Aluminium Mirrors: An Alternative For Ground Based Cherenkov Telescopes

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Abstract

We present a novel alternative to the use of glass mirrors on ground based Cherenkov telescopes. Glass mirrors, whilst having excellent imaging characteristics, can become a limiting factor in the design of such telescopes, due to their weight and expense. We produce mirrors using an innovative vacuum forming process (global patent applied for), using only aluminium materials. The result is a mirror weighing and costing a fraction of that of a glass mirror. The method of production is described together with preliminary results of the shape conformity and reproducibility. The properties of the reflective surface are outlined, including robustness and specular reflectivity. This is shown to be superior to its glass equivalent particularly at wavelengths relevant to Cherenkov radiation.

1. Introduction

Two of the crucial factors affecting the performance of any atmospheric imaging Cherenkov telescope e.g. energy threshold, sensitivity etc, are the size of the light collecting area and the specular properties of the reflecting elements. These two factors are often limited not only by the engineering challenges of providing a stable support neccessary for the weight of a large reflecting area, but also by financial constraints. We concentrate here on the case where glass mirrors are used as reflectors, but the proposed alternative has advantages which could also be applicable to other reflector systems.
Low expansion glass mirrors, whilst having excellent optical properties are not ideally suited to the task of a ground based Cherenkov telescope, having several disadvantages:

- they are expensive to produce. Typically a half metre diameter spherical mirror costs in the region of US$1000;

- the aluminised surface has a limited lifetime and cannot be cleaned or even

pp. 2915–2918

touched without damage. The removal and shipment of mirrors for re-coating becomes a regular expense;

- the reflective properties are not optimal for Cherenkov radiation. Specular reflectivity on a good mirror may reach 85-90%;
- finally, and one of the most important factors, is their weight. The aforementioned mirror would weigh between 10-15kg. On a large telescope where several hundred of these mirrors would be used, this has major implications for the whole telescope structure e.g. construction, slew speed, stability.

The aluminium mirrors produced at the University of Durham are designed to address all these shortcomings.

2. Durham Mirror Construction

The method for producing the aluminium mirror (global patent applied for) is quite straightforward. A sheet of highly reflective aluminium, hereafter referred to as Miro^{TM}, is vacuum formed into a spherical concave shape over a suitable convex mould. The process is not limited to spherical shapes and gently curving parabaloid surfaces are equally attainable. Initially, a circular piece of aluminium honeycomb is bonded to the rear surface of the Miro. The adhesive used is an extremely strong compound with a low co-efficient of expansion, comparable to that of aluminium. An aluminium casing of a suitable shape is then bonded to the perimeter and rear surface of the honeycomb and Miro. Fig. 1. illustrates the construction method.

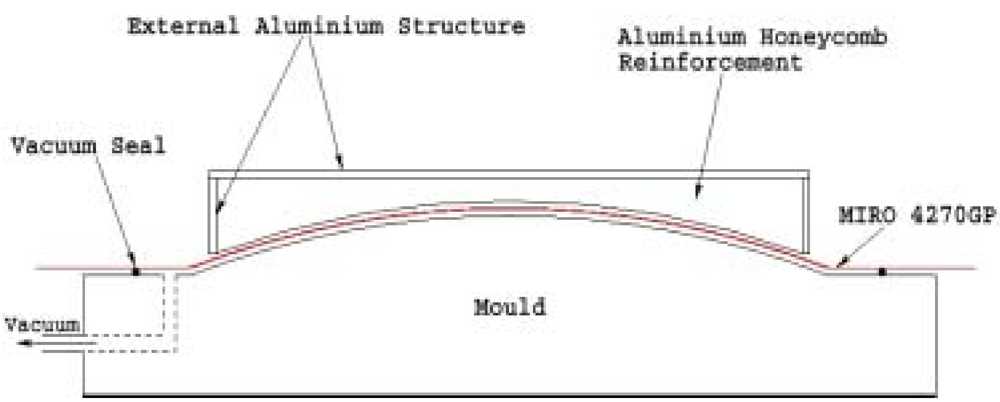

Fig. 1. Mirror Construction. (Not to scale, curvature exaggerated)

Depending on the temperature and humidity, the construction is left to cure for 2-4 days. Higher temperatures can significantly shorten the curing time but also makes the adhesive harder to work with.

3. Reflective Properties

The reflective surface (Miro 4270) used in the process is provided by Alanod Aluminium-Veredlung GmbH & Co. KG. It consists of an anodised aluminium base with an almost pure (99.99%) aluminuim layer bonded to it using a physical vapour deposition process. To protect this surface from the environment an oxide layer containing titanium and silicon oxides is then applied. The special techniques used by Alanod result in a surface with spectral reflectivity ≥95% in the blue region of the EM spectrum. (Fig. 2.).

