Magnetic field effects on the growth of zinc and iron electrodeposited arborescences

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Pattern formation in the electrochemical deposition under magnetic field, in thin gap circular geometry, were recently investigated[1,2,3]. We present here a study concerning magnetic field effects on the growth of arborescences of a diamagnetic metal (Zn) and a ferromagnetic metal (Fe).

Under in-plane field, while no effect is observed for zinc (at least when B< 0.2 T), a spectacular morphology symmetry breaking[3], associated with a divergence of the crystal coherence length, is observed for iron (fig. 1). In situ optical microscopy indicates that the rectangular shape is the result of a selection of the orientations of the growing branches with respect to the magnetic field (fig.2a). No in-plane field effect is found out at the scale of the transmission electron microscopy (TEM)[4]: singlecrystalline dendrites are observed whatever the field value (fig. 2b). It seems then that the effect of the magnetic field on the growth is through the dipolar interactions between the branches and the field.

Under normal field, zinc arborescences show the expected spiraling morphology (fig. 3), due to the convective motion of the electrolyte induced by the Lorentz body force. On reducing the cell thickness the fluid motion is suppressed and the spiraling desappears[5]. No spiraling at a macroscopic scale is observed in iron arborescences. However distorted branches are seen by TEM[4], associated with arched spots in the electron diffraction pattern, indicating a chirality induced at that scale by the field (fig. 4). To clarify the origin of the inhibition of the spiraling at the macroscopic scale in iron arborescences, experiments combining normal magnetic field and a rotation of the cell were performed. Again, dipolar interactions between branches seems to be responsible for the spiraling inhibition.

In summary, both in-plane and normal field effects on the growth of magnetic and non magnetic arborescences appear undistinguishable at the scale of the TEM observations (no effect in in-plane field, spiraling in normal field). That is not the case at the macroscopic scale. An essential difference between magnetic and non magnetic arborescences is that dipolar interactions should come out in the latter case. These interactions should then be relevant at a larger scale than the nanometric scale of the TEM experiments.

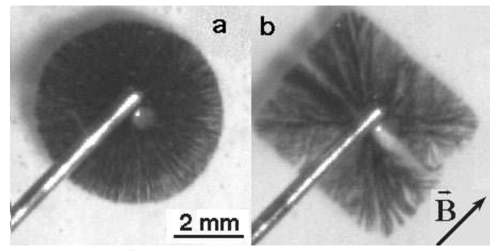

Fig. 1: Fe arborescences (0.06M, 5V). (a) B=0. (b) B=0.2 T, parallel to the plane of growth.

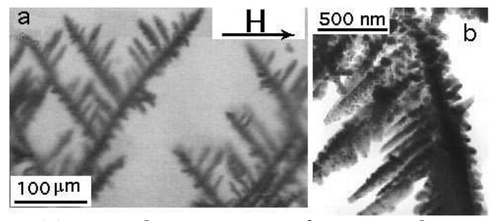

Fig.2: (a) Optical microscopy of an iron arborescence (0.06M, 5 V) grown under B=0.2 T parallel to the plane of growth. (b) TEM image of a dendritic branch.

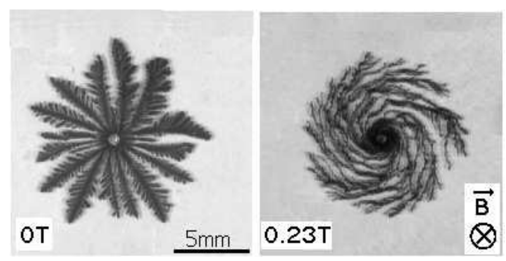

Fig. 3: Zn arborescences (0.06M, 10 V) for B=0 and B=0.23 T perpendicular to the plane of growth.

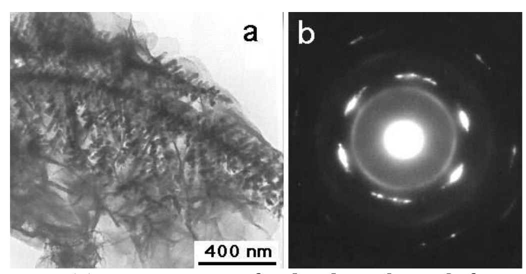

Fig. 4: (a) TEM image of a dendritic branch from an iron arborescence (0.06M, 5 V) grown under B=0.2 T perpendicular to the plane of growth. (b) corresponding diffraction pattern

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