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Magnetic liquid marbles as potential chemical sensors

Authors: Rafał Bielas[1]; Tomasz Kubiak[2]

[1] *Chair of Acoustics, Faculty of Physics and Astronomy, Adam Mickiewicz University in Poznań*

[2] *Department of Physics of Functional Materials, Faculty of Physics and Astronomy, Adam Mickiewicz University in Poznań*

The development of modern societies requires the use of an increasing number of chemicals that may become harmful to the environment once they contaminate soil or water. Therefore, robust detection methods for such substances are needed. There are, however, situations in which the quantities of liquids or powders involved are very small, but their leakage is still undesirable. This applies, for example, to medical and biological laboratories, where handling of human or animal samples must be performed under controlled conditions. In such cases, miniature sensors capable of detecting trace amounts of material, and responding to external stimuli such as magnetic fields, could support safe manipulation of miniaturized samples.

In our work, we prepared liquid and hydrogel marbles. i.e., millimeter-sized droplets whose air–liquid interface was coated with solid particles, to examine their suitability for detecting simple chemical reactions. We tested chemiluminescence using luminol in the presence of hemoglobin-based animal feed, as well as Benedict's test for reducing sugars as examples of reactions. The marbles were intentionally designed to be sensitive to magnetic fields, which allowed controlled coalescence of droplets and on-demand triggering of reactions. A broad range of particles, including bio-derived materials such as zein, baobab powder and lycopodium spores and thermochromic powders was used to stabilize the magnetic fluid droplets. These particles differed in size, morphology and surface properties, which directly influenced the shape of the marbles, the structure of their interfaces and their long-term stability. Depending on the coating, the droplets remained spherical, deformed, or formed textured shells, which consequently affected their robustness during manipulation. The findings open the possibility of developing droplet-based tools for handling small, sensitive samples in laboratory environments where leakage prevention is essential.

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