Don Groom 20 Nov 2019

G10-FR4

Extracted from wikipedia:

> "G-10 is a high-pressure fiberglass laminate. It is created by stacking multiple layers of glass cloth, soaking in epoxy resin, and compressing the resulting material under heat until the epoxy cures.
>
> "FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant. It contain 7-8 % Bromide as Tetrabrombisphenol A."

The exact composition is manufacturer-dependent and likely not reproduceable, and we have in most cases been unable to find even a typical example.

The best we find is the specification list for materials used in the ALICE silicon strip detector (SDD): `http://personalpages.to.infn.it~tosello/EngMeet/ITSmat/SDD/` , and in particular `http://personalpages.to.infn.it~tosello/EngMeet/ITSmat/SDD/SDD_G10FR4.html` :

1. The glass fiber is E-Glass. The SSD pages give a detailed composition, but since many of the oxides appear only in trace amounts, we use the nearly-identical composition given in `https://www.azom.com/article.aspx?ArticleID=764` :

> "E-Glass is a low alkali glass with a typical nominal composition of SiO_2 54wt%, Al_2O_3 14wt%, CaO+MgO 22wt%, B_2O_3 10wt% and Na_2O+K_2O less then 2wt%. Some other materials may also be present at impurity levels."

I actually used 22wt% CaO and ignored the small amount of MgO.

2. The epoxy binder is Epoxy resin Epotek 301-1:

Part A

Diglycidyl Ether of Bisphenol A
$C_{19}H_{20}O_4$
70% of Part A by weight
56% of Epotek 301-1 by weight

1,4-Butanediol Diglycidyl Ether
$C_{10}H_{18}O_4$
30% of Part A by weight
24% of Epotek 301-1 by weight

Part B

1,6-Hexanediamine 2,2,4-trimethyl-
$C_9H_{22}N_2$
20% of Epotek 301-1

3. Between 1986 and 2006 the Review of Particle Physics listed G10 as 60% SiO_2 and 40% epoxy, presumably by weight. The source of these numbers is unknown. They were adopted for the SDD materials list, and interpreted as wt% of E-Glass and Epotek 301-1. We have been unable to find any references to typical proportions of glass and epoxy, and so use this ratio here.

While our results for the E-Glass and Epotek 301-1 are consistent with the SDD numbers, our radiation length in G10 is 32.17 g/cm^2 rather than their 30.17 g/cm^2.