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Characterization of the Radiation Resistance of Glass Fiber Reinforced Plastics for Superconducting Magnets

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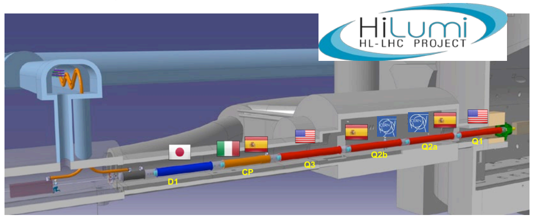
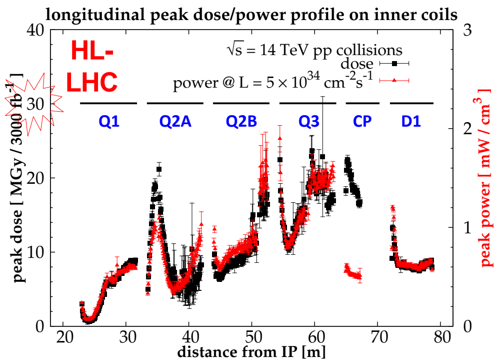
Abstract

- The overall performance of accelerator magnets strongly relies on electrical and mechanical robustness of their components. With an increase of the energy, future particle accelerators will have to withstand integral doses of ionizing radiation of up to ***several tens of MGy***.
- **Characterization of a spectrum of Glass Fiber Reinforced Polymers and resins** potentially interesting for superconducting magnets in **high radiation environment**, as a collaboration between CERN and KEK.
- An irradiation campaign was held with gamma-ray doses going from **10 to 100 MGy at QST Takasaki**.
- This paper describes the different methodologies applied to perform mechanical and chemical tests, both at room and cryogenic temperatures on a wide range of materials and resins.

Demand of SC magnets in high radiation environments

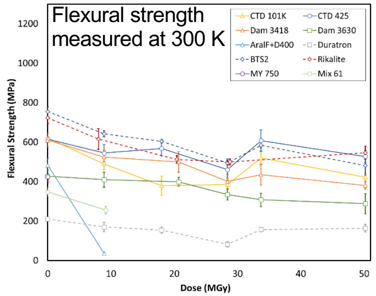


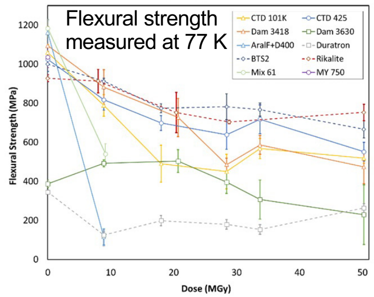


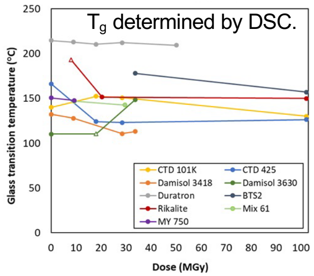
Materials

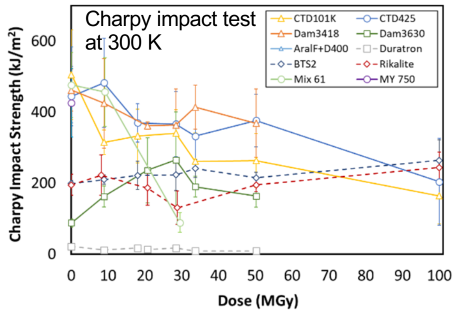
Denomination	Resin / Hardener	Vf %	Supplier
Duratron® PEI U2300	Polyetherimide / Unkown	17	Mitsubishi Chemical
BTS2 (S-BT6070)	Bismaleimide triazine / Unkown	55	Arisawa
Rikalite	Bismaleimide triazine / Unkown	52	Nippon Rika
CTD 101K	DGEBA epoxy / Methyl nadic anhydride	50	CTD
CTD 425	DCBE blend / Para-nonylphenol	50	CTD
Damisol®3418 API	DGEBA epoxy / Tetrahydrophthalic anhydride	50	Von Roll
Damisol®3630 HTP	Polyesterimide / Butanediol Dimethacrylate	50	Von Roll
Araldite F	DGEBA epoxy / Polyetheramine	50	Huntsman
Mix 61	DGEBA epoxy / Polyetheramine	50	Huntsman
Araldite MY 750	DGEBA epoxy / Aliphatic polyamine	50	Huntsman

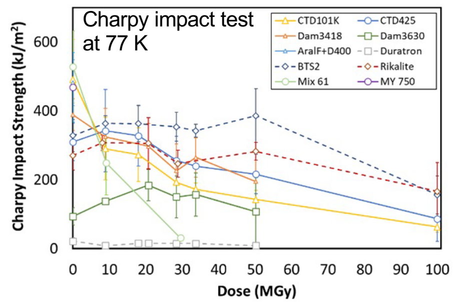
Results

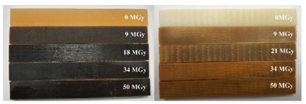




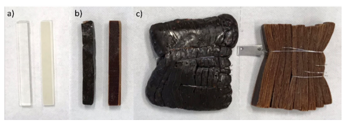






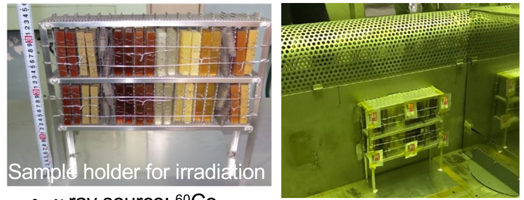


Colour changes in different radiation levels for CTD 101 K laminate (left) and Damisol 3418 laminate (right)

