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Independent Study Application: Ferrofluids and Logic Circuits

Brief Background on Ferrofluids:
A ferrofluid is a colloidal suspension created from ferrous particles, a surfactant, and carrier fluid. The particles (average size: 10nm), suspended in the carrier and separated by the surfactant allow for a magnetic liquid that is usable for a wide variety of purposes. To prevent adhesion of the particles, the surfactant reduces Van der Waals forces and magnetic forces by partially coating the ferrous material in a non-attractive substance. The magnetic moments of the particles are randomly oriented when no external magnetic field is applied, but can re-orient almost immediately when a field becomes present.

For the purposes of many of these experiments, no specific surfactant or carrier fluid is needed, as the thermal and colloidal stability requirements are relatively easy to achieve with nearly any common ferrofluid mix.

Theoretical Application:
The original premise of this work was the idea of easily modifiable hardware. Instead of FPGAs or firmware upgradeable hardware, the intent is to create dynamic hardware capable of changing form, function, and purpose through self-modification of physical structure. These experiments are meant as a proof of concept, and will attempt to show that it is possible to build modifiable logic circuits through the combination of ferrofluids and magnetic controllers.

Overview of the Experiments:
Notes: In the interest of brevity, a basic knowledge of modern semiconductor applications is assumed. "Dynamic" refers to a group of semiconductors created entirely of ferrofluids.

1. *Creation of a variable resistor:*
    a. Experiments will consist of using ferrofluids in varying particle concentrations to produce variable resistors
    b. Tests will include resistance checking and recording, and an attempt at a mathematical equation for approximating the necessary applied field strengths and distances to achieve specific resistances in a system.

2. *Logic circuits:*
    a. AND Gate
        i. Experiments will include usage of ferrofluids to create a simple AND gate with static diodes and transistors connected via ferrofluids to act as resistors and basic semiconductors.
        ii. Tests will include checking reliability of the circuit, truth table reliability with varying fields, etc.
    b. OR Gate

i. Experiments will be similar to those of the AND gate and more testing will occur.

3. *Advanced logic circuits*
    a. Ferrofluid diodes
        i. Experiments will include attempts at creating a working dynamic diode with doped p-type and n-type semiconductor ferrofluid mixes. If it is proven possible to control a dynamic diode, the logic circuit experiments will be reconsidered with the intent of creating a fully ferrofluid-derived logic circuit.
        ii. Tests will be extensive, and include reliability checks of various diode types, ferrofluid mixtures with varying surfactants and carriers, and reverse-voltage threshold tests of each working diode.
    b. Ferrofluid transistors
        i. Experiments and tests will be very similar to those done on the ferrofluid diodes.

Needed Materials and Equipment, and Possible Vendors:
Ferrofluids (general, "educational kit) – Carolina Biological Supply, Ferrotec
Ferrofluids (specific, differing carriers or surfactants, doped particles) – Ferrotec
Plexiglass containers – Carolina, home improvement stores
Permanent magnets – Carolina, hardware stores
Electromagnets – Electronics stores, some will need to be improvised and hand-built
Diodes, transistors – Radio Shack, various electronics stores
Non-toxic, non-conducting carrier – 3M
Various safety items – already possess needed items

Additional Explanation of Experiments, Estimated Timeline, and Miscellaneous:
Explanation of Experimentation Procedures:
Each set of experiments will be completed at Incline High School, with results recorded and observed by David Allison and Tyler Yates. Results will be reviewed, and experiments will be overviewed by Mr. Resney when time permits.

Miscellaneous Notes:
There are inherent challenges based on the very nature of ferrofluids – namely that application of an electric current creates a magnetic field throughout the particle system, making controlling the position of the particles much more difficult. The creation of a variable resistor from ferrofluids is expected to be trivial: a combination of materials and careful placement of electromagnets. However, the creation of the logic circuits, especially the diodes and transistors made up of ferrofluids, should prove much more complicated. Beyond the creation of p-type and n-type ferrofluids and viable carriers and surfactants that work well together, combining the two different mixes to form a simplistic diode is expected to be a complex task. It will likely involve multiple magnet controls, sieve processes using magnetic fields, and could very well prove to be beyond the scope of a high-school physics project. It is also possible that acquisition or creation

of the necessary semiconductor particles for use in the ferrofluids will be either too costly or too time-consuming for the constraints on teacher availability and funding imposed by the project and circumstances.

Estimated timeline:
Acquiring the first set of needed materials – 2 weeks for funding, ordering, and delivery
Variable resistor creation and testing – 2 weeks
Beginning logic circuits – 2-3 weeks
Diode and transistor creation and testing – unknown, likely to be at least several months