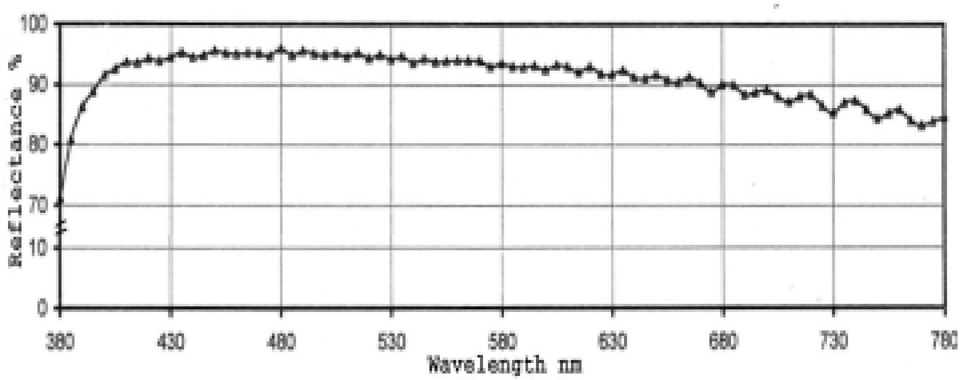

Fig. 2. Total spectral reflectance of Miro 4270KK. (Courtesy of Alanod.) (Note: The 'KK' suffix denotes that a clear laquer has been applied to the finished surface. Durham mirrors are made using Miro 4270GP (unlaquered), which has identical properties but is more suitable for this application)

This region of the spectrum is of particular interest to γ-ray astronomers since the emitted Cherenkov spectrum peaks at around 340 nm [1], diminishing gently into the optical. The detectable Cherenkov spectrum peaks at a longer wavelength, ∼380 nm due the frequency response of the fast photomultiplier tubes used in ground based Cherenkov telescopes. One of the advantages of Miro is that Alanod are able to 'tune' the reflectivity to different wavelengths by modifying the oxide layer. Fig. 2 shows the reflectivity declining sharply below 400 nm. This is due to absorption by the TiO_2 in the oxide layer. By reducing the amount of TiO_2, the reflectivity remains high, well into the near UV part of the spectrum. Fig. 3. demonstrates this shift for Miro 4400UP (a version providing slightly more diffuse reflection than Miro 4270).

4. Discussion

Optical tests and micron scale surface measurements of the mould show that the mirrors conform well to the shape of the mould and reproducibility is achievable. It has been noted that any small imperfection on the mould is

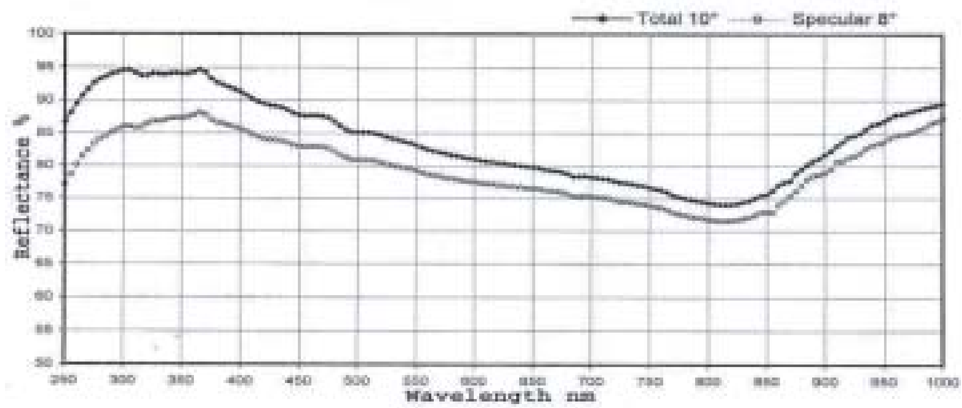

Fig. 3. Total spectral reflectance of Miro 4400UP at near normal incidence. (Courtesy of Alanod)

reproduced on the mirror surface. Further independent reflectivity measurements of the various grades of Miro will be conducted in the near future to determine the most suitable surface for the Cherenkov imaging technique.

5. Conclusion

Using a novel vacuum forming technique, we can produce aluminium mirrors with properties far more suitable for ground based Cherenkov telescopes than glass mirrors.

- The reflective surface, Miro, has a higher reflectivity in the region of Cherenkov radiation and is far more resistant to damage from handling, cleaning and environmental factors;
- The aluminium mirror is structurally less fragile than glass and easily allows connection of ancillary equipment e.g. steering controls;
- The aluminium mirror weighs ∼6kg compared to ∼15kg for glass. This reduces the restriction on the size of the telescope collecting area, due to the weight of the mirrors: an important factor when considering the energy threshold of a telescope;
- The aluminium mirror costs significantly less than a glass mirror, with a lower expected failure rate due to the simplicity of manufacture.

6. References

1. K.-M. Aye et al. Proc. 27th Int. Cosmic Ray Conf., 2919 (2001)