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APPLICATION OF ACOUSTIC STREAMING FOR IMPROVING METALS DIFFUSION DURING ELECTROCHEMICAL DEPOSITION

P. Poćwiardowski[1], A. Stepnowski[1] L. Bjørnø[2]
[1]Technical University of Gdańsk, Remote Monitoring Systems Department
Narutowicza 11/12, 80-952 Gdańsk, Poland,
[2]Technical University of Denmark, Institute for Product Development
Lyngby, Denmark,

The efficient method of improving diffusion of more noble metal through barrier layer created during electrochemical deposition process, by means of acoustic straeming was investigated. The results obtained from the experiments demonstrates the possibility of controlling the amount of liquid injected to the vicinity of cathode by the change of acoustic intensity. This results in accomplishing the controlled migration inside barrier layer and thus the inspecting of the mass of more noble metal in the plated alloy. The Schlichting type of acoustic streaming was mostly used in investigation.

INTRODUCTION

The process of metal and metal alloy films fabrication, conducted under the influence exerted by an external electric field in electrolyte where the manufacturing process takes place, is called electrochemical deposition (ECD). When electroplating process satisfy particular condition on the cathode surface a thin gel layer is formed, called barrier layer [5]. As a consequence of barrier layer activity, which retards the diffusion of more noble metal, deposited alloy becomes richer in less noble metal in the bath. Usually this zone has less than 300 μm of thickness and in most cases it is between 1 μm and 50 μm [5]. As noticed in [6], it is possible to influence barrier layer by means of cathodic current density (CCD), the electrolyte pH or the Cl - content of the electrolyte, and the level of agitation at the cathode surface. Furthermore, barrier layer can act as a mass transport controller. Which means that it is possible to control the mass of more noble metal in the plated alloy by direct act to the barrier layer. That is why the controlled influence on this layer is of the main importance.

1. ACOUSTIC STREAMING

It is supposed that by means of ultrasound it is possible to control the behaviour of a resistant cathodic layer, and as though provide a change with ions transportation mechanism. This can be accomplished by means of acoustic streaming instead of other possible agitation like pump, air agitation, heat agitation etc., which in particular cases are unacceptable due to air bubble production and in turn negative influence on the wafer surface [5]. Furthermore, unlike these kinds, acoustic streaming, in reasonable conditions, provides non-turbulent, laminar fluid movement and fully controlled behaviour dependent on well-known and controllable quantities. In this paper onlu Schlichting type of streaming is investigated, influence of Eckart streaming will be discussed in following papers.

When a rigid boundary is subjected to the oscillated acoustic field, the rotational streaming is generated [4]. This type of streaming is called Schlichting streaming. The thickness of an acoustic boundary layer δ_{ac} is an important quantity, which generally determines the distance from a rigid boundary, where non-uniform acoustic energy is propagated near a surface and therefore Schlichting streaming can be generated. It is given by following equation:

$$\delta_{ac} = \sqrt{\frac{2 \cdot \nu}{\omega}} \tag{1}$$

Schlichting streaming comprises near-boundary vortices, whose dimensions are determined by acoustic wavelength and the mentioned thickness of an acoustic boundary layer. The character of Schlichting streaming is schematically indicated in Fig. 1. The tangential dimension of vortices is quarter of the wavelength, and the second dimension is confined to the boundary-layer vortex thickness Δ, which particularly for Schlichting streaming equals to $1{,}9\delta_{ac}$ [3]. As it is illustrated in the Fig. 1, near-surface mass transportation occurs from particle velocity nodes to antinodes, and proceeds in the opposite direction. This is significant that directions of near-boundary vortices occur in opposite direction than vortices outside acoustic boundary layer.

