Plasma Analysis
Application Note 235

EQP
Studies of Magnetron Sputter Deposition of Thin Films

Summary

Thin films such as those of zinc oxide, iridium-tin-oxide (ITO) and titanium nitride are successfully deposited on a range of substrates by using magnetron sources. Typical arrangements are those described recently by Matsuda et al (Japan J. Appl. Phys, 36, 4922, 1997) for ITO and by Lee et al (J. Mater. Res. 13, 1260, 1998) for ZnO. Both d.c. and r.f. magnetron sources have been used.

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It is clear that the quality and growth rate of the deposited films are strongly influenced by the nature and energies of the species generated at the magnetron and subsequently arriving at the substrate. For example Lee et al say "Even though the energy and species in the plasma near the substrate could not be analysed, it was believed that the effect of highly energetic species bombardment on the growing film surface was dominant at this deposition condition. It has been reported that the highly energetic species, including reflected argon ions from the target, negative ions emitted from the target surface, and ions accelerated from the plasma had an average energy as high as several hundred eV or more (see Tominga et al Jp. J. Appl. Phys. 32, 4131, 1993)". They also quote work in which the bombardment of the growing films by energetic oxygen species considerably modifies the physical, electrical and optical properties of the films and their morphology. There is also growing awareness of the improvements which may be made to such films by bombardment using low energy (≤50eV) ions.

The experimental conditions employed in the deposition systems used by Matsuda et al. and by Lee et al. - gas pressures of 5 - 20 mtorr, argon/oxygen gas mixtures, discharge powers ≈ 300W, discharge currents ≈ 50 mA - are similar to those which have used elsewhere for the growth of titanium nitride films (except for the replacement of the oxygen by nitrogen). The experiments which can be carried out using the EQP include:

1. **Residual gas analysis of the processing chamber.**
2. **Analysis of the processing gas mixture with the magnetron source switched off or on.** This is helpful since operating the magnetron/plasma can frequently generate impurity traces which may affect the growing films.
3. **Identification of the ionised species arriving at the sampling orifice of the EQP.** Ideally the EQP should be mounted so that it samples through, or close to, the substrate. If this is not possible it may be mounted elsewhere in the chamber. The EQP can be supplied with a sampling orifice plate which can be biased to a positive or negative potential (or with an r.f. signal) to simulate the conditions used for the substrate. The instrument samples both positive and negative ions.
4. **Measurement of the energy distributions of the various ion species arriving at the grounded or biased sampling electrode.** The standard EQP energy range is ± 100eV, higher ranges are available. Again positive or negative ions may be examined.
5. **Identification of the neutral species arriving at the sampling electrode.** Valuable information can often be obtained by carrying out threshold ionisation studies of the neutral species sampled from the plasma or, in the use of electronegative species by examining their electron attachment behaviour at low electron energies.

Experimental Data

As examples of data acquired, figures 1, 2 and 3 show measurements obtained in a TiN deposition system.

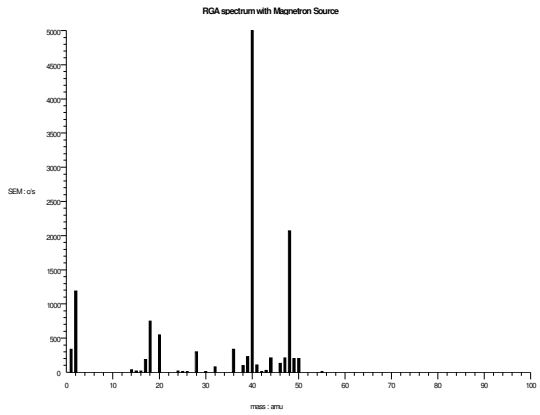

Figure 1: An RGA scan taken with an Argon/Nitrogen gas mixture admitted to the reactor and the magnetron operating using a titanium target.

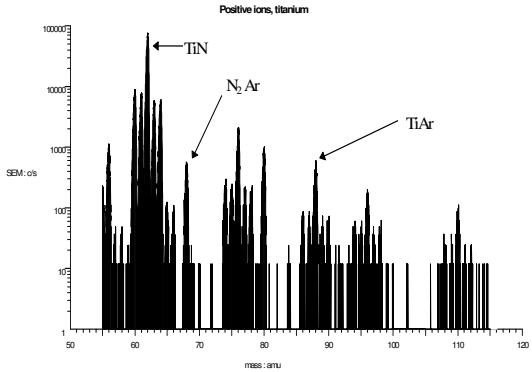

Figure 2: A partial spectrum of the positive ions arriving at the EQP, showing TiN+ and other ions, including traces of the unusual compounds TiAr and N2Ar generated in the plasma.

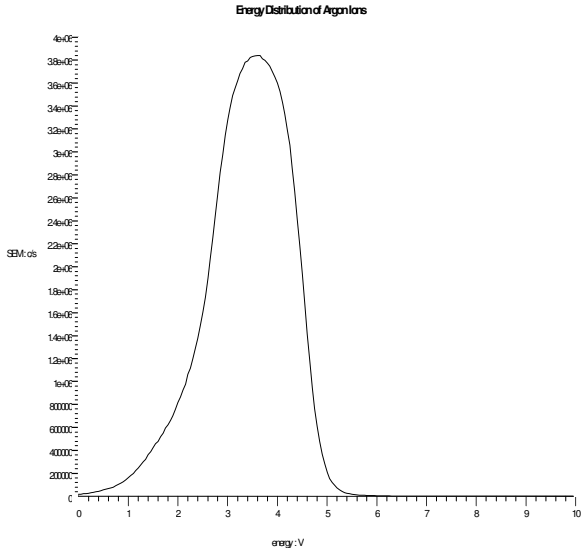

Figure 3 : An energy distribution for the argon ions reflected from the magnetron to the EQP when the bias conditions gave low energy (≤5 eV) ions.