Study of Silicon fiber sheet and read out strips panel based on it for the underground laboratories

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Introduction

The primary criterion for any underground laboratory is that almost all instruments and tools must be fire resistant. Keeping this in mind we have searched and tested various materials for making the readout strips panel for Resistive Plate Chamber (RPC) detector which will be used in India Based Neutrino Observatory (INO). INO required ~ 30k RPC detectors during full-fledged operation i.e. at least 60k readout panels to pickup the signals generated in gas chamber will be required. We have done short characterization of Silicon Fiber Sheet (SFS) [1-3], in addition to that we have investigated the elemental composition, effect of temperature, effect of pressure in term of weight on signal reflection for long duration, in this paper. Above mentioned investigations becomes very helpful for us in making our decision that silicon fiber sheet will be useful for us or not for the fabrication of the readout strips panel for underground laboratories.

Study of Elemental composition of SFS

Since we are planning to use the readout strip panels in an underground laboratory, it is necessary to have detailed knowledge about the composition of the material. For this, we have used the X-ray fluorescence technique because X-ray fluorescence (XRF) technique is the best possible available technique to determine the elemental composition of metals ceramics, glass and building materials around us. Elemental composition report of the SFS material is shown in Table 1.

Table 1: List of elemental composition of SFS material.

Compound	Wt. (%)	Std. Err.	El	Wt. (%)	Std. Err.
SiO_2	55.47	0.25	Si	25.93	0.12
Al_2O_3	39.63	0.24	Al	20.97	0.13
ZrO_2	2.62	0.08	Zr	1.94	0.06
SO_3	0.908	0.045	Sx	0.364	0.018
Na_2O	0.551	0.046	Na	0.409	0.034
Cl	0.362	0.018	Cl	0.362	0.018
P_2O_5	0.155	0.017	Px	0.0677	0.0074
HfO_2	0.0528	0.0042	Hf	0.0448	0.0035
CaO	0.0521	0.0043	Ca	0.0373	0.0031
Fe_2O_3	0.0454	0.0023	Fe	0.0318	0.0016
PdO	0.0376	0.0027	Pd	0.0327	0.0024
MoO_3	0.0262	0.0013	Mo	0.0175	0.0009
TiO_2	0.0206	0.0027	Ti	0.0123	0.0016
WO_3	0.0129	0.0035	W	0.0102	0.0028
CuO	0.0120	0.0022	Cu	0.0096	0.0018
NiO	0.110	0.0013	Ni	0.0086	0.0010
Y_2O_3	0.0093	0.0007	Y	0.0073	0.0005
Ag_2O	0.0065	0.0026	Ag	0.0061	0.0024
Ga_2O_3	0.0064	0.0009	Ga	0.0048	0.0007
K_2O	0.0050	0.0017	K	0.0042	0.0014
ZnO	0.0045	0.0009	Zn	0.0036	0.0007
Am_2O_3	0.0038	0.0012	Am	0.0035	0.0011
U_3O_8	0.0032	0.0013	U	0.0027	0.0011
Co_3O_4	0.0015	0.0007	Co	0.0011	0.0005

From table 1, one can see that around 98% of SFS is made up of mainly Si, Al and Zr as highlighted in the table, which are very common materials that form rock and sand. Therefore it almost fulfills our necessary criteria for the fire resistant property. Rest elements are just trace of SFS material.

Effect of temperature on SFS

To study the sustainability with temperature of Silicon fiber sheet dielectric material, we have placed small-small pieces of SFS into a tubular furnace in which MDC-1901 was used as temperature controller. We have observed that up to 100 ^{0}C there is no change in its physical appearance due to the effect of temperature. But after that it starts fuming. Figure 1 shows the variation in physical appearance of SFS with respect to temperature.

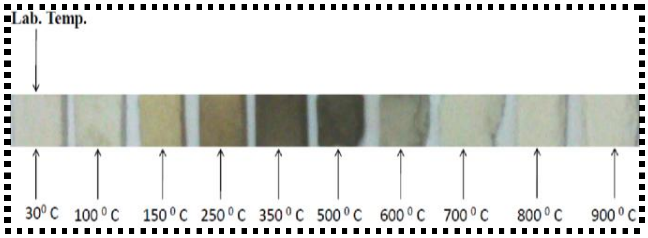

Fig. 1: Effects of temperature on SFS material.

