MECHANICAL PROPERTIES OF DIRECTLY SLICED MEDIUM GRAIN NIOBIUM FOR 1.3 GHZ SRF CAVITY

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Introduction

- ILC-250 is an electron-positron collider that requires 7800 1.3 GHz SRF cavities.
- The TDR is already published but the cost of its construction is a major hurdle.
- High purity Niobium (costly) is used to manufacture 9-Cell 1.3 GHz SRF cavity.

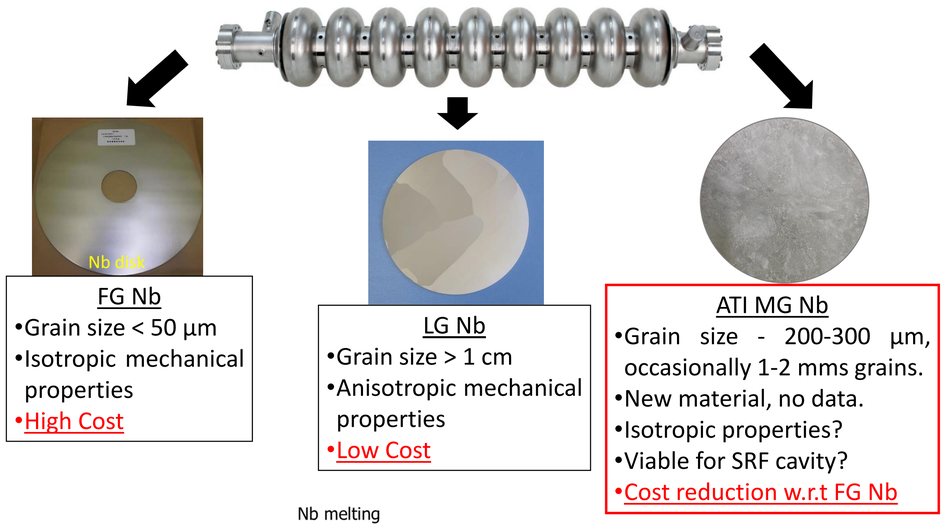


Fig. ATI MG Nb manufacturing and direct slicing with microscopic view of its grains

Table. ATI MG Nb specification

Chemical composition of ATI MG Nb billet →	C	H	O	N	RRR	Hardness (HV10)
	<20	<3	<50	<20	> 300	~ 41

In ppm

Mechanical properties measured by ATI →	ATI billet location	Y.S [MPa]	T.S [MPa]	Elongation [%]
	Top	56	146	52
	Bottom	61	141	52

Methodology

- Tensile tests are conducted to obtain mechanical properties of a material.
- Material is subjected to tension until failure to obtain Young's Modulus (E), 0.2% Yield Strength (Y.S), Tensile Strength (T.S) and Elongation.
- Shimadzu Autograph AG-5000C with Kyowa strain gages and Kyowa strain amplifier were used to conduct tests.
- Cross-head speed kept constant at 2 mm/min with strain rate of 4.4E-4 s^{-1}.

