Adoption of MgB_2 Superconducting Magnets for the Ignitor Machine and Relevant R&D

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Introduction

The progress made in the fabrication of MgB_2 long cables, and related superconducting magnets of relatively large dimensions has led to the decision of adopting this material for the vertical magnetic field coils of the Ignitor machine. These will be the largest magnets (about 5 m in diameter) of the machine and will be cryocooled at temperatures around 10 K. This value is compatible with the He-gas cryogenic cooling system of Ignitor of the actual machine design as well as with the projected superconducting current density of the MgB_2 material, for magnetic field values ($\simeq 4 - 5$ T) in which these coils are designed to operate. The MgB_2 coils solution will avoid the adoption of a separate liquid-He cryogenic system that otherwise should be used for conventional superconducting NbTi wires. MgB_2 superconductors hold the promise of becoming suitable for high field magnets by appropriate doping of the material and of replacing gradually the normal conducting coils adopted, by necessity, in high field experiments. Therefore, an appropriate R&D program on the development of improved MgB_2 material and related superconducting cabling options has been undertaken, involving different institutions .

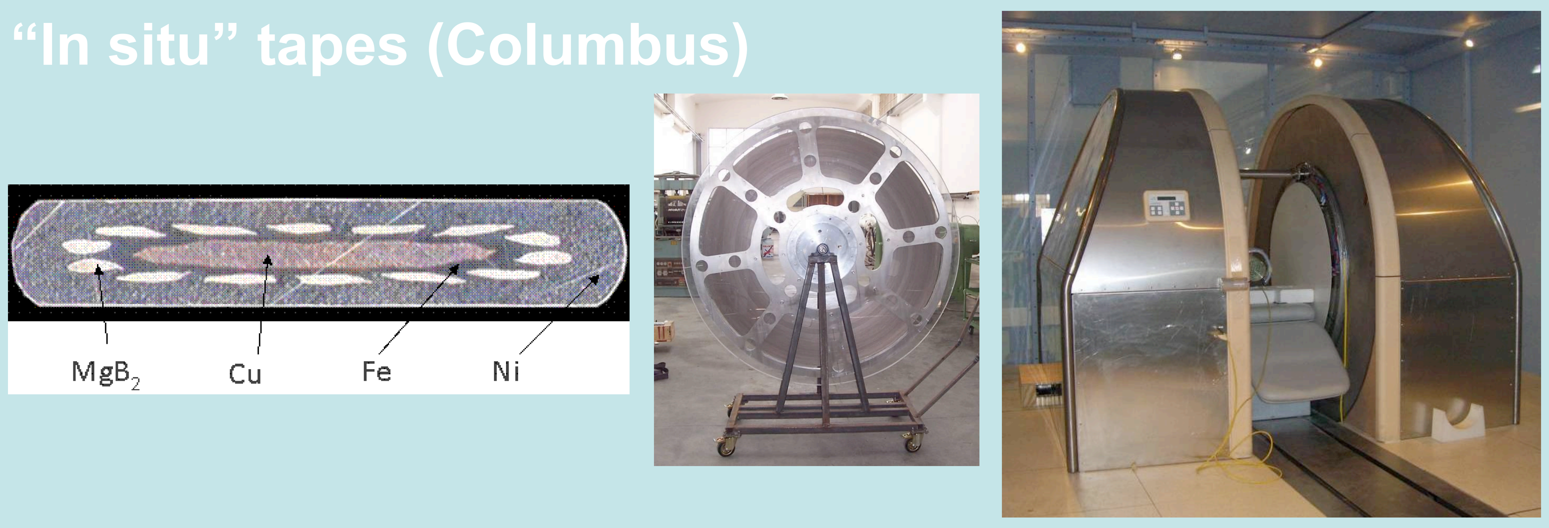
The MgB_2 wires : basic properties

The superconductivity of the MgB_2 , even if limited to temperatures lower than 39 K, represents a breakthrough in the field, due to several basic characteristics of the material. Its very simple crystal structure allows an easy conduction of the superconductive electronic pairs, even in the polycrystalline materials, being the coherence length substantially larger than the unit cell parameters. The most recent results indicate that an appropriate grain size reduction and crystalline substitutions by atomic dopants give a substantial improvement in the pinning properties and, consequentely, in the maintaining of the superconductivity at high magnetic fields. Furthermore all these beneficial physical characteristics are combined with very chip raw materials, a very low density that foresees low weigth large magnets and, finally, a relatively simple wire manufacturing.

