

Nanometrology Project Produces Technology That Advances Super-Smooth Optical Thin Films

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Magnetron sputtering produces super-smooth thin films and can be used for high-throughput production.

Nanometrologie-Projekt liefert eine Technologie, die superglatte optische Dünnschichtfilme ermöglicht
Magnetronsputtern produziert super-gleichmäßige dünne Schichten und kann für die Produktion mit hohem Durchsatz verwendet werden.

Un projet de nanométrie produit une technologie qui fait progresser les films optiques fins et super lisses

Le crépitement du magnétron produit des films fins et super lisses qui peuvent être utilisés dans des productions à haut rendement.

Un progetto di nanometrologia genera soluzioni tecnologiche che migliorano le deposizioni ottiche di film sottili a bassissima rugosità residua

La tecnica di sputtering tramite magnetron produce strati sottili estremamente "lisci" e può essere impiegata in produzioni su grandi volumi.

The smoothness of thin films in optical coatings is important because it affects scatter and haze and determines how the coating is damaged by lasers. Thin films produced by conventional electron beam evaporation are not sufficiently smooth for many applications, even with the addition of ion assist. Ion beam sputtering is known to produce super-smooth thin films, and the technique is used to deposit high-performance optical filters for applications such as ring laser gyroscope mirrors, high laser damage and telecommunications.

Unfortunately, the technique is limited as a production tool because deposition rates are comparatively low. The semiconductor and optical layer analysis and definition using interference microscopy (SOLADIM) project in the UK is aimed at developing new nanometrology technologies. Through the project, it has been

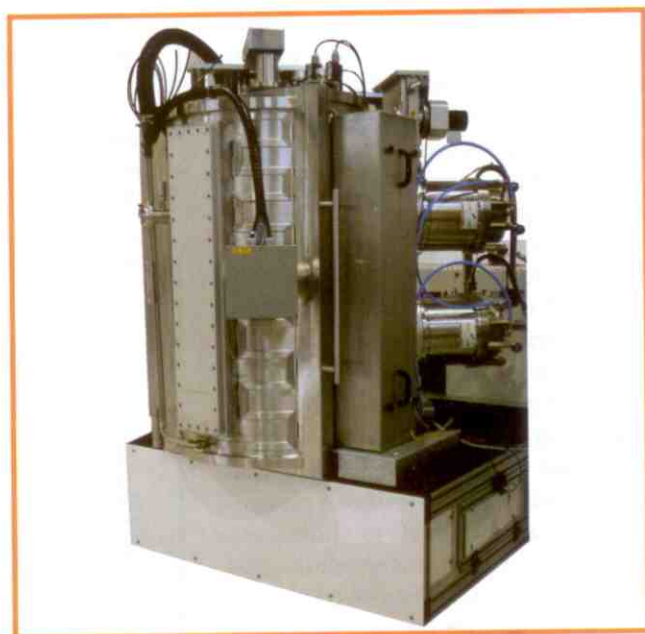


Figure 1. The CFM850 closed-field optical coating system has two 1-m linear magnetrons and a 0.5-m-diameter substrate carrier. The drum is removable for higher throughput.

discovered that closed-field magnetron sputtering also produces thin films that are super smooth. This sputtering technique also can be used for high-throughput production.

The project brought scientists with metrology expertise together with experts in semiconductor growth and optical film deposition. It has centred on the use of coherence correlation interferometry, a white-light interference tool recently developed by Taylor Hobson Ltd. of Leicester, UK.

The major advantage of coherence correlation interferometry over atomic force microscopy is that it is a fast, noncontact technique that takes data from a relatively large area, typically measuring $300 \times 300 \mu\text{m}$. The technique produces a quantitative three-dimensional image with 0.01-nm vertical (Z) and 400-nm lateral (X,Y) resolution. The data then can be used to generate accurate quantitative parameters such as root mean square surface roughness. The availability of rapid metrology

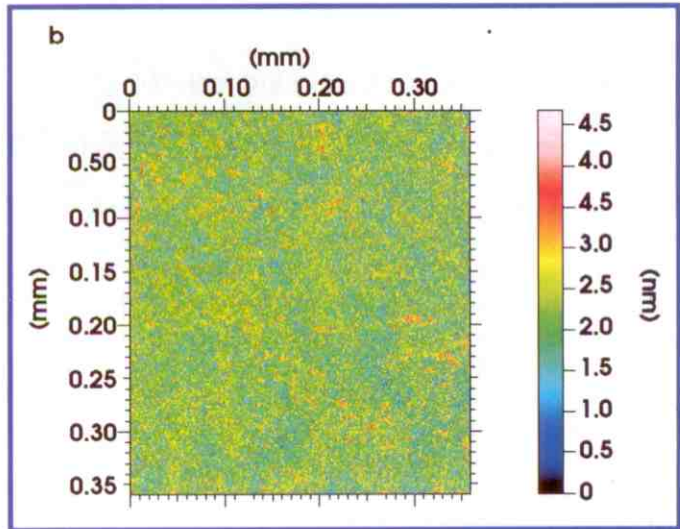
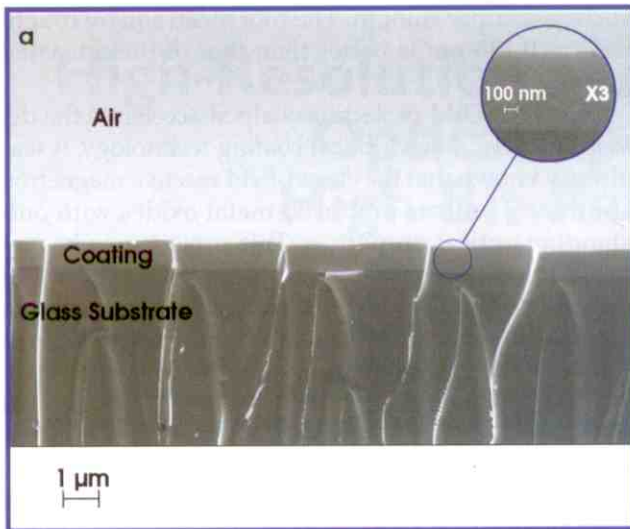