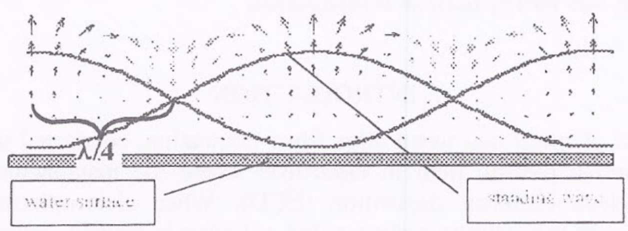

Fig. 1 Schlichting streaming near rigid surface

One can easily notice that the rotating fluid drags liquid from outer of the boundary layer and transfers it to the nearest to wafer surface. If dimensions of vortices are comparable with the thickness of the barrier layer it can be said that they inject fluid through the barrier layer apart from the chemical abilities of diffusion.

The Schliching streaming can be analysed by means of the boundary layer equation considered by Prandtl in [3] given by:

$$\frac{\partial \upsilon_x}{\partial t} + \upsilon_x \frac{\partial \upsilon_x}{\partial x} + \upsilon_y \frac{\partial \upsilon_x}{\partial y} - \nu \frac{\partial^2 \upsilon_x}{\partial y^2} = \frac{\partial U}{\partial t} + U \frac{\partial U}{\partial x}$$

$$\frac{\partial \upsilon_x}{\partial x} + \frac{\partial \upsilon_y}{\partial y} = 0 \qquad 2)$$

Here $_x$ and $_y$ are x and y components of the streaming velocity, and U(x,t) is the known velocity of the free stationary flow outside a boundary layer. According to [3] the second order approximation terms for periodic wave has the form:

$$\overline{\upsilon_{2x}} = -\frac{(\upsilon_0)^2}{4\,c_0}\left(n - n^2\right)\sin(2\,kx)$$

$$\overline{\upsilon_{2y}} = \frac{(\upsilon_0)^2}{4\,c_0}\,k\delta_{AC}\,n^2\cos(2\,kx) \qquad 3)$$

Where "n" denotes a nondimentional factor equal, in this case, to 1,9.

2. EXPERIMENTS

For the reason of lack of space in this paper, we do not present detailed experimental system. For further references considering experimental set please refer to [1].

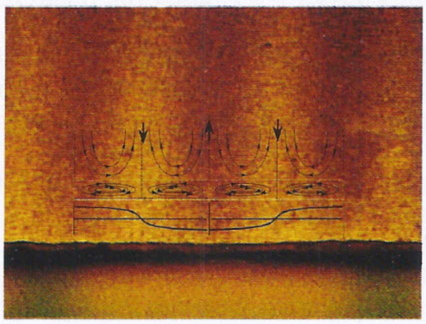

Fig. 2 Schlichting streaming at the wafer surface

The experiments show that the difference in Fe content between the node and antinode was about 20% with respect to the lower contest. In Fig. 2 one can see the obtained stripes, which rise from different agitation yielded by Schlichting streaming. It can be seen that the mass transportation to and from the surface occurs on the different stripes like arrows indicate it. The uneven line in bottom of the Fig. 2 is the wafer edge. The two green stripes are lines on millimetre paper to indicate the distance. The vortices have a form of rotating rolls tangential to the wafer surface. The radiuses of those rolls were given earlier and the lengths are confined to dimensions of wafer.

The stripe pattern shows perfectly that it is possible to control a barrier layer by means of Schlichting streaming. By changing dynamically the size of vortices one can obtain different impact on a gel layer. This can be done using nonmonochromatic wave [3], which produces vortices in different scales. One can imagine another way, when well-defined standing way is yielded. If two transducers faced directly towards each other are working on the same frequency, a standing wave will be produced. Then we can apply very slow phase modulation, which will move the standing wave left and right. Thus it will cause vortices movement and different areas of the surface penetration. The phase modulation can by controlled particularly to obtain some areas expected to be plated. In particular case when the phase shifting is of order of $\pi/2$ one can obtain successive movement of vortices and in turn smooth exchange of the liquid.

3. CONCLUSION

In the paper the acoustic method of improving the diffusion of ion transfer has been developed. The method is based on Schlichting streaming theory. Schlichting streaming comprises boundary layer vortices, which transport fluid from bulk to the cathode layer through barrier layer. In those circumstances the chemical constitution of barrier layer is not of major importance, but only its viscosity and thickness. This is original way of controlling coating process and wafer deposit content. Furthermore, it is non-invasive, cheap and easy to control.

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