

The Elasticity of an Aqueous Gel

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Abstract: The elasticity of an aqueous gel in the sub-millimeter range was studied by embedding iron filings and pulling the filings with an external magnet. Motion was observed with an inverted microscope. Aqueous gels play various roles in biology, including acting as models for tissue behavior. Understanding behavior at the scale between the microscopic and visible can lead to an understanding of how these realms are related.

Keywords: aqueous gel, tissue, elasticity, scale

INTRODUCTION

Aqueous gels play an important role in biological systems. For example, under mechanical stress, soft tissues such as liver behave as aqueous gels. Tissue engineering relies on an understanding of the elastic behavior of the cell cultures and the tissue scaffolds used for the repair of tissues. In particular, connective tissue, consisting of elastic fibers and found in the walls of arteries, in the dermis of the skin, and in certain ligaments and tendons, is under intense study. Many tissues and gels have been studied at microscopic [1] and visible scales. Connecting the two is the sub-millimeter scale, which has not been fully studied. The aim of this study was to develop a technique for studying the elasticity of aqueous gels at the sub-millimeter scale.

METHODS

An aqueous gel was produced by mixing 10 g of granular gelatin (catalog number 9455106, ScholAR Chemistry, West Henrietta NY USA) and 100 ml of hot water. Before setting, the mixture was poured to a depth of about 1 mm into a polystyrene Petri dish. Iron filings were sprinkled into the gel. The gel was refrigerated to solidify. The Petri dish was then placed on the stage of an inverted microscope (model 3032, Accu-Scope Inc., Sea Cliff NY USA). A calibrated 2 cm wide ceramic block magnet (model 07044, Master Magnetics, Inc., Castle Rock CO USA) was placed at various distances from the gel. The gel was imaged with a monochrome digital camera (model ProgRes MF, JENOPTIK Laser, Optik, Systeme GmbH, Jena Germany) fitted to the microscope with a reducing tube. The combination of 4x objective and 0.67X reducing tube resulted in an effective magnification of 2.68X. Images with and without the magnetic field of the block magnet were recorded with ProgRes CapturePro software (version 2.5, JENOPTIK) and analyzed in Photoshop (version CS3, Adobe Systems Inc., San Jose CA USA) running under the Windows XP operating system (Microsoft Corp., Redmond WA USA). Subsequent gel images were overlaid to determine gel motion in pixels. Pixels were then converted to μm by a microscope calibration produced in the author's laboratory.

The block magnet was calibrated by using a spring scale with a steel hook. The steel hook was attracted to the magnet. The hook and the magnet were spaced apart with strips of polycarbonate. The thicknesses of the strips were measured with electronic calipers (model CO 030150, Marathon Watch Co. Ltd., Richmond Hill ON Canada).

The experimental setup is illustrated in Figure 1. Because the magnet was significantly wider than the field of view of the microscope, the magnetic field transverse to the face of the magnet is considered to be uniform.

RESULTS

The results of the block magnet calibration are shown in the lower portion of Figure 1. A second-degree polynomial was fit to the data in an Excel spreadsheet (version 2003, Microsoft). The force, f (N) is empirically related to the distance from the magnet, x (mm) as $f = 0.0195x^2 - 0.2307x + 0.706$, with a goodness of fit $R^2 = 0.9963$.

As shown in Figure 2, the iron particles embedded in the gel showed motion on the order of a few μm under the influence of the applied magnetic field.

DISCUSSION

The gels were used promptly before the iron began to rust because the iron was in a gel with high water content. The rusting would significantly reduce the magnetic susceptibility of the iron filings. Also, after a couple of days, the gel tended to dry out, becoming stiffer.

The magnitude of the magnetic field is only a reference value, since the strength of the field depends in part on the test object.

The available iron filings were rather large and irregular. Smaller, more uniform particles, perhaps tiny steel balls, would provide a more spatially uniform probe of gel motion.

