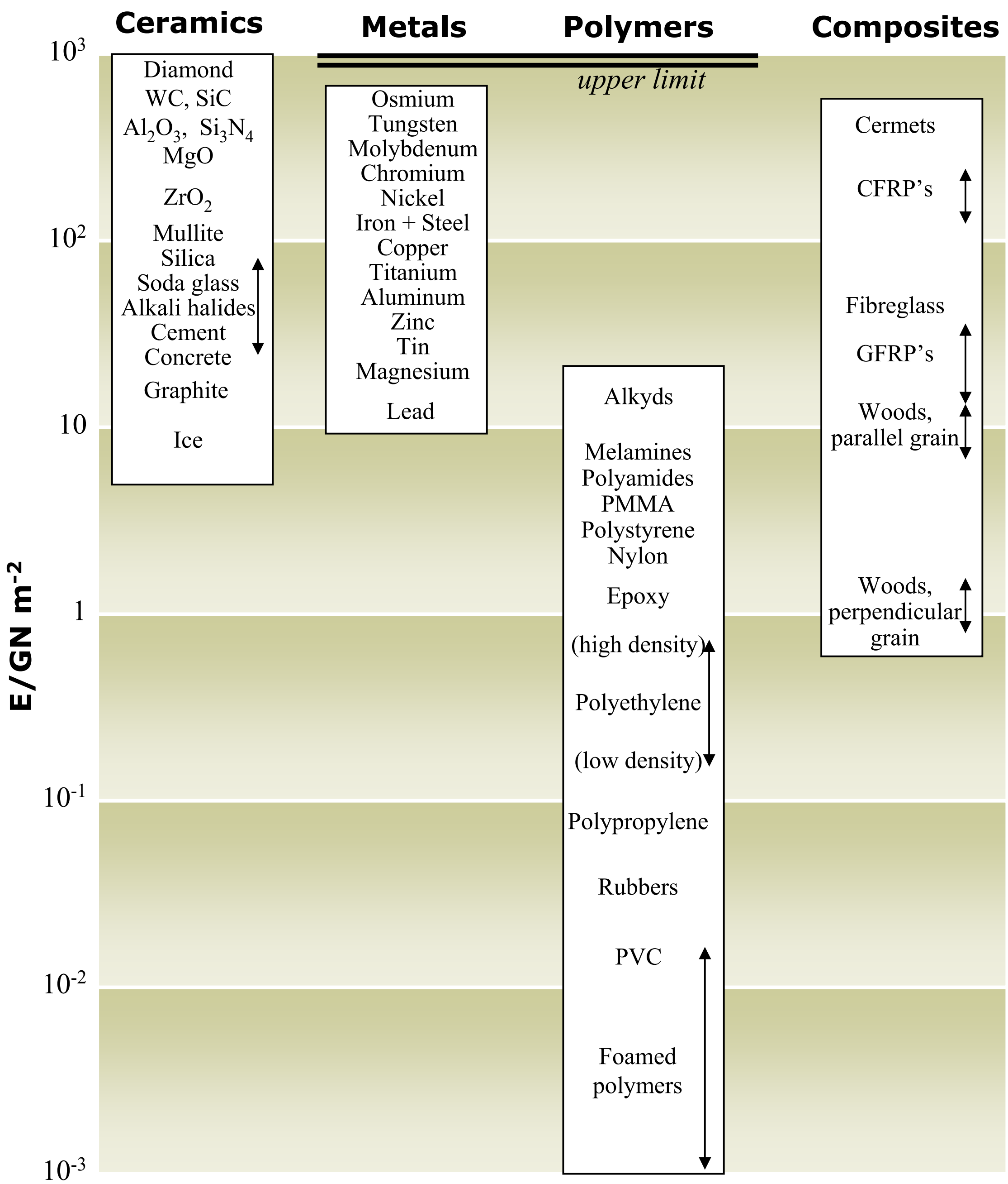
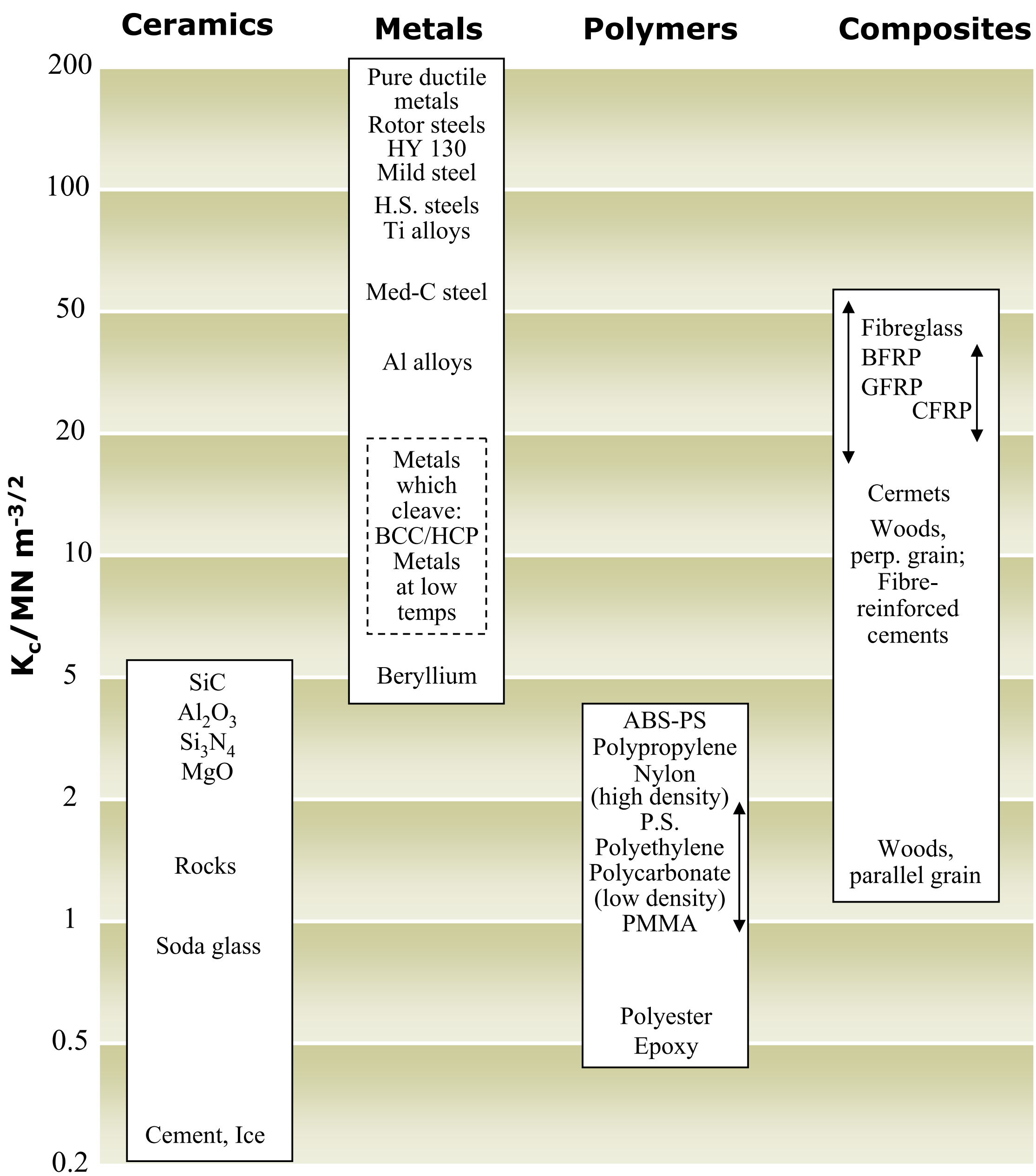
MATERIAL	Type	Cost ($/kg)	Density (ρ, Mg/m^3)	Young's Modulus (E, GPa)	Shear Modulus (G, GPa)	Poisson's Ratio (ν)	Yield Stress (σ_Y, MPa)	UTS (σ_f, MPa)	Breaking strain (ϵ_f, %)	Fracture Toughness (K_{Ic}, MN m$^{-3/2}$)	Thermal Expansion (α, 10^{-6}/C)
Alumina (Al_2O_3)	ceramic	1.90	3.9	390	125	0.26	4800	35	0.0	4.4	8.1
Aluminum alloy (7075-T6)	metal	1.80	2.7	70	28	0.34	500	570	12	28	33
Beryllium alloy	metal	315.00	2.9	245	110	0.12	360	500	0.0	5.0	14
Bone (compact)	natural	1.90	2.0	14	3.5	0.43	100	100	9.0	5.0	20
Brass (70Cu30Zn, annealed)	metal	2.20	8.4	130	39	0.33	75	325	70.0	80	20
Cermets (Co/WC)	composite	78.60	11.5	470	200	0.30	650	1200	2.5	13	5.8
CFRP Laminate (graphite)	composite	110.00	1.5	1.5	53	0.28	200	550	2.0	38	12
Concrete	ceramic	0.05	2.5	48	20	0.20	25	3.0	0.0	0.75	11
Copper alloys	metal	2.25	8.3	135	50	0.35	510	720	0.3	94	18
Cork	natural	9.95	0.18	0.032	0.005	0.25	1.4	1.5	80	0.074	180
Epoxy thermoset	polymer	5.50	1.2	3.5	1.4	0.25	45	45	4.0	0.50	60
GFRP Laminate (glass)	composite	3.90	1.8	26	10	0.28	125	530	2.0	40	19
Glass (soda)	ceramic	1.35	2.5	65	26	0.23	3600	35	0.0	0.71	8.8
Granite	ceramic	3.15	2.6	66	26	0.25	2500	60	0.1	1.5	6.5