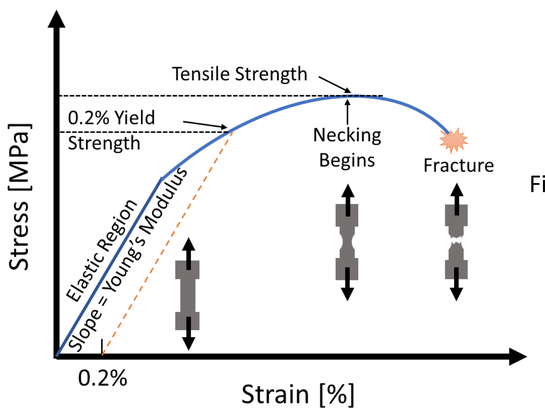


Fig. General stress-strain curve for a metal

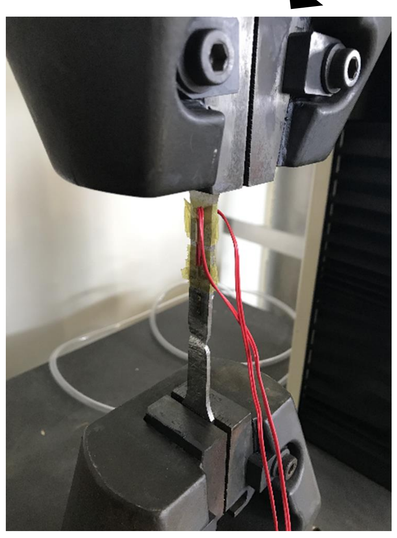


Fig. Room temperature tensile testing

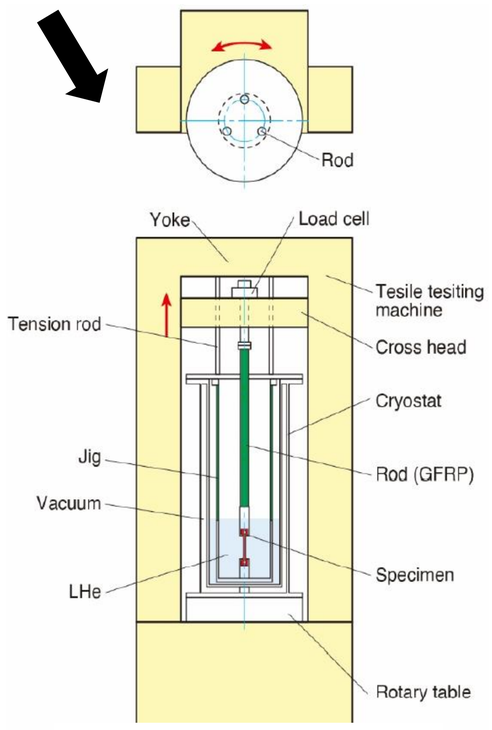
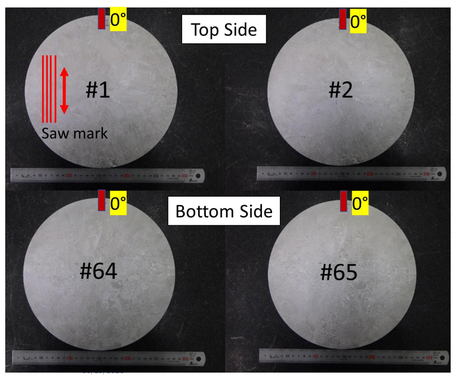
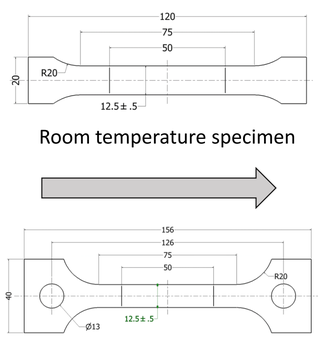


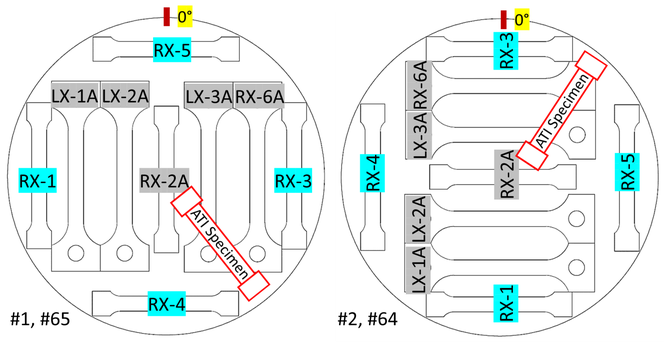
Fig. Tensile testing in liquid helium

Results and Discussion

- ATI MG Nb billet was sliced into 65 disks and specimens from top two and bottom two disks were cut for tensile testing.
- All disks were chemically polished, specimens were wire EDM cut and then chemically polished again (see fig below).
- A set specimens were annealed at 800 °C for 3 hrs and the remaining ones were not, considered as in As-received condition (ASR).
- Tensile tests were performed in room temperature and in liquid helium.







Specimen cut-out : R – room temperature, L – liquid helium temperature, X – Disk number, A – ASR.

