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Author: Mrs. Barbara Fritzsche
TU Dresden, Germany

Dr. Gerd Mutschke
Germany
Mr. Till Jannes Meinel
Germany
Dr. Xuegeng Yang
TU Dresden, Germany
Prof. Kerstin Eckert
Technische Universität Dresden (DTU), Germany

SURFACE INSTABILITY OF PARAMAGNETIC LIQUID IN NON-UNIFORM MAGNETIC FIELD

Abstract

Paramagnetic liquids, e.g. produced by dissolving salts of the rare earth elements, are an interesting class both from the viewpoint of fundamental studies and of application such as magnetic separation. The physical mechanism of magnetic separation of rare earth elements was unraveled in a recent study [1] and consists in the levitation of a boundary layer, enriched in rare earth ions due to solvent evaporation, by the magnetic field gradient force. Hence, a key element of this process is the existence of a free liquid-gas interfaces. However, non-uniform magnetic fields do not only modify the transport process in the solution but also affect the stability of this interface. The latter can be manipulated in a contactless manner, free of Joule heating. Unlike a super-paramagnetic liquid, e.g a ferrofluid, their dynamics is much less investigated which forms the focus of this contribution.

To observe the combined effect of gravity and magnetic force on paramagnetic solution, the permanent magnet was moved vertically above the free surface of $DyCl_3$ solution. The change of interface morphology was followed optically by means of microscope and recorded with a high speed camera. The spatial resolution was 210 pix/mm and the frame rate was set to 200 s^{-1}. The focus of the work is the description of the surface change with two main objects:

1. The temporal dynamic evolution of liquid level with a magnet above it.
2. The morphology of the free interface.

The objective one is investigated by changing the $DyCl_3$ concentrations as well as the speed of applying and removing of the magnet. The speed of the moving magnet falls into two categories. One relates to quasi-static magnetization and demagnetization and the second represents non-static magnetization and demagnetization, i.e. 0.5 mm/s and 20 mm/s respectively. By studying the dynamic behavior of the solution interface, the following conclusions can be made:

- The level of liquid is oscillating with specific frequency defined by $DyCl_3$ concentration and is independent of magnet's velocity.
- The amplitude of the disturbance caused by magnetic field depends on both quantities: concentration and magnet's velocity.

With the study we provide interesting information about the respond of paramagnetic liquids subjected to magnetic field.

[1] Z. Lei, B. Fritzsche, and K. Eckert, The Journal of Physical Chemistry C 121, 24576 (2017).