Ice (H_2O)	ceramic	0.23	0.92	9.1	3.6	0.28	85	6.5	0.0	0.11	55
Lead alloys	metal	1.20	11.1	16	5.5	0.45	33	42	60	40	29
Nickel alloys	metal	6.10	8.5	180	70	0.31	900	1200	30	93	13
Polyamide (nylon)	polymer	4.30	1.1	3.0	0.76	0.42	40	55	5.0	3.0	103
Polybutadiene elastomer	polymer	1.20	0.91	0.0016	0.0005	0.50	2.1	2.1	500	0.087	140
Polycarbonate	polymer	4.90	1.2	2.7	0.97	0.42	70	77	60	2.6	70
Polyester thermoset	polymer	3.00	1.3	3.5	1.4	0.25	50	0.7	2.0	0.70	150
Polyethylene (HDPE)	polymer	1.00	0.95	0.7	0.31	0.42	25	33	90	3.5	225
Polypropylene	polymer	1.10	0.89	0.9	0.42	0.42	35	45	90	3.0	85
Polyurethane elastomer	polymer	4.00	1.2	0.025	0.0086	0.50	30	30	500	0.30	125
Polyvinyl chloride (rigid PVC)	polymer	1.50	1.4	1.5	0.6	0.42	53	60	50	0.54	75
Silicon	ceramic	2.35	2.3	110	44	0.24	3200	35	0.0	1.5	6
Silicon Carbide (SiC)	ceramic	36.00	2.8	450	190	0.15	9800	35	0.0	4.2	4.2
Spruce (parallel to grain)	natural	1.00	0.60	9	0.8	0.30	48	50	10	2.5	4
Steel, high strength 4340	metal	0.25	7.8	210	76	0.28	1240	1550	2.5	100	14
Steel, mild 1020	metal	0.50	7.8	210	76	0.28	200	380	25	140	14
Steel, stainless austenitic 304	metal	2.70	7.8	210	76	0.28	240	590	60	50	17
Titanium alloy (6Al4V)	metal	10.25	4.5	100	39	0.36	910	950	15	85	9.4
Tungsten Carbide (WC)	ceramic	50.00	15.5	550	270	0.21	6800	35	0.0	3.7	5.8