- Mechanical properties are uniform throughout the billet with minimal deviation between annealed specimens (see table below).
- MG Nb initially thought to be isotropic, but it is likely anisotropic as grain size is non-homogeneous radially.

Table. Mechanical properties at room temperature

Position (sample no.)	Y.S [MPa]	T.S [MPa]	Elongation [%]	E [GPa]
	Annealed Specimen			
Top (8)	$38.1^{\pm0.5}$	$122^{\pm5.7}$	$26.4^{\pm3.7}$	$83.9^{\pm8.2}$
Bottom (8)	$37.9^{\pm1.4}$	$125^{\pm6.6}$	$22.5^{\pm3.9}$	$89.3^{\pm3.7}$
	ASR Specimen			
Top (4)	$48.3^{\pm7.1}$	$151^{\pm9.4}$	$17.7^{\pm4}$	$86.1^{\pm4.7}$
Bottom (4)	$41.1^{\pm2.7}$	$141^{\pm11.1}$	$22.9^{\pm5.6}$	$86.8^{\pm8.1}$
	15% drop	7% drop	uniform throughout	

Table. Mechanical properties in liquid helium

Position (sample no.)	Y.S [MPa]	T.S [MPa]	Elongation [%]	E [GPa]
		ASR Specimen		
Top (3)	-	$381^{\pm92.7}$	$1.3^{\pm0.1}$	$113.8^{\pm9.1}$
Bottom (3)	-	$375^{\pm18.7}$	$2.5^{\pm0.6}$	$114.4^{\pm18}$

- Average T.S is approximately 378 MPa.
- Y.S point couldn't be attained for most specimens.

