HIGH RATE REACTIVE SPUTTERING ONTO FLEXIBLE POLYMER SHEET

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The paper considers the use of a d.c. planar magnetron, used with optical emission control of the reactive gases and a controlled magnetic field, to allow plasma to be directed onto the growing film. It is demonstrated that these techniques lead to stable processes allowing the high rate production of compound films, with precisely controlled stoichiometry and structure, onto flexible polymer substrates.

Detailed examples are given for the production of indium oxide and titanium oxide films by the reactive sputtering of the metal in an argon/oxygen atmosphere. Film resistivities of around $4 \times 10^{-6}$ ohm.m were achieved with indium and indium/tin oxides during high rate production onto flexible P.E.T with films which had a high visible transmittance.

Refractive indices of up to 2.55, measured at 633nm, could be obtained with TiO$_2$ film made with self biasing above -20V.

INTRODUCTION

Modern polymers are highly desirable materials, having properties which include high strength with low weight and often with high visual transparency. The production of complex materials in thin film form onto polymer foils is complicated by the inability of these materials to tolerate high temperatures. Energy is required by the depositing film in order to produce the desired compound or structure, which cannot be given from substrate temperature. In order to produce stoichiometric compounds or precise alloys the deposition process must be accurately controllable, and energy supplied simultaneously to activate reactions for molecular or structural arrangement.

Vacuum techniques offer a means of creating refractory materials onto polymeric substrates at low temperatures and have the particular advantage that the energy of the depositing species can be controlled through the acceleration of charged particles in gas discharges. This gives substrate cleaning and also preparation of the surface for the growing film, whose properties can also be further modified.
The coating of a flexible polymer wound over a drum in front of a deposition system in a vacuum offers the following advantages which are not seen in other operational arrangements.

(1) High-rate equilibrium processes are possible. Lead-in times which eliminate shuttering disruption allow better cleaning in semi-sealed chambers.

(2) Rapid deposition gives pure deposits as the ratio of arrival rates of depositing species and residual gas impurities is high.

(3) High experimental productivity is obtained; many samples can be produced on one roll in one evacuation. In-situ monitoring facilitates parameter optimization in a short time.

(4) The results are applicable to commercial processes.

It remains however that with the high cost of vacuum equipment the process should have a high rate to give the low costs. This is necessary for products which have to compete with those on more expensive substrates that are not so easily handled but more easily coated. The starting materials have to be of low cost and be available on the scale appropriate for large area coating. A process which meets these requirements is reactive planar magnetron sputtering. A basic system is shown in Figure 1, this allows isolation and bias of the coating drum to give ion plating.

![Figure 1. Apparatus for the coating of sheet plastic transferred from roll to roll inside a vacuum using a planar magnetron source and an insulated substrate drum.](image)

REACTIVE PLANAR MAGNETRON SPUTTERING

The precision control of rate, combined with a high sputtering-rate capability and operation at a relatively high reactive gas pressure, has led us to the system of d.c. planar magnetron sputtering of the metal or alloy in an atmosphere of argon and oxygen. Ion bombardment of the substrate and growing film surface can lead to better adhesion, film structure and a greater utilisation of the oxygen gas provided for reaction giving the possibility of higher rates.2,3

The advantages of planar magnetron sputtering in such a system can be enumerated as follows:

(1) A high rate of sputtering is obtained because of the confinement of the plasma close to the target surface. The limit is determined by a factor involving the thermal conductivity of the target, the efficiency of the water cooling, the melting point of the sputtering material and its sputtering yield.