Source: Ashby, M.F. *Materials selection in mechanical design.* Boston: Butterworth - Heinemann, 1999.



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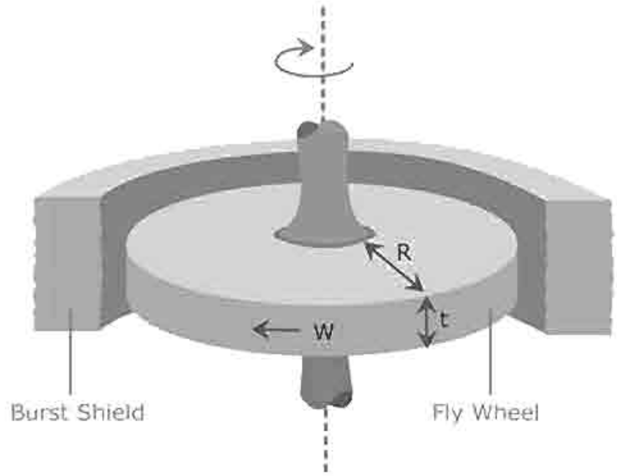
Materials Selection for Flywheels



Kinetic energy: $U = \frac{1}{2} I\omega^2 = \frac{1}{2}\left(\frac{\pi}{2}\rho R^4 t\right)\omega^2$

Mass: $m = \pi R^2 \cdot t \cdot \rho$

Energy per unit mass: $\frac{U}{m} = \frac{1}{4} R^2 \omega^2$

Stress: $\sigma_p = \left(\frac{3+\nu}{8}\right)\rho R^2 \omega^2$

Maximum energy density: $\frac{U}{m} = \frac{\sigma_f}{\rho} \cdot \left(\frac{2}{3+\nu}\right)$. ➔ Want maximum σ_f/ρ

See Fig. 10 in M.F. Ashby, *Materials Selection in Mechanical Design*, Pergamon Press, Oxford, 1992.