References

1) H. Oechsner and L. Reichert, Phys. Letters **23** (1966) 90;
2) R. V. Stuart, G. K. Wehner and G. S. Anderson, J. Appl. Phys. **40** (1969) 803;
3) M. W. Thompson, Phil. Mag. **18** (1968) 377.

2.10 Determination of sputtering yields for thin film targets

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In spite of the numerous investigations of different aspects of ion bombardment of solid targets, there are very few data on the fundamental parameters for sputtering of thin films. At low energies some studies were made in a glow discharge[1], and for some investigations the thin film target was placed in the ion source of a mass spectrometer[2]. More research has been done on defects induced in thin films by low energy ion bombardment[3,4].

Results given in this contribution show the determination of sputtering yields for thin film targets. The method used was the change in electrical resistance of thin films induced by low energy ion bombardment. It has already been shown by the authors that the change in electrical resistance of gold, silver, titanium and tungsten thin films is a function of the ion dose[5,6]. From the third part of the curve, where the resistance starts to increse to infinity as a result of sputtering of the thin film (pure ion erosion), the sputtering yield can be determinend. The experimental apparatus and techniques have been described elsewhere[7]. For bombardment A^+ ions with energies from 250 to 5000 eV were used. Ion current densities were up to 0.2 mA/cm^2. Thin films were evaporated in a vacuum of 10^{-7} torr onto heated pyrex glass slides. Fig. 1 shows a typical diagram for electrical resistance changes induced in a thin gold film by different A^+ ion doses with an energy of 1500 eV. The geometry of the experiment is shown in Fig. 2 ($l \times d$ is thin film area, $z \times d$ is ion beam profile, x is depth of ion erosion, R_m is sector resistance of the bombarded area and t is thickness of thin film).

The initial resistance is given by $R_t = R_T\ p/l + R_T\ z/l$ if R_T is the total resistance measured during ion bombardment. The resistance change induced by ion bombardment R is then $R = R_T\ z/t\ (1-t)/(t-x)$. Since the depth of erosion x is proportional to the product of ion dose and sputtering yield for a thin film ($x = DS_{TF}$), we can determine this suttering yield S_{TF} if we draw the conductivity of the bombarded area as a function of $1/D$. In the large dose region, where all the resistance changes are induced by ion erosion (thinning of the thin film), this dependence is linear and the slope gives the sputtering yield for the bombarded thin film. Table I shows the results of such a sputtering yield calculation for titanium, gold, silver and tungsten thin films. For comparison, sputtering yields for solid targets are also given[8]. All values for sputtering yields of thin films are larger than for solid targets. The difference is larger for higher energies (30—40 %), while for energies smaller than 500 eV the

difference is between 5 and 25 %, depending on the film thickness. Larger sputtering yields are influenced by different film densities. It is known that thin films of the thicknesses used here have 20 to 50 % smaller densities than the solid material. Therefore for precise measurements of sputtering yields the density and the thickness of thin films must be determined by as accurate a methad as possible[9].

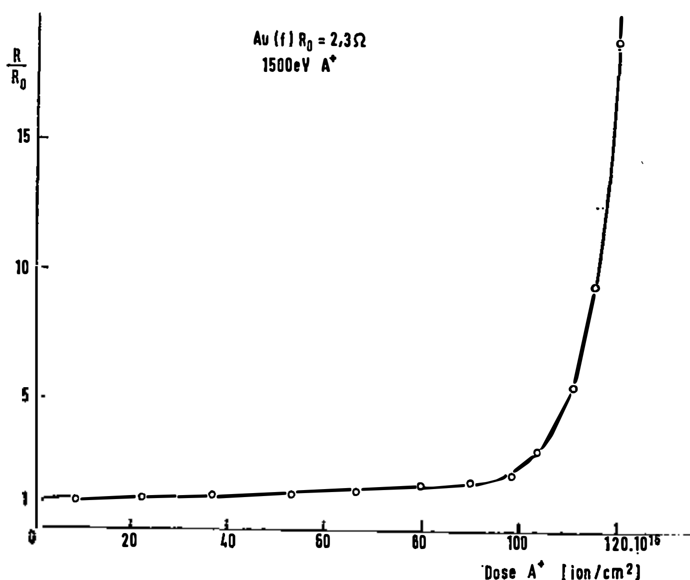

Fig. 1 Resistance changes induced in gold film by 1500 eV A^+.

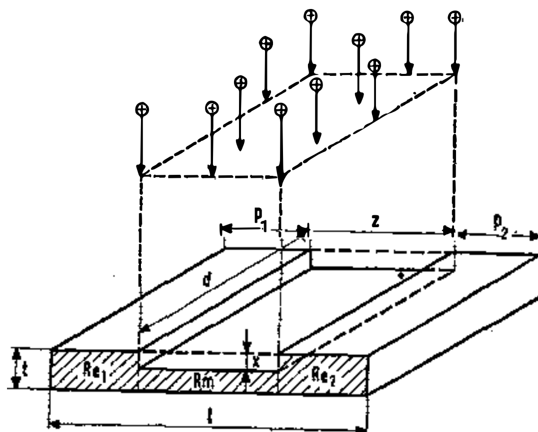

Fig. 2 Geometry of the experiment.

The method described can be applied to all metal, semiconductor, alloy ot dielectric thin films. Recent results in the field of ion etching, formation and shaping of thin film circuits in microelectronics and ion beam machining have shown the necessity for the sputtering yield data for various thin films.

TABLE I

Sputtering yields for thin films S_{TF} (at/ions)

Bomb. cond.	Target	Thickness (Å)	Our results	S for solid targets
500 eV A^+	Ti	100	0.68	0.50
1500 eV A^+	Ti	200	1.00	0.70
450 eV A^+	Au	270	2.30	2.20
1500 eV A^+	Au	200	4.20	3.50
450 eV A^+	Ag	200	3.40	2.90
1500 eV A^+	Ag	150	6.20	4.50
450 eV A^+	W	250	0.60	0.54

References

1) H. G. Scott, J. Appl. Phys. **33** (1962) 2011;
2) A. Benninghoven, Z. Angew. Phys. **27** (1969) 51;
3) P. Bowden and D. Brandon, Phil. Mag. **8** (1963) 935;
4) H. Diepers, Phys. St. Solidi, **24**, (1967) 235 and 623;
5) B. Navinšek and G. Carter, Appl. Phys. Letters **10** (1967) 91;
6) B. Navinšek and G. Carter, Can. J. Phys. **46** (1968) 719;
7) B. Navinšek and G. Carter, Int. J. Electronics **22** (1967) 421;
8) G. K. Wehner, Mills Report 2309, Minneapolis, Minnessota (1962);
9) B. Navinšek, Ph. D. Thesis, University of Ljubljana (1968).

2.11 Mass analysis of positive and negative secondary ions emitted from NaCl and KCl monocrystals bombareed by 40 keV argon ions

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The spectra of positive and negative secondary ions were measured from NaCl and KCl monocrystals bombarded by 40 keV Ar^+ ions. The magnet analyser was used. It was found that the secondary ion emission from these dielectrics was identical with the metal and semiconductor emission. The yield of the positive secondary ions is proportional to the reciprocal value of $(I - \Delta I - \Phi)$, i.e. reciprocal value of the difference between the ionization energy and the