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DEPTH RESOLUTION IN ION SPUTTERING - AN ASPECT OF QUANTITATIVE MICROANALYSIS

J. Giber, D. Marton and J. László

*Physical Institute of the Technical University, Budapest,
1111 Budafoki út 8., Hungary*

Résumé - La résolution en profondeur des profils de pulvérisation a été déterminée en utilisant des multicouches Ni-Cr. Nous avons aussi développé une méthode pour l'évaluation quantitative des résultats. La résolution en profondeur mesurée à l'aide des couches métalliques polycristallines, est fortement influencée par la diffusion intermétallique entre couches.

Abstract - The depth resolution of sputter depth profiling has been analysed using Ni-Cr multilayer structures. A new method has been developed to quantify the results. The depth resolution measured using polycrystalline metallic layers is strongly influenced by mutual diffusion of the layers.

The depth resolution of sputter depth profiling is a crucial factor from the point of view of quantitative analysis performed with SIMS, AES, ESCA etc. The finite depth resolution of the measurement leads to principal profile distortion which may be mathematically described by a resolution function $g(\xi - z)$ which is convolved with the measured profile $c(\xi)$ [1]:

$$I(z) = k \int_{-\infty}^{\infty} c(\xi) g(\xi - z) d\xi \quad (1)$$

where k is the sensitivity factor.

The determination of the real profile requires therefore determination of the g function that can be obtained experimentally from the sputter profiling of step function concentration profiles, which being distorted during the measurement may be characterized by the σ standard deviations of the measured nearly error function type profiles. The depth resolution is defined as $z=2\sigma$ [2]. The sample profiles should be strictly rectangular for this measurement, because deviations from that (which are usually due to diffusion processes in practical cases) lead to additional interface broadening. The independent interface broadenings due to different phenomena can be summarized quadratically [3]:

$$\Delta z^2 = \sum_i \Delta z_i^2 \quad (2)$$

The determination of depth resolution is required usually according to a depth scale, because it is necessary partly when using eq. (1) and when one studies the sputtering process [4]. The use of

Fig. 1

Δz^2 vs z determined by
AES method using PHI SAM
545 equipment, 5 keV Ar^+
ion sputtering

Fig. 2

Δz^2 vs z determined by
SIMS method using Balzers
equipment, 3 keV Ar^+ ion
sputtering without (" Ar ")
and with oxygen jet (" O_2 ")

single layer systems for this purpose is difficult, because one needs then a series of identical interfaces. A more advantageous method that has been suggested by Hofmann et al. [5] uses multilayer structures with uniform layer thicknesses. The evaluation of the wave-like depth profiles obtained in such measurements is also difficult, but can be carried out under certain assumptions:

1 - the distorted profile is well approximated by superposition of error functions centered at the interfaces,

2 - the nearest neighbour approximation is valid, i.e. $\Delta z < d$,

3 - the sensitivity factors are independent of the concentration within the limits of the minimal and maximal occurring concentrations.

While assumption 1 holds for the most cases except if the information depth or cascade mixing are the main factors determining the interface blurring, and assumption 2 holds unless very thin layers or very deep lying interfaces are analysed, the validity of assumption 3 is questionable, before all in SIMS depth profiling.

Unequal sensitivity factors for different concentrations can change the depth resolution for ion yields as compared with the depth resolution of concentrations. In this sense the depth resolutions determined from SIMS ion yields are influenced by sensitivity factor changes with concentration and can be different for different types of ions.

On the basis of the assumptions listed above the depth resolution can be calculated according to the expression

$$\Delta z = d \left[\sqrt{2} \cdot \operatorname{erf}^{-1} \left(\frac{y_{\max}}{y_{\max} + y_{\min}} \right) \right]^{-1} \quad (3)$$

The results of evaluated measurements carried out on different Ni-Cr samples are shown in Figs. 1, 2 and 3. These samples were obtained by vacuum evaporation on unheated substrates. The details of the experiment are described elsewhere [6]. The experimental results can be fitted to an eq.:

$$\Delta z^2 = \Delta z_c^2 + az \quad (4)$$

where Δz is the "measured" depth resolution and Δz_c and a are

Sample 342
d=10,6nm

Fig. 3

Δz^2 vs z determined by AES method using PH SAM 545 equipment, 3 keV Ar^+ ion sputtering. The $\Delta z^2 = 1.2z$ and $\Delta z^2 = 0.6z$ lines correspond to straight lines in Fig. 3 ref. [4].

determined by the chemical composition of the samples and for Ni-Cr multilayer sandwiches analysed here $\Delta z_c = 6-8$ nm and $a=0,2...0,5$ nm. The interface blurring due to sputtering and measurement factors are then

$$\Delta z_s = \sqrt{\Delta z^2 - \Delta z_c^2} = \sqrt{az} \quad (5)$$

in accordance with what is predicted by the theories of statistical sputtering and cascade mixing [7, 8] on one hand, and by surface roughening [9] on the other.

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