AMORPHOUS DIELECTRICS AS SENSORS FOR PARTICLE BOLOMETRIC DETECTORS AND MAGNETOMETRY

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Abstract

Recent experiments on the thermal, dielectric, and polarization properties of multicomponent silicate glasses at low temperatures have revealed a giant response to external perturbations in the presence of very weak and moderate applied magnetic fields. The general physical properties of amorphous dielectrics make them useful materials for low-temperature capacitive thermometry and this has prompted the quest for applications in the field of bolometric rare-event particle detection. Indeed, the dielectric constant in the absence of a magnetic field has a linear dependence on the logarithm of temperature below 1 K and this can be exploited to convert the energy released by a rare event into a capacitive electric signal when a ~ 1 kHz voltage is applied to the sensor. The proof of principle for the reactive criogenic bolometer has been demonstrated by the Como-Florence-Pavia DERBY project group by means of an alpha-emitting source attached to a capacitive glassy detector at 1 kHz frequency. This proof of principle experiment will be reviewed, however for applications concerning rare-event bolometric detection a d.c. voltage supply is preferred and this leads to loss of sensitivity for this type of capacitive sensors. The multicomponent glasses still hold the promise of becoming useful new temperature sensors for bolometric detection of rare events in particle physics research. Working detectors of neutrinos from, say, double-beta decay in TeO_2 crystal elements like in the CUORE experiment under the Gran Sasso, make use of resistive sensors coupled to the TeO_2 crystals that are made up of doped Ge wafers. These resistive sensors have the advantage of speed in response, but are intrinsically limited by the dissipative nature of the temperature-voltage conversion. We have therefore proposed to use capacitive thin-film low temperature sensors made up of a suitable glass film that, although not so quick in response, can offer theoretically a much higher inherently signal-to-noise-ratio based on the dielectric properties of the glass. It will be reported how the new sensor can be coupled to the bolometric detector and how its linear dependence of the dielectric constant as a function of the logarithm of the temperature for T<100 mK can be exploited to make improved particle detectors. It remains to exploit, however, the great sensitivity of multicomponent, multiphase glassy materials on the external magnetic field. This could be used in the search for exotic particles like magnetic monopoles or axions. Research is in progress to fabricate glassy materials with optimal colossal response to the magnetic field at low temperature. At very weak fields the response is of the quadratic type C(B)-C(0)=AB^2, with A positive or negative according to the material's phase composition. It is found that nanocomposite glassy matrices containing nanocrystals are candidate materials for reaching sensitivities on the magnetic field rivalling the SQUID superconducting magnetometers and work is in progress to demonstrate such proposition. A quantum statistical-mechanics theory will be presented to explain quantitatively this experimentally accessible possibility, notably the colossal

magnetocapacitance enhancement at $B<1000$ G and $T<100$ mK. The theory is based on an extension of the standard tunneling model for structural low-temperature glasses, suitably adapted to the problem. Many of the complicated features of the experimental findings in the presence of a magnetic field can thus be explained and hopefully exploited in particle research.