During the performance of this experiment whatever we observed has been listed in Table 2.

Table 2: Sequential effects of temperature on the SFS material are tabulated.

Temperature (^{0}C)	Effect Observed
30	No effect
100	No effect
150	Starts slowly fuming and became slightly less in weight and also of light brown color.
250	Starts slowly fuming and became a little rigid than earlier and brown in color.

350	Starts fuming and became some more rigid than earlier, finally became dark brown.
500	Starts fuming and became like soft foam, finally became dark black.
600	Starts fuming but is faster than earlier and became little softer than earlier and finally became slightly white.
700	Starts fuming quickly and became completely white in color also was much softer than earlier.
800	Fuming is over within <5 seconds and became completely white; ultimately it also became very soft foam nature.
900	Fuming is over within <5 seconds and became completely white and finally it became very soft and very light in weight.

From the visual observation listed sequential in the Table 2, we may conclude that up to 100^0C temperature SFS sustain its chemical and physical properties. Although, the temperature of underground labs tend to be constant and is controlled at least in the main laboratories by air conditioning system. However the ambient rock temperature at 6010 mwe underground depth is 42^oC in the case of SNO lab [4] without any ventilation system. The 100^oC temperature is far away than the normal main laboratory temperature of any underground labs operated by human beings. One of the main observations is that we did not observe any flame coming out from the SFS at any time and at any applied temperatures. It shows that the use of SFS in any underground laboratories will not put any threat related to fire. In addition even up to certain temperature it will prevent other instruments from catching fire, which we must want for any underground laboratory for at least safety purpose. We have also observed that Polycarbonate (honeycomb) catches fire very rapidly. It seems that the polycarbonate based pickup strip panels which are commonly used in various gaseous detectors now-a-days are not suitable for the underground based laboratories in bulk.

Physical Properties of SFS

We have observed that Polycarbonate is rigid enough, so that, sometimes it cannot make proper contact with the surface of the detector's electrodes, however in case of SFS, we observed that it is flexible enough, so that it can be properly placed over the detector for making good contact with its electrodes surface. Due to the flexible nature of the SFS based read out strips panel it will be very easy to pick up the signals from the detector. Therefore such pick up panel may enhance the signal detection efficiency of the detector.

The SFS is a compressive material that can be pressed under pressure that may cause change in the thickness of the SFS material. We have observed the change in thickness with respect to pressure in terms of weight for longer time period [5]. Due to the pressure, equivalent to the pressure exerted by the two layers of float glass applied, small change in the thickness of SFS material is observed. This small change in thickness is not making any significant change in the value of impedance of pickup strip panel. We have dually checked this observation directly by using impedance matching circuit as well as LCR meter.

In Table 3 we have tabulated the comparative physical properties of SFS and Polycarbonate materials.

Table 3: Physical properties of materials under observation.

Properties	**Silicon fiber sheet**	**Plastic honeycomb**
Density (ρ)	0.3-0.6 (gram/cm^3)	1.20-1.22 (gram/cm^3)
Flammability	Non flammable	High
Water absorption over 24 hours	High resistant to moisture	0.1 %
Flexibility	Good	Poor
Radiation resistance	High	Fair
Ultraviolet (1-380nm) resistance	High	Fair
Melting temperature (Tm)	2100 ^{0}C	155 ^{0}C
Linear thermal expansion coefficient	80×10^{-6}	$65-70\times10^{-6}$
Dielectric constant @ 1 MHz	3.2	2.9

From Table 3 It may be seen that SFS based pickup strip panel will put less weight over the glass electrodes due to less density with respect to polycarbonate material. It may also be seen that laboratory humidity will not affect the performance of the SFS based pickup strip panel because SFS material is more prone with humidity.

Results and Outlook

From above discussion we may conclude that Silicon fiber sheet is more suitable material than polycarbonate i.e. plastic honeycomb material for making the readout strips panel for the underground laboratories. Therefore, we are in favour of making the Silicon fiber sheet based (as a dielectric material) readout strips panel for the underground laboratories. Study of the performance of SFS based pickup strip panel is ongoing.

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References

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