LETTERS TO THE EDITOR

Effect of Ion-Pump Evacuation on the Adhesion of Evaporated Thin Films

(Received January 25, 1971)

The adhesion of thin evaporated films to their substrates has been a problem of physics as well as technology and many approaches have been made to get more adherent films. It has been recognized that one of the factors which determine the adhesion is the physical state of the substrate ; most of attempts to prepare more or less contamination-free substrate surface have succeeded to improve the adhesion(1)~(3). Therefore, it is interesting to compare the adhesion of thin films produced by evaporation in vacuum obtained by means of the ion pump (dry system) with the adhesion of those produced in vacuum obtained by means of the oil diffusion pump (wet system). The former vacuum should be far free from contamination of hydrocarbon vapours compared with the latter.

Glass plates were used as the subsrates in the present experiment. After chemical cleaning they were placed in a dry vacuum system and it was evacuated first by sorption pump and then ion pump. Thin films of aluminum were produced by evaporation from a tungsten filament on to the substrate kept at room temperature. Taking out the films (with the substrates) from the system to the atmosphere, the adhesion of them was measured by means of an apparatus* which had been described in a previous paper(1). The adhesion obtained is satisfactorily high (~7 kg/mm^2) independent of pressure at the evaporation (10^{-7}~10^{-5} Torr). On the other hand, the adhesion is poor (~2 kg/mm^2) when thin aluminum films were produced in a wet system at pressures from 10^{-5} to 10^{-4} Torr, as already reported in the previous paper(1).

The improvement of adhesion obtained by means of dry system evaporation is considered to be due to the cleaning effect of ion bombardment on the substrate; the ions presumably come from the ion pump in the dry system. A current associated with such ions was detected in such a manner as shown in Fig. 1. When the substrate was replaced by a metal sheet S which was connected to the ground through a resistance R, an electrical potential difference appeared across R when the ion pump was in operation. The current density estimated from the potential is shown in Fig. 2 (upper curve) as a function of pressure. The linear relationship between the current and pressure may evidently show the above presumption.

* Principle of the measurement is to pull off the film from the substrate. The value of adhesion determined by this method is not so exact that it should be considered only as a measure of adhesion. Considerations on the value itself will be made elsewhere.

Total flux of ion particles which strike the substrate before the evaporation of aluminum is estimated as 1×10^{15}/cm^2, from the current and the time for the evacuation. As already reported(1), glow discharge in low

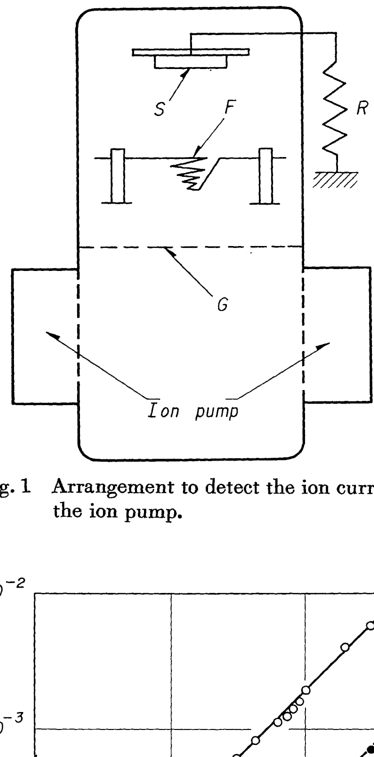

Fig. 1 Arrangement to detect the ion current from the ion pump.

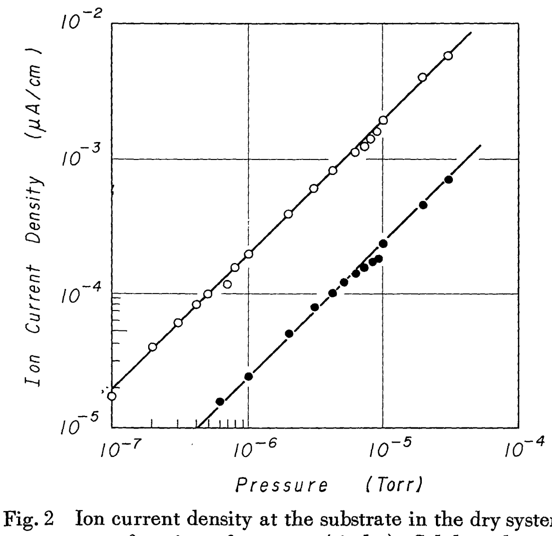

Fig. 2 Ion current density at the substrate in the dry system as a function of pressure (circles). Solid circles are obtained when the stainless steel gauze is placed between the source and ion pump.

(1) K. Kuwahara, S. Nakahara and T. Nakagawa : *Proc. Int. Conf. on Strength of Metals and Alloys*, Supplement to Trans. JIM, Vol. 9 (1968), 1034.
(2) J. M. Ohno : *ibid.*, Vol. 9, (1968), 1038.
(3) C. Weaver : *Advances in Vacuum Science and Technology*, Ed. by E. Thomas, Pergamon Press, New York, (1960), 734.

vacuum also improves the adhesion in the case of wet system evaporation. It is noted that total flux of ion particles which strike the substrate in this case is estimated to be of the same order as that above mentioned. Such a consideration that the improved adhesion in a dry system evaporation is due to the ion bombardment is also confirmed from the following experiment. When a stainless steel wire gauze G was inserted between the source F and the ion pump as illustrated in Fig. 1, the ion current decreased as shown in Fig. 2 (lower curve). It was found that evaporation in this situation produces thin films of not so high adhesion, say 4 kg/mm^2 ; this would be caused by insufficient ion bombardment.

There is another evidence that the substrate is cleaned by dry system evacuation. When evaporation was made in a wet system on to the substrate which was replaced from a dry system vacuum, thin films were obtained which had nearly the same adhesion ($\sim$7 kg/mm^2) as that of those evaporated in the dry system. The substrate once placed in the dry system should be cleaned by ion bombardment and this effect should continue to act even if the substrate is exposed to air and further placed in the wet system.

It is concluded that the surface of substrate placed in a dry system is cleaned by ion bombardment which is associated with the ion pump operation. Contaminations removed by such a process would be inherent ones that already existed before the installation of the substrate in the system. Contaminations supposed to be introduced in the process of wet system evacuation seem to have no serious effect on the adhesion as long as the conditions of the present experiment are involved. This work was partially supported by the Grant-in-Aid from the Ministry of Education.

By Kaizo Kuwahara*, Toyokatsu Nakagawa**
and Keizaburo Kuramasu***

* Faculty of Engineering, Hiroshima University, Hiroshima, Japan.
** Graduate School, Hiroshima University, Hiroshima. Present address : Fujitsu Ltd., Kawasaki, Japan.
*** Graduate School, Hiroshima University, Hiroshima, Japan.