PREFERENTIAL SPUTTERING EFFECTS OF CARBIDES

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Introduction

Sputtering of multicomponent material is a field of very active research at the present time. This is due to the basic interest in the understanding of compound sputtering and also the potential applications in new technologies. For instance, titanium carbide is a prime candidate for first wall coatings in fusion devices. Ion bombardment of compound material in general leads to changes in surface composition due to the effect of preferential sputtering /1,2/. There are several possible reasons for this effect, e.g. differences in surface binding energy of the various constituents, mass effects depending on the ratio $A = M_{Target}/M_{Projectile}$, and also effects due to chemical reactions on the surface.

In this paper we present results from sputtering of TaC and TiC by a variety of ions, ranging from Xe^+ to H^+. Mass effects are anticipated for large mass differences of the constituents, i.e. TaC, whereas for the case of TiC, the other effects can be expected to be of comparatively higher importance.

Experimental

The targets were bombarded and analyzed in an UHV-chamber with a background pressure of $5 \cdot 10^{-12}$ mbar, their surface composition was monitored by Auger electron spectroscopy (AES). The electron beam had no detectable

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influence on the surface composition. Ion bombardment of the samples generally changes the surface composition up to an equilibrium value which depends on the mass and energy of the bombarding ion /3/. For H^+ and He^+ ions fluences of the order of several 10^{18} ions/cm^2 are necessary to reach equilibrium in our energy range (300 eV to 2 keV). All measurements are done at room temperature.

Results and discussion

The measured saturation values for bombardment with Xe^+, Ar^+, Ne^+, He^+ and H^+ are plotted in Fig.1 for TaC and in Fig.2 for TiC. The Auger peak-to-peak ratios given in the figures happen to represent roughly (within 20 %) the actual concentration ratios, as can be deduced from the higher mass ion bombardment and from quantitative evaluation of the Auger signals /4/. The concentration values are plotted as a function of the ratios of the energy transfer factors γ_C/γ_M, $\gamma = 4A/(1+A)^2$, for the respective ions and the two constituents C and M. This ratio of the γ-values was assumed ad hoc to account for the mass dependence of the effect.

As shown in Fig.1, there is a large change in surface composition observed with TaC which strongly depends on the mass of the bombarding ion. This pronounced mass effect is certainly due to the large difference in mass between Ta and C. For low energies and light ions the different sputtering threshold energy for Ta and C is also important.

Figure 2 shows the results for TiC. The preferential sputtering effect is fairly small for Xe, Ar and even He. That is, if we compare the changes in surface concentration for the same projectile, it is much larger with TaC than with TiC, thus indicating that the mass effect is more important in TaC, as expected (for 500 eV the effect

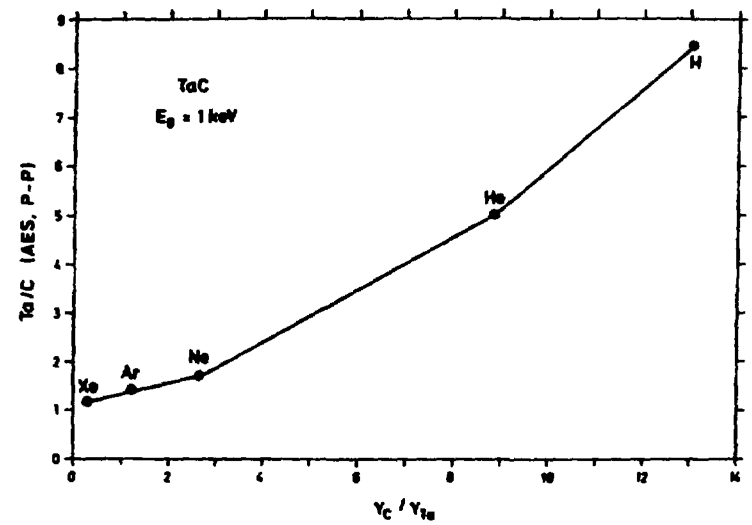

Fig.1: Equilibrium surface concentration ratio of TaC for bombardment with ions of the indicated elements (1 keV; 30° to surface normal).

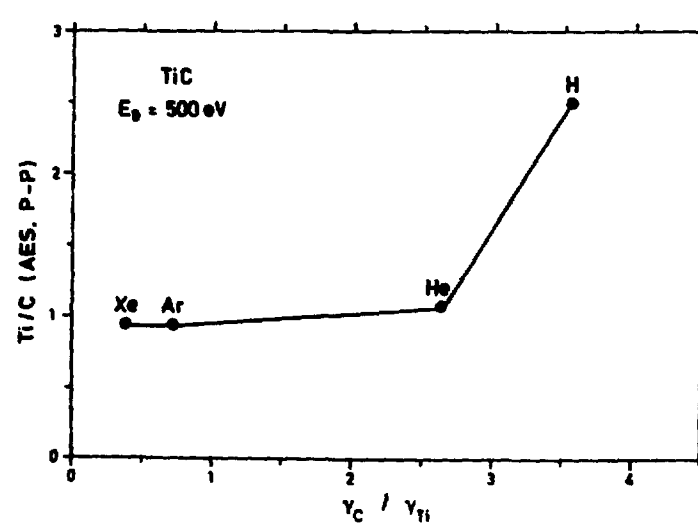

Fig.2: Equilibrium surface concentration ratio of TiC for bombardment with ions of the indicated elements (500 eV; 30° to surface normal).

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in TaC would be larger). The effect for TiC remains relatively smaller even if we do the comparison for the same γ_C/γ_M value. This indicates that there are additional effects operative which are not properly accounted for by this ratio. The collision cascades and the deoposited energy in the two (C and metal) sublattices certainly develop differently for TaC and TiC. Also, in TiC it is to be expected that the surface binding energy plays a more important role compared to the mass effect.

Another striking observation is the abrupt increase of the carbon depletion between He and H in the case of TiC. It is therefore assumed that with hydrogen chemical reactions become important and enhance the preferential sputtering effect, i.e. the carbon depletion. This is supported by recent results from Yamada et al. /5/ who determined the methane formation during sputtering of TiC with protons. They observed a strong dose dependence of the CH_4 formation which decreases with increasing fluence and levels off at values comparable to those we need to obtain equilibrium surface composition. This means that the methane production during proton bombardment depends directly on the carbon concentration in the surface and becomes constant as soon as equilibrium surface concentration is reached.

In conclusion, different effects of preferential sputtering show up in the surface concentration of TaC and TiC due to bombardment with various ions. For TaC mainly mass effects are important, whereas binding energy and particularly chemical effects are found with TiC.

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