Table 1 – MgB_2 basic properties

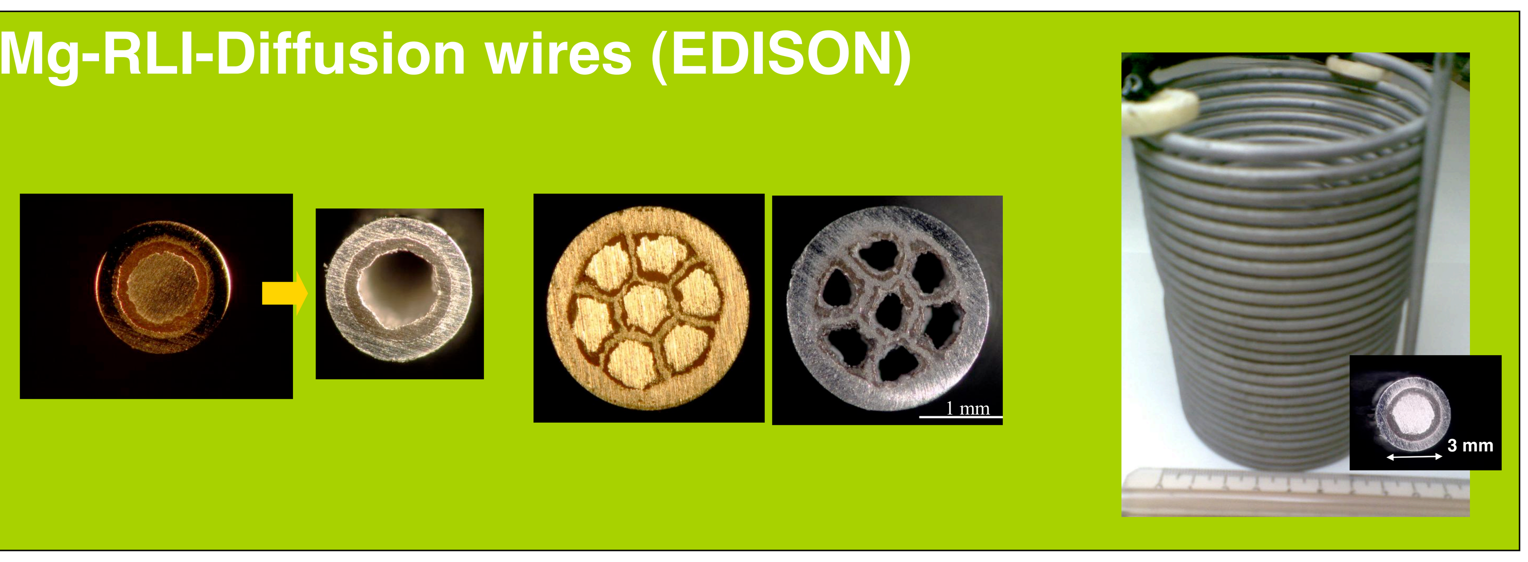
Tc (K)	39	
ξ = Coherence length (nm)	(//ab) 6	(//c) 3
Hex Unit cell (nm)	a=b= 0.3083	c= 0.3520
H_{irr}= Irreversibility Field (T) @ 20K	(Pure) 5.2	(C doped) 7.5
Density (g/cm^3)	2.63	

“In situ” tapes (Columbus)



“Ex situ” wires (Hyper Tech Res.)

Mg-RLI-Diffusion wires (EDISON)



The MgB_2 wire manufacturing

The issues related to the wire manufacturing of a ceramic-like material, as MgB_2, have been deeply explored, starting from the advent of the High Temperature Superconducting Oxides, and have originated a process route named “Powder in Tube” (PIT). In the MgB_2 case, both variants of the PIT process, “In situ”(B+Mg powders) and “ex-situ” (MgB_2 powders), have been attempted, both giving rise to the first industrial scale production of km long wires or tapes[1,2]. Together with these “conventional” wire processing routes the MgB_2 has demonstrated to be processable by a novel technique: the Reactive Mg-Liquid Infiltration (Mg-RLI) , obtaining very high density[3]. With this process, based on the self diffusion of the Mg melt, inside the B powders, bulk materials, wires and cables can be manufactured, hopefully bringing to better properties and a further simplification in the manufacturing of the MgB_2 material