DESIGN AND TESTING OF A 4π TPB EVAPORATION SOURCE

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Many astronomical observations today can best be explained by postulating the presence of large amounts of never before observed non-baryonic particles. At the same time, many extensions to the standard model of particle physics predict new types of particles. Both fields call for a particle that does not interact through the strong force or electromagnetically and is thus invisible, or "dark." Attempts to detect interactions between normal matter and this Dark Matter have so far been unsuccessful or inconclusive because of the small interaction cross section.

The DEAP (Dark matter Experiment using Argon Pulse-shape discrimination) experiment aims to directly detect Dark Matter particles in the form of Weakly Interacting Massive Particles (WIMPs). At the center of the DEAP detector, shown in Fig. 1, are 3600 kg of liquified argon, which emits UV scintillation light in the rare event that a WIMP recoils from it. The argon is contained in an acrylic vessel with a radius of 85 cm to which photo multiplier tubes (PMTs) are optically coupled.

The inside of the acrylic vessel is coated with a thin film of the organic wavelength shifter 1,1,4,4-tetraphenyl-1,3-butadiene (TPB). It absorbs the UV scintillation light and reemits it as visible light, to which acrylic is transparent and to which the PMTs are most sensitive. The TPB will be applied by vacuum evaporation, and the thickness of the TPB layer determines the reemission efficiency. TPB comes as a crystalline powder with a nominal evaporation temperature of 205°C.

DESIGN OF THE EVAPORATION SOURCE

An evaporation source needed to be designed with the following requirements: Heat TPB up to its evaporation temperature and coat the 9 m^2 inner surface of the spherical acrylic vessel with a uniform and mechanically stable 0.90±0.25 μm [1,2] thick layer of TPB, without rotating the source or the vessel. No loose TPB must fall into the vessel and the source must fit through the detector neck.

SUMMARY

We describe the design and testing of the evaporation source that will be used to coat the inside 9 m^2 surface of the spherical acrylic vessel of the DEAP dark matter detection experiment with the organic wavelength shifter tetraphenyl butadiene.

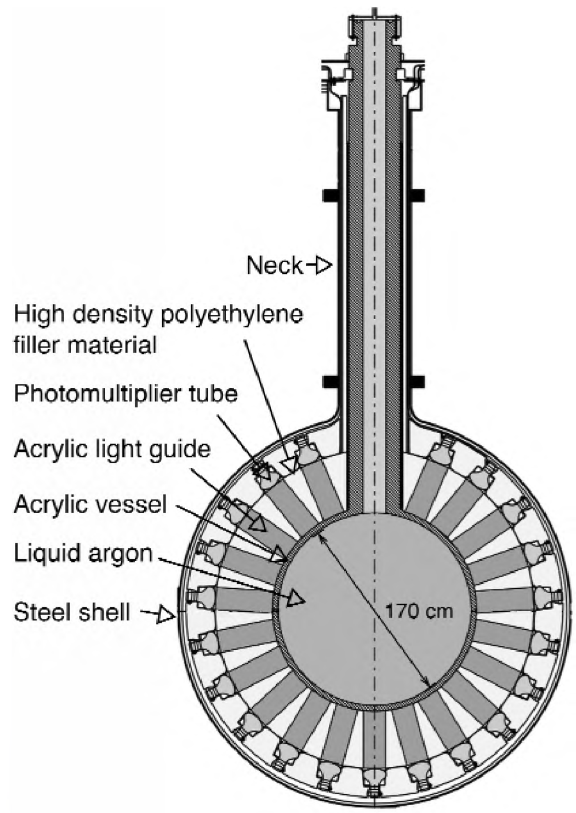

Fig. 1 Cross section of the DEAP-3600 dark matter detector. The TPB needs to be applied to the inside of the acrylic vessel.

A prototype TPB evaporation source was designed and built, shown in Fig. 2, which consists of an 11 cm diameter aluminum sphere punctured by 20 holes 1.3 cm in diameter, and a cylindrical copper crucible hanging in its center. The holes are arranged evenly on the surface while leaving as much of the bottom and the top of the sphere as possible closed, and the area of the holes was calculated such that random motion of the TPB molecules inside the sphere is ensured.

Fig. 2 The prototype large area TPB evaporation source.

The sphere is heated by running a current through the kapton-insulated nichrome wire wrapped around it, and the crucible with the TPB in it is heated radiatively from the sphere. The evaporation is controlled with two temperature sensors attached to the crucible and to the inside of the sphere.

TESTING

To test the performance of the source, a vacuum chamber in the shape of a cross was constructed, with the arms spanning the diameter of the acrylic vessel. Each arm was instrumented with a quartz crystal deposition monitor and the evaporation source was suspended from the top of the system to hang in the center of the cross.

