Coating Deposition Techniques

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Discussion on relevant coating deposition techniques

Thin film coatings are an essential component of all current and future gravitational wave detectors, particularly in relation to the multilayer mirror coatings required for high reflectivity. In addition to this, various other thin film coatings are being considered for applications such as (1) protective and/or conductive coatings for the suspension components (particularly the suspension elements), and (2) high emissivity films for the baffle pipes and other components located nearby to the cryogenic payload.

Ion-beam deposition (IBD): IBD is the current coating technique for the highly reflective laser mirror coatings for all interferometric gravitational wave detectors. Significant effort has been invested within the ELiTES program to better understand the cryogenic mechanical loss measurements of multilayer coatings of silica and tantala between the labs in Japan (Tokyo) and in Europe (Glasgow/Jena). Finding methods by which the room- and low-temperature mechanical losses can be reduced in these amorphous coatings will be crucial for future GW detectors, unless alternative fabrication techniques can be found (that can satisfy the optical and mechanical requirements). IBD exhibits the beneficial combination of high energy sputtering (resulting in a highly compact, non-porous, smooth/uniform, homogenous film) with the ability to minimise contamination. This enables optical absorptions at 1064 nm to be at the ppm level. Strong links are established between the ELiTES groups and various suppliers of ion beam sputtered coatings, *e.g.* O.S.I Industry Co (Japan), LMA (France), MLD (US), Gooch and Housego (US) *etc*.

Alternative sputtering/evaporation techniques: Various other methods are available for sputtering multiple layers of amorphous optical coatings, however reaching the low level of optical absorption achievable from IBD remains a significant challenge. Further development of these alternative sputtering technologies is underway within the ELiTES grouping. Facilities exist within UWS for carrying out e-beam evaporation with plasma assistance. **E-beam evaporation**, due to the lower energy levels involved, results in a lower density film. Researchers at UWS are developing a new generation of (clean) plasma assist sources that will compact the films without the introduction of contamination, with the aim to reducing the optical absorption. Various members of the ELiTES groups are also studying other sputtering techniques, such as **reaction magnetron sputtering**, which can be used to fabricate high quality laser mirror coatings. Reducing the optical absorption to levels comparable with IBD also remains a significant challenge here.

Protective, conductive and high emissivity coatings are also being considered for the suspension elements and other nearby components. These can be fabricated from a range of oxide and semiconductor materials using the above techniques. In addition, UWS has a unique **hollow cathode plasma-enhanced chemical vapour deposition (HC-PECVD)** system that was originally developed for coating the interior surface of cylindrical substrates with DLC (diamond-like carbon). The system features dual glass-sheathed tungsten anode heads, with the central section between the anodes forming the cathode. The central (pipe or tube) section of the system itself forms the reaction chamber, and the gas entry head can be moved on fixed rails to accommodate different lengths of cylinder substrate. Such a system is ideally designed for coating long substrates, such as the suspension elements and/or baffle tubes of future GW detectors.

The growth of crystalline thin films is also available through techniques such as **molecular beam epitaxy (MBE)** and **molecular organic chemical vapour deposition (MOCVD)**. Again, groups within ELiTES are actively studying MBE crystal films that are fabricated by academic and industrial partners in Stanford, Vienna, LMA (Lyon) and Glasgow. These films have the ability to be grown atomically smooth, with excellent control over the material composition and impurities. Crystal coatings look highly promising for use in future GW detectors, however significant work remains in characterising all of the relevant optical and mechanical properties at both room- and low-temperature, in addition to the suitability of these coatings being scaled-up for large mirror test masses (at least many tens of kilograms).