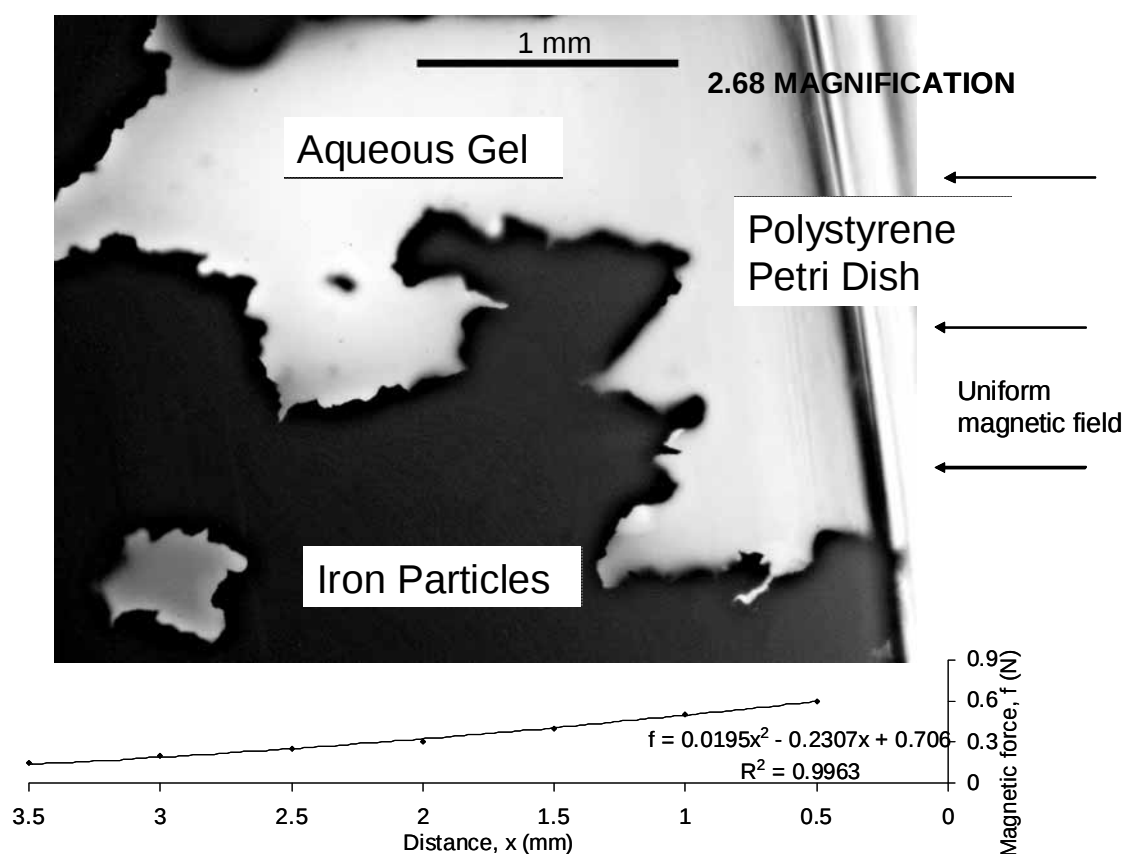


Figure 1: Apparatus and magnetic field.

CONCLUSION

It is possible to measure small motions in an aqueous gel by embedding iron filings and attracting the filings to a magnet. By embedding magnetically susceptible particles in other gels and tissues, it should be possible to study the sub-millimeter scale motion of these materials.

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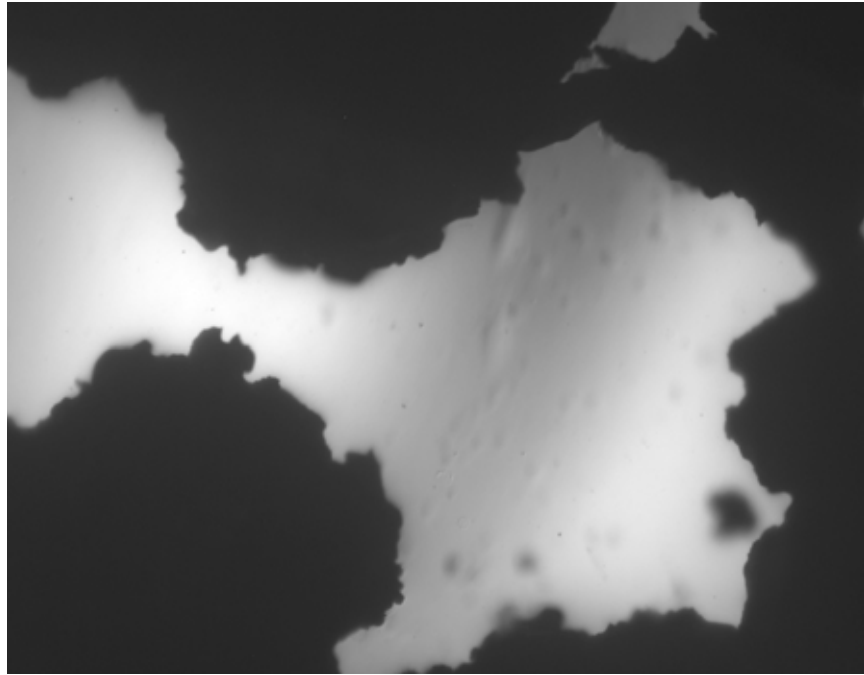


Figure 2: Two overlaid gel images, taken under the conditions shown in Figure 1. One image was in the absence of the external magnetic field, and one image was in the presence of the field. Around the periphery of the dark iron filings, some motion is visible on the order of μm .

REFERENCES

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