Three evaporation trials were run with 9.5, 4.2 and 6.3 g of TPB evaporated, at a pressure of 1 to 9×10^{-5} mbar in the system. Acrylic beads were placed in the system for the third trial to simulate the rest-gas atmosphere in the DEAP-3600 vessel. Besides the thickness readings from the deposition monitors, the TPB uniformity and thickness on glass and acrylic samples placed in the system during each evaporation were evaluated using a stylus profile meter.

An average heat-up rate not larger than 2.6°C per minute was maintained to prevent micro-explosions and premature melting of the TPB in direct contact with the crucible. Once evaporation temperature was reached, the power to the nichrome wire was controlled by a computer to maintain a constant crucible temperature. The sensor readings for one evaporation are shown in Fig. 3.

RESULTS

The temperature profile during heat-up of the evaporation source was as expected and the crucible reached and maintained 200°C with fluctuations of less than 2°C.

The measured thicknesses for each evaporation, shown in Fig. 4, indicate an overall uniformity within the design

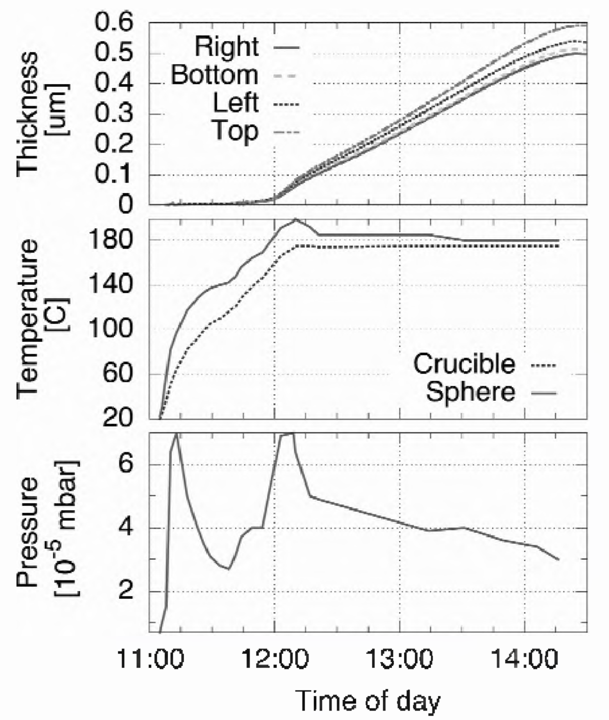

Fig. 3 Sensor readings during an evaporation. Top: Thickness readings from the four quartz crystal deposition monitors. Middle: Temperature sensor readings on the deposition source. Bottom: Pressure in the vacuum test system as measured at the right arm. The Pressure spikes each time the power to the heating wire is increased.

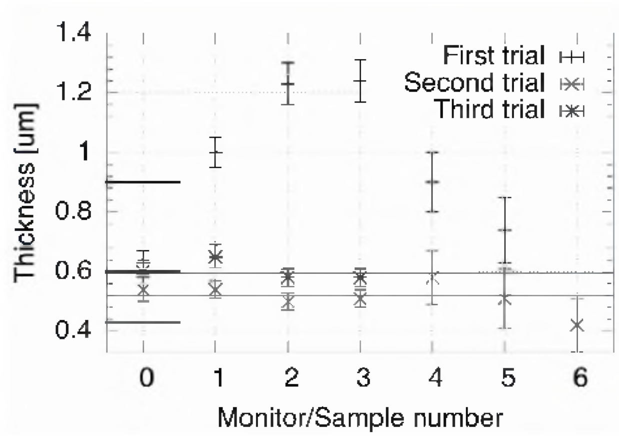

Fig. 4 Distribution of thicknesses at 85 cm radius from the source. Numbers 0 to 3 are the readings from the deposition monitors. Numbers 4 through 6 are the thicknesses glass and acrylic samples. The expected thickness is indicated by the short thick bars. The averaged thickness is indicated by the long thin lines.

specifications, with trial two and three several times better than the specification. The first sensor was shaded during the first trial and therefore did not give an accurate reading. All sensor readings were elevated for the first and second trial because they were taken before the system had cooled down. The third trial with accurate sensor readings indicates excellent uniformity and an averaged thickness matching the expectation.

The coatings on the glass samples were uniform with thickness variations less than 0.2 μm. Glass samples not in good thermal contact with the vacuum system were not reliably coated, probably because of the radiative heat load from the crucible. All acrylic samples had good coatings.

DISCUSSION

We have designed and tested an evaporative deposition source to coat the 9 m^2 of the DEAP-3600 acrylic vessel with the wavelength shifter TPB. The requirements of large scale and small scale uniformity were achieved. Even the trials where the deposition monitor readings were unreliable had a uniform enough TPB thickness distribution for the final experiment. The true uniformity, as seen in the last trial, is better than 5%. One drawback of this system is that the distribution of thicknesses could only be tested at four angles. The source was not kept at the same rotation angle for each evaporation, remedying this shortcoming to some extent. In future work, an evaporation test is planned on a small scale mock up of the detector vessel, before deploying the source in the actual detector.

REFERENCES

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