Based on the reinforcement type, composites can be divided into 3 basic groups

Basic classification

Composites

	1 Particle-reinforced	2 Fiber-reinforced	3 Laminate/sandwich
Description	A matrix reinforced by small or large particles	A soft, low-density matrix reinforced with stiff fibers to achieve high strength	Several sheets of different matrices bonded together to make one structure
Types	**Large-particle composites** E.g., cermet (ceramics and sintered metal) reinforced rubber **Polymer nanocomposites** Polymer based composites filled in with nanofillers (e.g. carbon nanotubes, montmorillonite)	**GFRP[1]** base resins (phenolic, epoxy) reinforced with glass fibers **CFRP[2]** thermosets (epoxies) or thermoplastics (e.g., nylon, PP, PU) reinforced with carbon fibers **Biocomposites** thermoplastics reinforced with natural fibers (e.g. wool, cotton, linen) **Aramid fiber composites** **Carbon-carbon** (carbon fibers in a carbon matrix) **Hybrid composites** (2 or more reinforcement fibers)	**Laminates** ▪ Alternating layers of 2 matrices (e.g., aluminum and glass fiber) held together by an adhesive ▪ The most widely used is GLARE[3]
4 Matrix	**Metal-matrix composites** Metal reinforced by very hard particles (e.g., ceramics) Alloys reinforced with woven/ filament-wound carbon fiber **Ceramic-matrix composites** Ceramic matrix reinforced with particles Ceramic matrix reinforced with fibers		**Sandwich structures** ▪ 2 thin, stiff skins are attached to a thick, lightweight core ▪ E.g., the core can be a honeycomb structure

1 GFRP: Glass Fiber Reinforced Plastic 2 CFRP: Carbon Fiber Reinforced Plastic 3 GLARE: Glass Fiber Reinforced Aluminum

SOURCE: Commentary on Composites (Aerostrategy, September 2006); Metal Matrix Cast Composites, LLC Web site; Hexcel Web site; Airbus Web site; Delft University of Technology; University of Virginia; McKinsey

With their superior properties composite materials can be used in variety of industries

		Application drivers	Existing challenges
	**Transportation**	Light weight, corrosion resistance, fatigue strength, styling and system cost savings	High material costs, lack of efficient manufacturing process
	**Marine**	Durability, design flexibility, impact and corrosion resistance	Already high adaption rate, need for extended life cycle
	**Aerospace**	Light weight, high strength, design and aerodynamics, sound dampening	Manufacturing process, specific maintenance requirements
	**Construction**	Light weight, design flexibility, increased durability and toughness	Higher cost, contractors' preference to use materials they are familiar with
	**Wind Energy**	Demand for renewable energy, high strength and toughness, corrosion resistance	Competition from traditional sources of energy, physical limits of wind energy, utilization of wind turbines
	**Sporting Goods**	Light weight, design flexibility, increased durability and toughness	Higher cost compared with traditional equipment
	**Industrial**	Increased durability and safety, corrosion resistance, insulating properties	Higher cost, contractors' preference to use materials they are familiar with

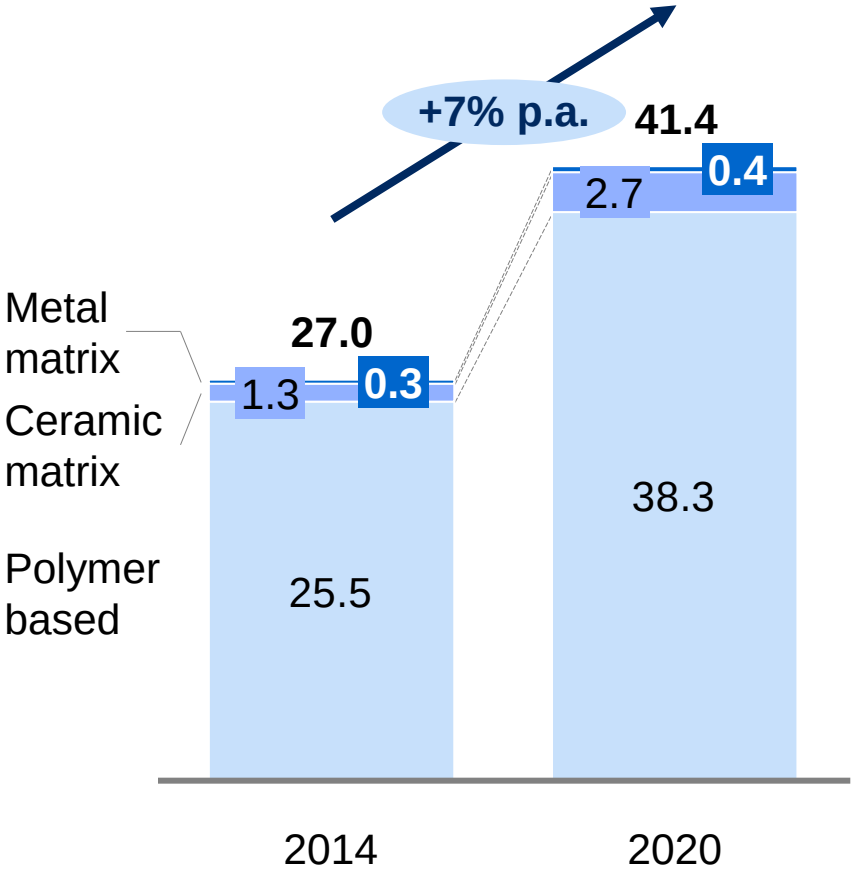
SOURCE: Composite World, Lucintel

Global composite market is dominated by polymer composites

ESTIMATES

USD billion

Global composite market by type[1]