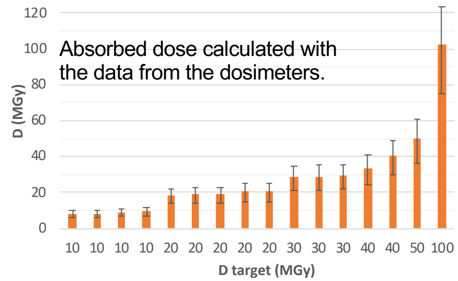


MY 750 (pure on the left and laminate on the right) irradiated at (a) 0 MGy, (b) 10 MGy, (c) and 20 MGy.

Experimental Procedure

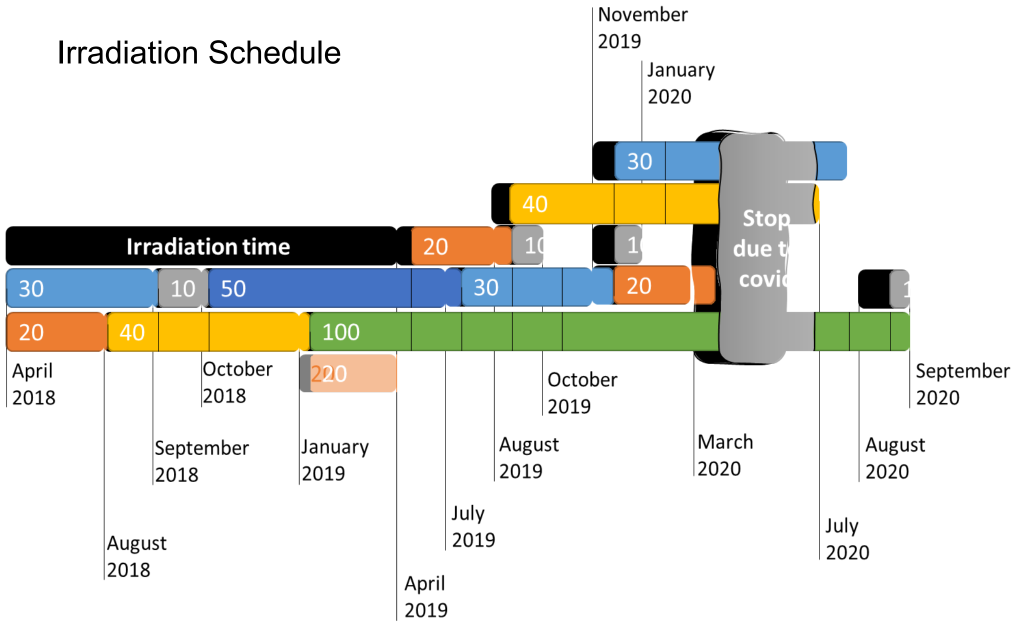


- γ ray source: ^{60}Co,
- average absorbed dose rate: 6 to 13 kGy/h,
- maximum sample temperature: 40-50 ºC,



Conclusion

- BTS2 and Rikalite showed better mechanical properties than the other laminates after irradiation.
- CTD 101K, CTD 425 and Damisol 3418 presented in general similar behaviour, although CTD 425 had slightly better mechanical properties.
- Damisol 3630 provides no significant advantage compared to them. Damisol 3418 could be a possible European alternative to the CTDs, but it should be noted that the resin takes a long time to degass and problems of voids formation are not uncommon in the samples.
- Mix 61 presents a significant loss of properties at 77 K at 10 MGy.
- Araldite F with Jeffamine D400 and MY 750 with Aradur HY 5922 should only be considered for doses much lower than 10 MGy.
- Duratron has the highest T_g (more than 210 ºC), but it has the lowest mechanical properties, which is expected since it was the only short glass fibre reinforced polymer tested.
- The Charpy impact test is a fast test that requires little preparation, but the dispersion of the results was too high to draw conclusions in most cases, especially for the resins.
- The thermograms obtained by DSC usually presented a difficult definition of T_g and a low repeatability of the results. The possibility of using other techniques to obtain T_g, such as the Dynamic Mechanical Analysis (DMA), should be studied.
- Looking at the dependence of Tg on many variables (curing, real absorbed dose, post-irradiation effects, operator, machine and interpretation of the thermograms) it should also be considered if this is a good parameter to detect the chemical changes in resins and laminates after irradiation.


Irradiation Schedule
Irradiation time
Stop due to covid
30
10
50
30
20
40
100
20
40
30
November 2019
January 2020
April 2018
August 2018
September 2018
October 2018
January 2019
April 2019
July 2019
August 2019
October 2019
March 2020
July 2020
August 2020
September 2020