Micro-MHD Effects on Electrodeposition under Parallel and Vertical Magnetic Fields

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It is well known that the electrochemical reactions receive various effects from the magnetic fields. Especially, the MHD effect induced by the Lorentz force is remarkable for increasing diffusion current since the mass transfer process is easily enhanced by resultant fluid motion.

At first time, the fluid flow called the MHD flow was thought simple and plain in structure. However, recently it has been shown that such flow is composed of complicated intrinsic fluid motions called the micro-MHD flows. Their sizes are of the order of μ m, so that it is possible that they interact with the non-equilibrium fluctuations accompanied by nucleation. In the electrodeposition, there are two kinds of non-equilibrium fluctuations; one is the asymmmetreical fluctuations, which are defined as one-sided deviations from the electrostatic-equilibrium during two-dimensional nucleation in the electric-double layer, and another the symmetrical fluctuations emerging around the average values during three-dimensional nucleation in the diffusion layer. The former fluctuations control the total reaction rate, being characterized by large wavelengthes (e.g. 0.1 mm), whereas the latter ones possess small wavelengthes (e.g. 1 μ m).

The application of the magnetic field to an electrode is roughly classified into two cases, i.e., parallel and vertical magnetic fields to the surface. For examining the MHD effect, the parallel case is usually selected since the Lorentz force induced takes a maximum value when the magnetic field and the electrolytic current are vertically arranged. Consequently, as shown in Fig.1, the macroscopic MHD flow arises along the electrode, so that the micro-MHD flows are effectively produced just like rollers moving along the surface: the development of the fluctuations is therefore blocked by the interference of the flows, so that surface leveling takes place all over the surface.

For the vertical magnetic field, since the parallel arrangement of the magnetic field and electrolytic current does not yield the effective Lorentz force, it is believed that the MHD effect does not emerge, or at least it is negligibly small. However, the non-equilibrium fluctuations bring different conclusions: numerous vortexes of two kinds corresponding to the fluctuations mentioned above are generated over the surface. As shown in Fig. 2, they collaborate for the occurrence of intense upward streams (micro tornados), which are thought to locally suppress the nucleation growth. As a result, quite different morphology of the deposited surface can be obtained.

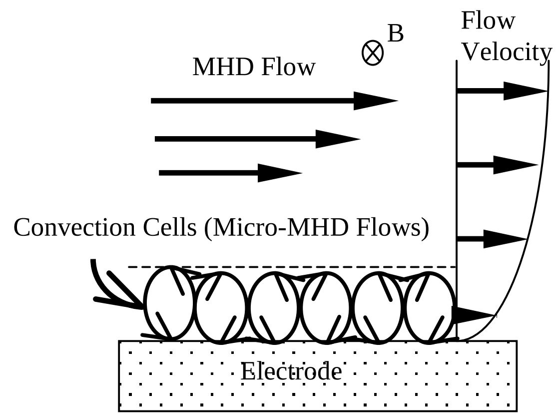
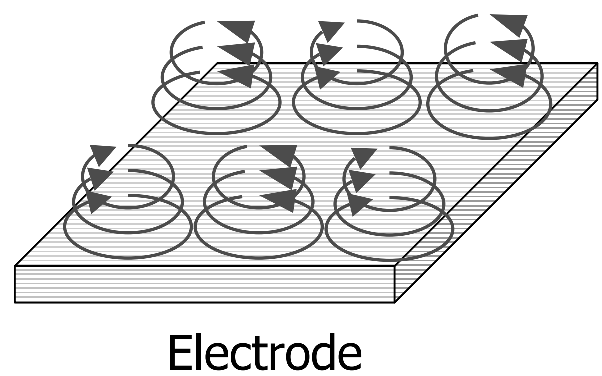
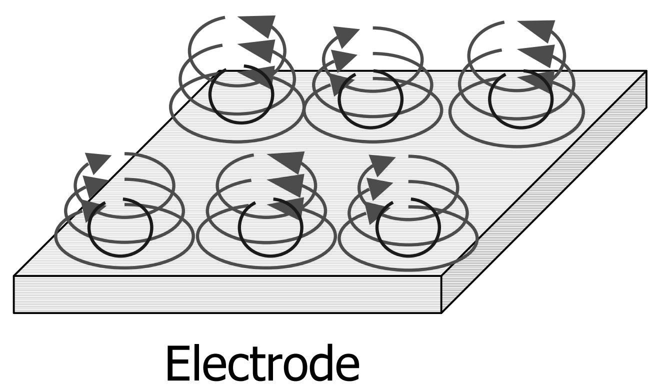


Fig.1 Micro-MHD flows in the parallel magnetic field



1) Vortexes arising from the asymmetrical fluctuations. Total angular momentum remains zero.



2) Convection cells occurring from the symmetrical and asymmetrical fluctuations

Fig.2 Micro-MHD flows arising from asymmetrical and symmetrical fluctuations in the vertical magnetic field

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