CAGR 2014-20

7%

14%

7%

Types of raw materials

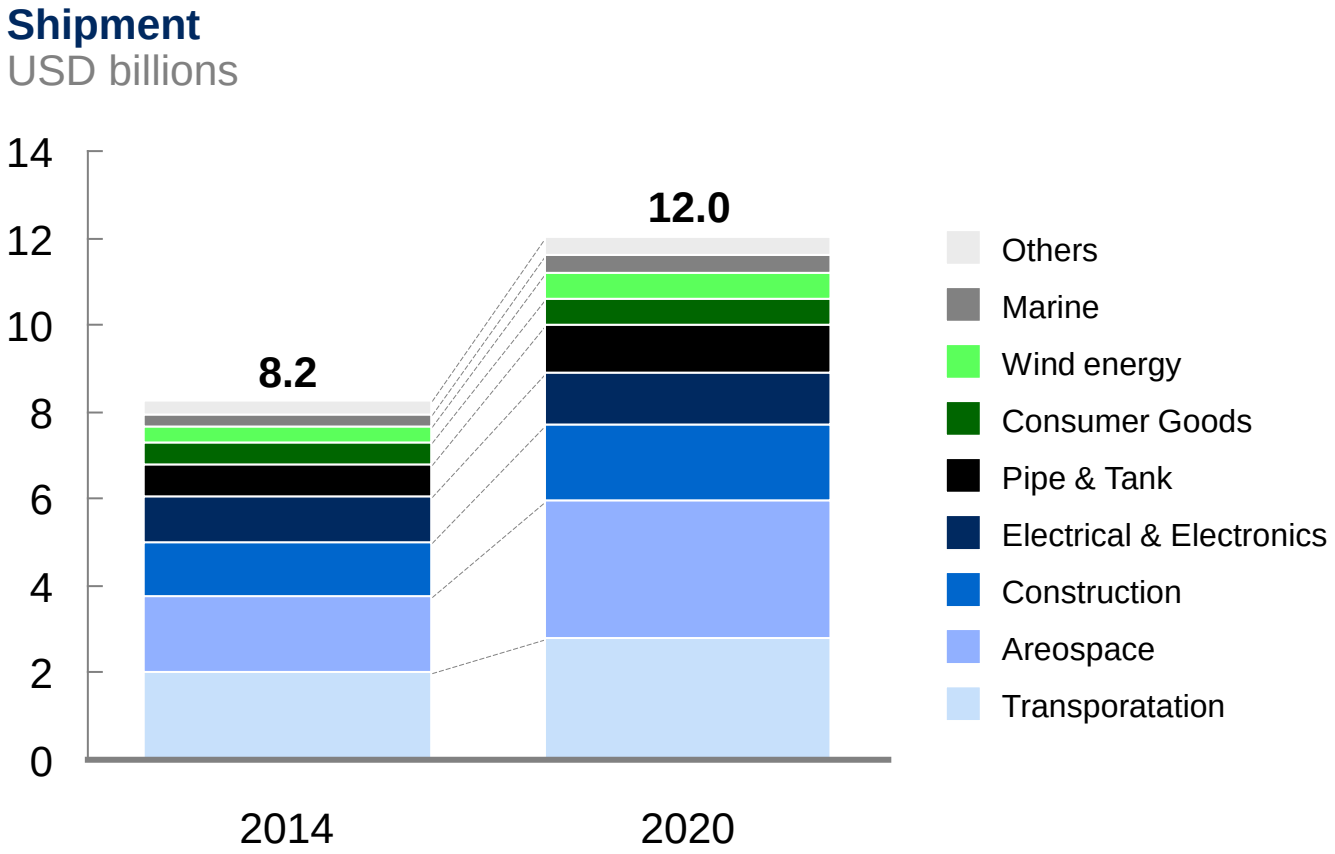
- Aluminum, nickel and refractory
- Oxide/oxide, silicon carbide/silicon carbide, carbon/ carbon and others
- Carbon fiber, glass fiber and aramid fiber reinforced plastics

1 Composite market as given in: Polymer based Lucintel (March 2014); Ceramic matrix Markets and Markets (December 2014); Metal matrix Transparency Market Research (May 2014)

SOURCE: Based on press releases announcing publication of reports from Markets and Markets, Transparency Market Research, Lucintel

Polymer composites are mainly used in transportation and aerospace industries, with the fastest growing market being aerospace

The US composite materials market forecast by application segments



SOURCE: Lucintel (from CompositesManufacturing Jan/Feb 2015)