Figure 2. A scanning electron microscope image of a fracture cross section of 1- μm -thick niobia film on glass reveals a dense smooth coating (a). A coherence correlation interferometry image from the same film reveals a root mean square roughness of 0.452 nm (b).

has enabled fast optimization of the new closed-field reactive sputtering process.

Magnetron sputtering is acknowledged to have advantages over evaporation processes for deposition of the metal oxides used in optical coatings. The sputtering process is "cold," making it suitable for use on various substrates including polymers. The drum format provides more efficient loading for high-throughput production than a culotte does. The process is also easier to control and to maintain.

The CFM850 system from Applied Multilayers uses a 0.5-m-diameter drum substrate carrier (rotating at 50 rpm) and as many as six 1-m linear magnetrons (Figure 1). The targets are simple metals. Oxidation of the metal is achieved in an oxygen plasma around the drum, created by the unbalanced magnetrons and held by the

closed field between the magnetrons of opposite magnetic polarity. The combination of high current densities ($>5 \text{ mA/cm}^2$) with a substrate bias in the range of 25 to 40 V creates optimum thin-film growth conditions.

In this system, the oxidation of the metal target is held constant by feedback from the target voltage to the mass flow controller regulating the supply of oxygen. Individual thin-film thickness can be controlled with sub-nanometre precision using time only. Deposition rates of 0.5 nm/s are achievable even on a 0.5-m drum diameter. The closed-field process also can be used to produce pure metal thin films (such as reflectors), metal nitrides and metal carbides.

The closed-field reactive magnetron sputtering process can be exploited in various formats with a choice of

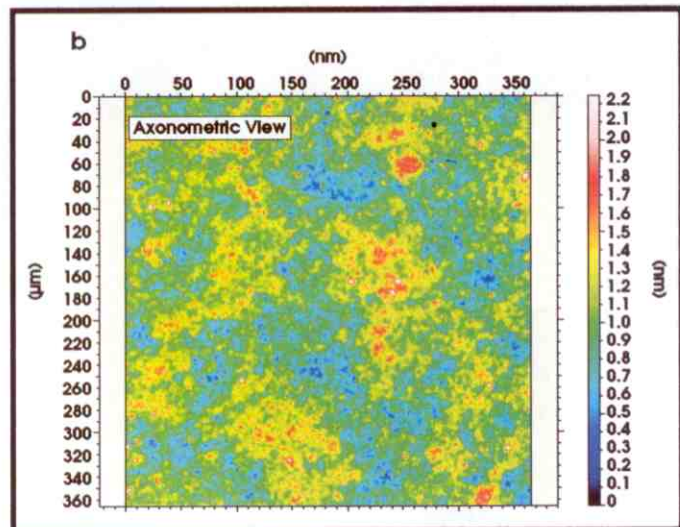
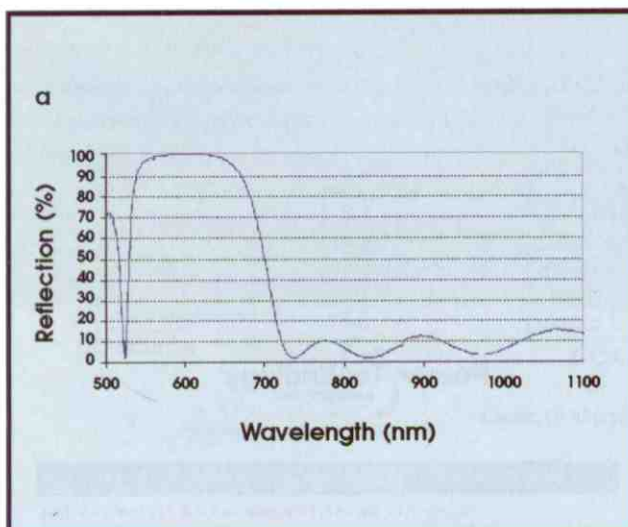


Figure 3. The reflection is shown from a simple 15-layer test edge filter (a), and a coherence correlation interferometry image from the surface of the same coating reveals a root mean square roughness of 0.188 nm (b).