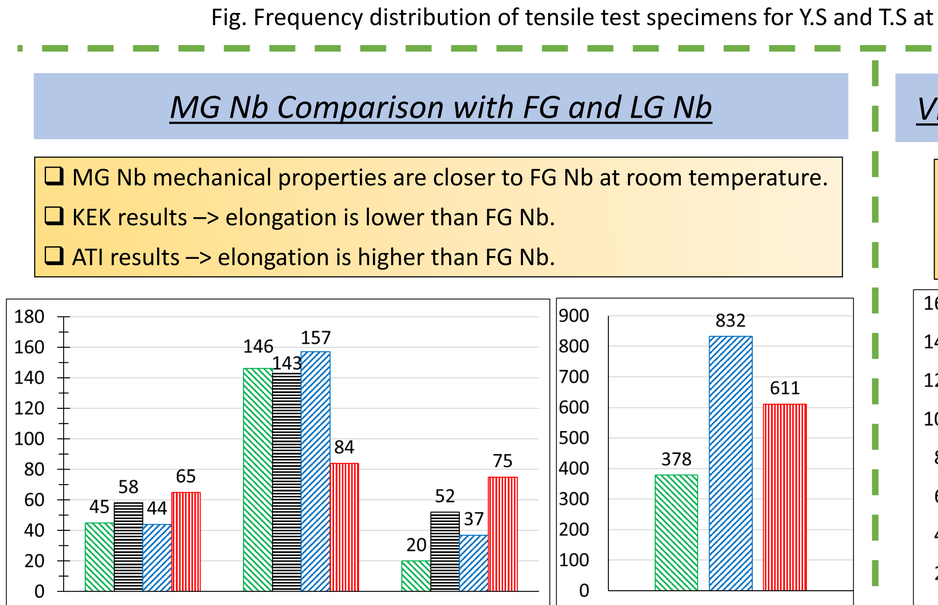


Fig. Stress-strain curves at room temperature for some specimens

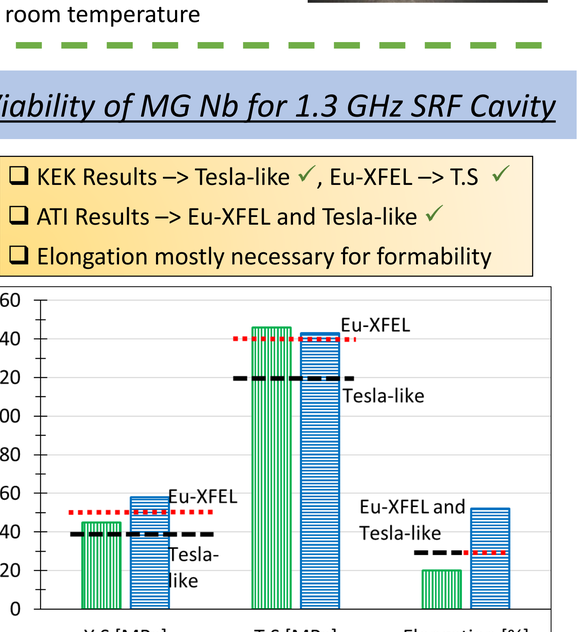
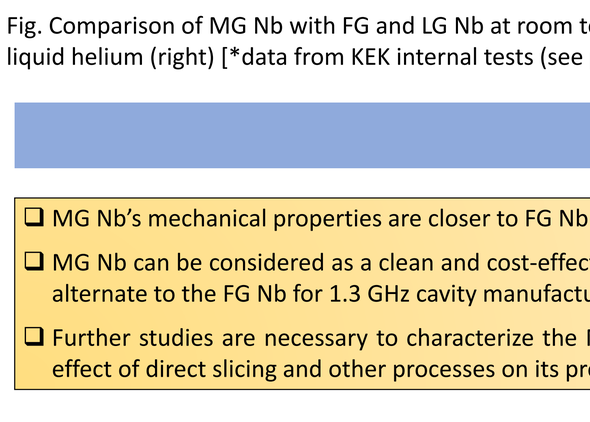
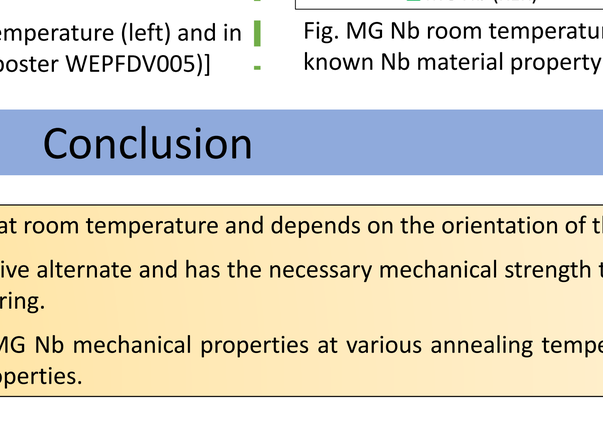


Fig. Stress-strain curves in liquid helium





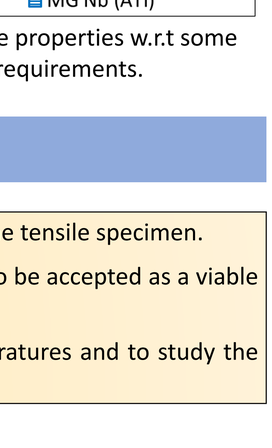


Fig. Frequency distribution of tensile test specimens for Y.S and T.S at room temperature

MG Nb Comparison with FG and LG Nb

- MG Nb mechanical properties are closer to FG Nb at room temperature.
- KEK results –> elongation is lower than FG Nb.
- ATI results –> elongation is higher than FG Nb.

Fig. Comparison of MG Nb with FG and LG Nb at room temperature (left) and in liquid helium (right) [*data from KEK internal tests (see poster WEPFDV005)]

Viability of MG Nb for 1.3 GHz SRF Cavity

- KEK Results –> Tesla-like ✓, Eu-XFEL –> T.S ✓
- ATI Results –> Eu-XFEL and Tesla-like ✓
- Elongation mostly necessary for formability

Fig. MG Nb room temperature properties w.r.t some known Nb material property requirements.

Conclusion

- MG Nb's mechanical properties are closer to FG Nb at room temperature and depends on the orientation of the tensile specimen.
- MG Nb can be considered as a clean and cost-effective alternate and has the necessary mechanical strength to be accepted as a viable alternate to the FG Nb for 1.3 GHz cavity manufacturing.
- Further studies are necessary to characterize the MG Nb mechanical properties at various annealing temperatures and to study the effect of direct slicing and other processes on its properties.