Comment on ‘‘Ion mixing of metal/Al bilayers near 77 K’’ [Appl. Phys. Lett. 5 4, 413 (1989)]

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Comment on "Ion mixing of metal/Al bilayers near 77 K"

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In a recent publication[1] Ma, Workman, Johnson, and Nicolet (MWJN) presented experimental data of Xe ion mixing of 3*d*-metal/Al bilayer targets with an average atomic number in the vicinity of 20. Their aim was to check the validity of a theoretical prediction, based on the application of the fractal concept to collision cascades, that spikes should not occur in targets with $Z < 20$. The observed mixing efficiencies were then compared with predictions by both the phenomenological model of Johnson *et al.*[2] for diffusion in a thermal spike and the collision cascade model of Sigmund and Gras-Marti.[3] The results indeed span a wide range in values as would be expected when the dominant mixing mechanism changes in character.

This comment concerns the value for the mixing efficiency in the Fe/Al bilayer (900 keV Xe^{3+}, 77 K) appearing in Ref. 1. Unfortunately, the authors used a set of data incorrectly treated in a first version of an unpublished paper (MWJN, Ref. 17). The right values of the amount of mixing ($4Dt$) for this system under the above bombardment conditions will appear in Ref. 4. The corresponding mixing efficiency in Ref. 1 (MWJN, Table I) must be changed to $[d(4Dt)/d\phi]_{\exp} = 5.67 \times 10^4$ Å^4. The location of the corrected experimental point for the Fe/Al system in the normalized mixing efficiency versus $\Delta H_{\rm mix}/\Delta H_{\rm coh}$ diagram (MWJN, Fig. 1) is presented here in Fig. 1.

Before drawing any conclusion, an independent study of Xe ion mixing in the Fe/Al system at 300 K carried out by Gaboriaud *et al.*[5] is analyzed here in order to compare our experimental value. Since the authors of Ref. 5 reported their results in terms of an amount of mixing, Q, defined as the number of atoms per unit area which have moved across the interface, some data reduction is needed in order to relate Q with $4Dt$. This can be easily accomplished by integrating the concentration profile of the mixed atoms, $C(x)$, in one side of the interface. In the case of B atoms moving into the A atoms region,

$$Q_B = \int_A C_B(x)\,dx. \tag{1}$$

Now, we assume $C_B(x) = \rho_B\{1 + \mathrm{erf}[(x-a)/2\sqrt{Dt}\,]\}/2$, where ρ_B is the atomic density of pure B (bottom layer) and a is the original position of the interface. Under the hypothesis that the atoms of the bottom layer have not appreciably reached the surface of the top layer, i.e., $a > 4\sqrt{Dt}$, we obtain

$$Q_B = \rho_B\sqrt{Dt/\pi}. \tag{2}$$

Application of Eq. (2) to the data of Ref. 5 which fit the above requirements leads to a mixing efficiency of about $[d(4Dt)/d\phi]_{\exp} = 3.28 \times 10^4$ Å^4. The corresponding normalized mixing efficiency, obtained by taking the energy deposited per unit path length at the interface (ϵ) from Ref. 5, is also plotted in Fig. 1.

Apart from the quantitative differences which may be related to the inverted order of the elements in the bilayers and different temperatures of ion mixing experiments of Refs. 4 and 5, both results conform reasonably well to the predictions of the thermal spike model.[2] The sample temperature is probably not critical in the differences reported above, since only a weak temperature dependence of the mixing efficiency is generally observed between 77 and 300 K in metal/metal systems. The critical temperature above which mixing becomes more strongly dependent on temperature for the Fe/Al system is theoretically determined[6] to be near or slightly above room temperature.

It seems to us that the modification introduced by this comment in the location of the Fe/Al experimental point does not appreciably change the conclusions drawn in Ref. 1 since Fe/Al is a borderline case. It is worth noticing, however, that the prediction that spikes cannot be expected in a matrix consisting of elements with $Z < 20$ was made by assuming 30 eV for the minimum displacement energy E_d, while the corresponding average value $\overline{E_d}$ for the system under consideration is 17 eV.

A question that remains to be answered is how critically

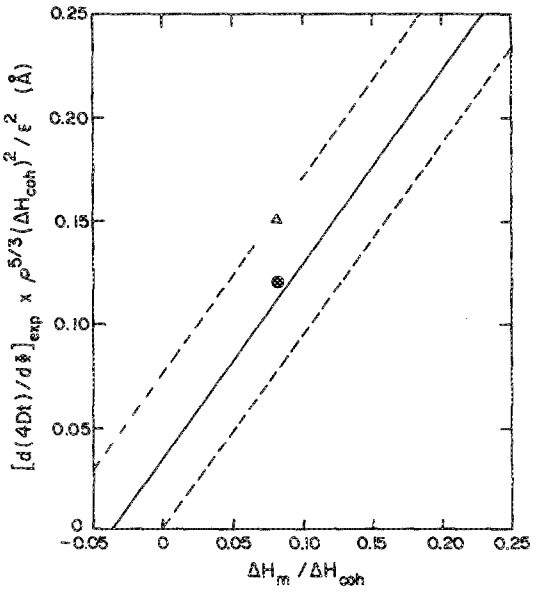

FIG. 1. Normalized mixing efficiency vs $\Delta H_{\rm mix}/\Delta H_{\rm coh}$. The dashed lines encompass experimental points for transition-metal bilayers (MWJN, Ref. 9). The solid line is a linear fit of these data. (●) Our corrected result for the Fe/Al bilayer; (△) reduced normalized mixing efficiency from Ref. 5.

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the prediction of the threshold Z for the transition from the ballistic to spike regime depends on E_d. We feel that further investigation of Xe ion mixing in bilayer targets with an average atomic number $\bar{Z}$ below 20 can help to clarify this point.

[1]E. Ma, T. W. Workman, W. L. Johnson, and M. A. Nicolet. Appl. Phys. Lett. **54**, 413 (1989).
[2]W. L. Johnson, Y. T. Cheng, M. Van Rossum, and M. A. Nicolet, Nucl. Instrum. Methods B **7/8**, 657 (1985).
[3]P. Sigmund and A. Gras-Marti, Nucl. Instrum. Methods **182/183**, 25 (1981).
[4]M. A. Z. Vasconcellos, J. A. T. Borges da Costa, W. H. Schreiner, and I. J. R. Baumvol, Phys. Status Solidi A **111** (in press).
[5]R. J. Gaboriaud, C. Jaouen, J. J. Grob, and A. Grob. Appl. Phys. A **41**, 127 (1986).
[6]B. Rauschembach, Phys. Status Solidi A **102**, 645 (1987).