absorption.)

STAINLESS STEEL

Thermal Protection (8/10)

- Stainless steel keeps heat from passing through, so it's excellent at thermal protection.
- It doesn't melt until the temperature is very high.

Flexibility (6/10)

- The flexibility of stainless steel depends on its thickness.
- Stainless can be cut, welded, and stretched—but it's more difficult to bend.

Density (8/10)

- Stainless steel is nearly eight times heavier than water, and it's about three to four times heavier than aluminum.

Strength (6/10)

- Stainless steel is hard and durable.
- When stainless steel is made at lower-than-normal temperatures, it gets better at resisting forces that could pull it apart.

Usefulness as Armor (8/10)

- Stainless steel resists rust and stains, so it's easy to take care of.
- Stainless steel isn't fireproof, but it can be used at very high temperatures.

Camouflage (0/10)

- Stainless steel has a shiny silver color.
- It isn't used for camouflage.

Cost (1/10)

- Stainless costs very little at $2.5 to $3.0 per kilogram. (A kilogram is 2.2 pounds.)

Notes and Links

- Stainless steel is not toxic to humans (or any other living thing).

SYNTACTIC FOAM

FACT: Syntactic foam is formed by binding together tiny, hollow spheres that are made of materials such as glass or metal.

Thermal Protection (7/10)

- It's hard for heat to pass through syntactic foam.
- Syntactic foam doesn't expand much when it's heated.

Flexibility (8/10)

- It's easy to customize this foam by changing the tiny spheres (for example, changing their size or the material they're made from).
- Syntactic foam is stiff and hard to squeeze together.

Density (4/10)

- Syntactic foam is very lightweight.
- It's up to nine times less dense than aluminum.

Strength (8/10)

- Syntactic foam is probably the strongest foam in the world.

Usefulness as Armor (8/10)

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- Same features that are listed for Strength.

Camouflage (0/10)

- Syntactic foam is not used as camouflage.

Cost (4/10)

- Syntactic foam costs about $250 per kilogram. (A kilogram is 2.2 pounds.)

Notes and Links

- Syntactic foam is a great choice for making artificial hip joints and for other medical uses.
- Syntactic foam is good at resisting water.

TITANIUM

Thermal Protection (8/10)

- It's hard for heat to pass through titanium.
- Titanium melts at an extremely high temperature—about 200°C higher than the melting point of steel.

Flexibility (6/10)

- When it's cold, titanium is easy to break (we say it's brittle).
- When it's heated up, titanium is easier to squeeze and stretch.

Density (4/10)

- Titanium is 45% lighter than steel.

Strength (8/10)

- Titanium is the strongest of all metals that have the same mass. (For example, one kilogram of titanium is stronger than one kilogram of steel.)

Usefulness as Armor (8/10)

- Titanium is fire-resistant and bulletproof.
- It doesn't corrode (break down) easily.

Camouflage (0/10)

- Titanium has a silver color and is not used as camouflage.

Cost (2/10)

- Titanium costs $16 to $18 per kilogram (that's 2.2 pounds).

Notes and Links

- Titanium is not toxic.
- Titanium is not good at conducting electricity. (It conducts only about 3% as much as copper does.)

TUNGSTEN

FACT: You can't find pure tungsten metal in nature. It's rare and found only in certain minerals (we call that its "raw" form).

Thermal Protection (7/10)

In its pure form:

- Tungsten melts at a higher temperature than any other metal,
- It expands less than any other metal when it's heated,
- BUT…it lets heat pass through it easily (it's a good "conductor").

Flexibility (2/10)

- In its raw from: tungsten breaks easily and is hard to work with.
- In its pure form: tungsten stays hard but becomes easier to work with.

Density (8/10)

- Tungsten is one of the heavier materials you'll find in the toolbox: it's 1.7 times denser than lead.

Strength (6/10)

- It's difficult to pull tungsten apart (although it gets easier as the temperature goes up).

Usefulness as Armor (5/10)

- Tungsten's high strength is good for armor—but it's not bulletproof.

Camouflage (0/10)

- Tungsten is not used as camouflage.

Cost (4/10)

- Tungsten costs mostly in the range of $100 to $350 per kilogram (that's 2.2 pounds).