Design Materials with Specific Applications

Texture of metals is linked to specific physical properties, so the need to characterize it at nanometer scale

Titanium alloys are metals which contain a mixture of titanium and other chemical elements. Such alloys have very high tensile strength and durability (even at extreme temperatures). They are light weight, have extraordinary corrosion resistance and the ability to withstand extreme temperatures. However, the high cost of both raw materials and processing have limited so far their use in military applications, aircraft, spacecraft, medical devices, connecting rods on expensive sports cars and some premium sports equipment and consumer electronics. Auto manufacturers Porsche and Ferrari use titanium alloys in engine components due to its durable properties in these high stress engine environments.

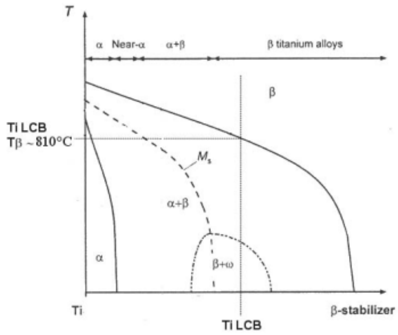
fight aircraft

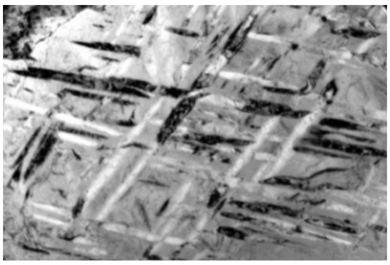
Guggenheim Museum, Bilbao, Spain

The challenge:	Identify orientation of a variants with respect to the mother phase
Solution:	ASTAR technique coupled with precession electron diffraction

Although "commercially pure" titanium has acceptable mechanical properties and has been used for orthopedic and dental implants, for most applications titanium is alloyed with small amounts of aluminum and vanadium, typically 6% and 4% respectively, by weight. This mixture has a solid solubility which varies dramatically with temperature, allowing it to undergo precipitation strengthening. This heat treatment process is carried out after the alloy has been worked into its final shape but before it is put to use, allowing much easier fabrication of a high-strength product.

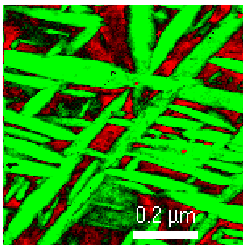
Nowadays, new titanium alloys are being designed, using cheaper elements as alloying elements. For example, Vanadium is replaced by Molybdenum or Niobium. This new alloy family is called Low Cost Beta (LCB) because of the stabilization at high temperature of the b bcc phase, giving rise to many variants of a hcp phase. These new compositions allow titanium alloys to be developed towards new applications such as in architecture (see the Guggenheim museum in Bilbao) where the exceptional properties of the alloy give rise to new shapes that defy gravity!



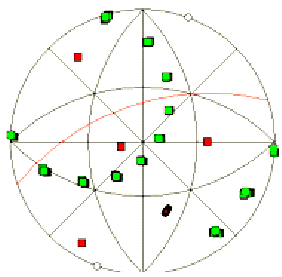


Crystal Structure

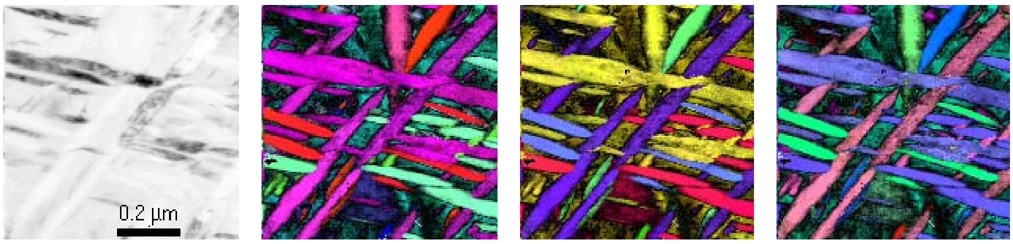
Ti α-phase:
Hexagonal $P6_3/mmc$
a=2.97 Å, c=4.72 Å
Ti β-phase:
Cubic $Im\bar{3}m$
a=3.28 Å



Red = β Green = α



(111) Pole figure



Experimental Data

TEM type: Jeol 2100F
Map resolution: 5 nm
Spot size: 1.6nm
Scanned area: 750x750nm

figure 1 (A) Ti alloy bright field TEM image (B) ASTAR phase map (C) ASTAR orientation map at nm scale z direction, (d) x direction, (e) y direction

Courtesy of Dr. Dong Qui, University of Queensland, Australia
W. Elmay, F. Prima, et al J. *of the Mech. Beh. of Biom. Mat.* in press (2012)