Institution: Loughborough University

Unit of Assessment: B9 Physics

Title of case study: Control of Reactive Sputter Deposition

1. Summary of the impact (indicative maximum 100 words)

Modern vacuum deposition processes for anti-reflection coatings on spectacles and other optical components which are in use by commerce and industry in the period 2008-2013 have been influenced by research on deposition process control that was undertaken in the Department of Physics at Loughborough University between 1993 and 2000. The primary impacts are a contribution to the development of stable processes that can be used at an economic rate by unqualified staff and by transfer of skilled people.

2. Underpinning research (indicative maximum 500 words)

The Physics Department at Loughborough University has always been active in research into thin film deposition. A key aspect of this has been the research on improving processes for depositing thin films, including oxides and hard coatings led until 2000 by the late Professor **R P Howson** (1967-2000, with 1996-7 at Kyoto University).

Planar magnetron sputtering is one of the most important methods for depositing thin films. Metal atoms are sputtered from a metal target and condense on a substrate. As many important coatings are non-metallic, the process gas is often a mixture of an inert gas, argon, and a reactive gas, for example oxygen, which reacts with the growing metallic film to make a compound. Unfortunately the oxygen or other gas also reacts with the surface of the target (source material) to make an insulating layer that changes the electrical circuit and reduces the deposition rate dramatically. This effect is known as "poisoning". Control methods for the avoidance of poisoning are known but often require skilled intervention. One of the themes of the Howson group at Loughborough University was improving control methods to provide stable, reliable, configurations for more routine use.

The importance of oxide thin films to modern technology cannot be overstated. Examples of their application are as transparent conducting coatings for energy-conserving architectural coatings and flat-screen displays, hard and anti-reflective coatings on spectacles, and diffusion barriers for food packaging. The Howson group researched primarily in transparent conducting coatings but then used this process expertise to inform other developments in other areas.

Part of Ron Howson's research, including the period 1993 and 2000, focussed on making reactive sputtering controllable: this particular know-how underpins the impact. The central principle was to control the reactive gas automatically using feedback from techniques such as target voltage monitoring **[3.1, 3.2]**, plasma emission monitoring **[3.2, 3.3]**, and medium frequency power supplies **[3.1]**. The aim was to control the magnetron on the edge of poisoning to maximise deposition rate and so minimise deposition time. It also aimed to maximise the use of energetic deposition from unbalanced magnetrons, to densify the films and improve adhesion **[3.1, 3.2]**. In this scheme some plasma leaks from the magnetron and impinges on the growing film, improving structure and increasing oxidation. The reactive sputtering research programme during this period was supported both by UK industry and the Research Councils, including a LINK grant **[G3.1]** and an EPSRC grant **[G3.2]**.

3. References to the research (indicative maximum of six references)

Comment: these are all published in peer reviewed international journals.

3.1. N Danson, G W Hall and R P Howson, *Improved control techniques for the reactive magnetron sputtering of silicon to produce silicon oxide and the implications for selected film properties*, Thin Solid Films, 289(1-2) (1996) 99-106. DOI: 10.1016/S0040-6090(96)08881-5.

3.2. N Danson, I Safi, G W Hall, R P Howson, *Techniques for the sputtering of optimum indium-tin oxide films on to room-temperature substrates*, Surface Coatings and Technology, 99(1-2) (1998) 147-160. DOI: 10.1016/S0257-8972(97)00436-2.

3.3. **R P Howson**, N Danson and I Safi, *High rate reactive sputtering using gas pulsing: a technique for the creation of films onto large, flat substrates*, Thin Solid Films, 351(1-2) (**1999**) 32-36. DOI: 10.1016/S0040-6090(99)00081-4.

Grants

G3.1. “Multilayer nanometre thin films for ophthalmic lenses” LINK Scheme between Loughborough University and Applied Vision Ltd, **R P Howson** and J M Walls £101,300, **1/4/94-31/6/97**

G3.2. “Display Technology Alliance: Advanced Substrates for Displays” M D Cropper and **R P Howson** EPSRC £50k **1/1/97-31/3/00**

4. Details of the impact (indicative maximum 750 words)

An important pathway to impact for this research on the coatings industry was knowledge transfer. It is now widely recognised that energetic deposition provides superior films to those made by other methods and that careful plasma control is essential. Several former Loughborough University research students work for UK and international coatings research and production companies or run thin films consultancies, offering expertise in thin films deposition, including oxides.

One clear example of the impact of thin film technology is coatings for spectacles and precision optics. Anti-reflective coatings (lens blooming) are well known. However, former coating technology was less suited to mass production at an economic rate. In addition, technology switched from single layers to much more effective multilayer coatings, requiring more advanced technology. Sputter deposition offered a route to economic production of multi-layers using robust equipment with long service intervals, provided the control issues could be overcome. The wide-spread modern-day availability of same-day scratch resistant and antireflective coatings from high street opticians speaks volumes for the impact of this area of applied physics. There is a real high-street need for lens coating technology: modern spectacle lenses are plastic and therefore need hard coating. In addition, fashion dictates that customers wish to have an anti-reflective coating.

Loughborough University has played a role in these developments. The joint grant **[G3.1]** between Loughborough University and Applied Vision (a local SME) assisted production of a stable, reliable, commercial process for coating anti-reflective coatings onto spectacles **[5.1]**. The Unit is aware of at least ten of these coaters still in use in UK and European manufacturing operations **[5.1]**, they are robust and can be operated by non-specialists. Before this REF period, Applied Vision sold one hundred and eighty machines each capable of coating about one hundred lenses/per day: 95% for export to Europe and the rest of the world. The key selling point was its simplicity of operation resulting in the continued use of this equipment to date.

This process and machines such as those produced by Applied Vision have contributed to the time saving convenience such as chains of opticians enabling them to offer spectacles to customers within the hour. Such technology, to which research at Loughborough contributed, thus contributed to improved business processes and helped shape the modern high street. Hence the work that was done at Loughborough in developing stable reactive deposition processes has helped change the commercial landscape in the UK and elsewhere.

[Text removed for publication]

5. Sources to corroborate the impact (indicative maximum of 10 references)

The following sources of corroboration can be made available at request:

5.1. Letter from Proprietor, Alacritas Consultancy Ltd., 196 Main Street, Markfield, Leicestershire, LE67 9UX.

5.2. [Text removed for publication]