# Effect of Polyvinylpyrrolidone Concentration on 3D Printable Magnetite Inks

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## Abstract

Iron oxide and specifically the magnetic magnetite can be suspended in a water-based ink, which allows them to be 3D printed. The ink itself has many different polymer components that add vital traits, yet also influence the end print behavior and material properties dramatically, thus making optimizing each component incredibly important. In this study we focus on one component of the ink: Polyvinylpyrrolidone, or PVP. PVP acts as a crowding agent, allowing the coated iron oxide particles to agglomerate and form a network. This is important in shape retention of the final print as well as stabilizing the ink and having it behave as a gel before it is printed.

## Experimental

PVP concentration was tested at three different concentrations with three samples for each concentration. It is important to note that a 350mg PVP/5mL DI water solution was created, so the various concentrations are different amounts of the solution added which are 280mg of PVP, 350mg of PVP, and 420mg of PVP. Besides changing the PVP concentration all samples were kept the exact same way and were tested all on the same day. The samples were characterized on a parallel plate Mars IQ rheometer.

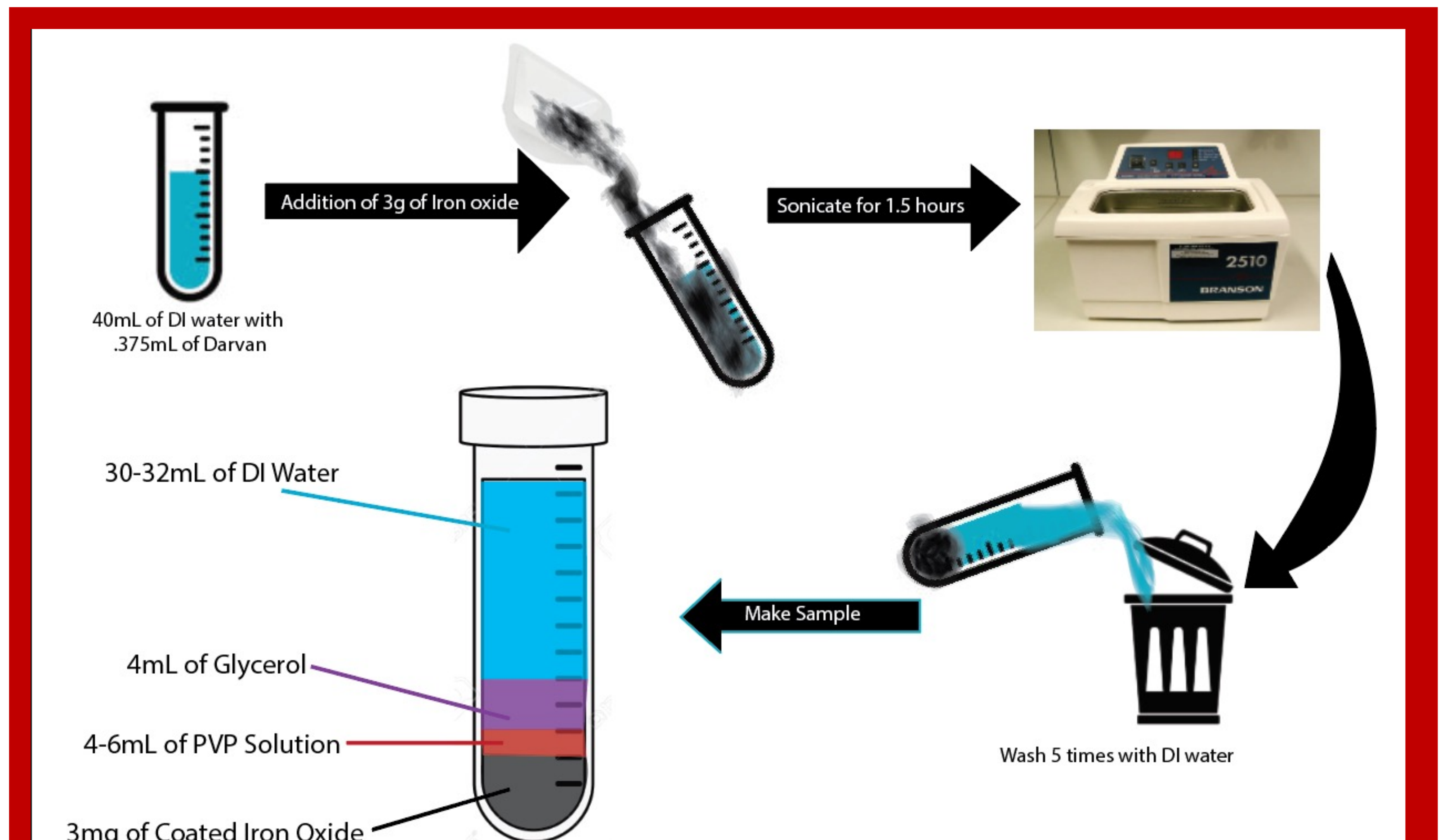


**Figure 1. A diagram of the ink making process**

The tests we are running are a frequency sweep which give us viscosity data at low frequencies and can tell us the behavior of the samples, and an amplitude sweep which tells us the Linear Visco-Elastic Region (LVER) and the yield behavior.

## Results

### Coating of Particles under TEM

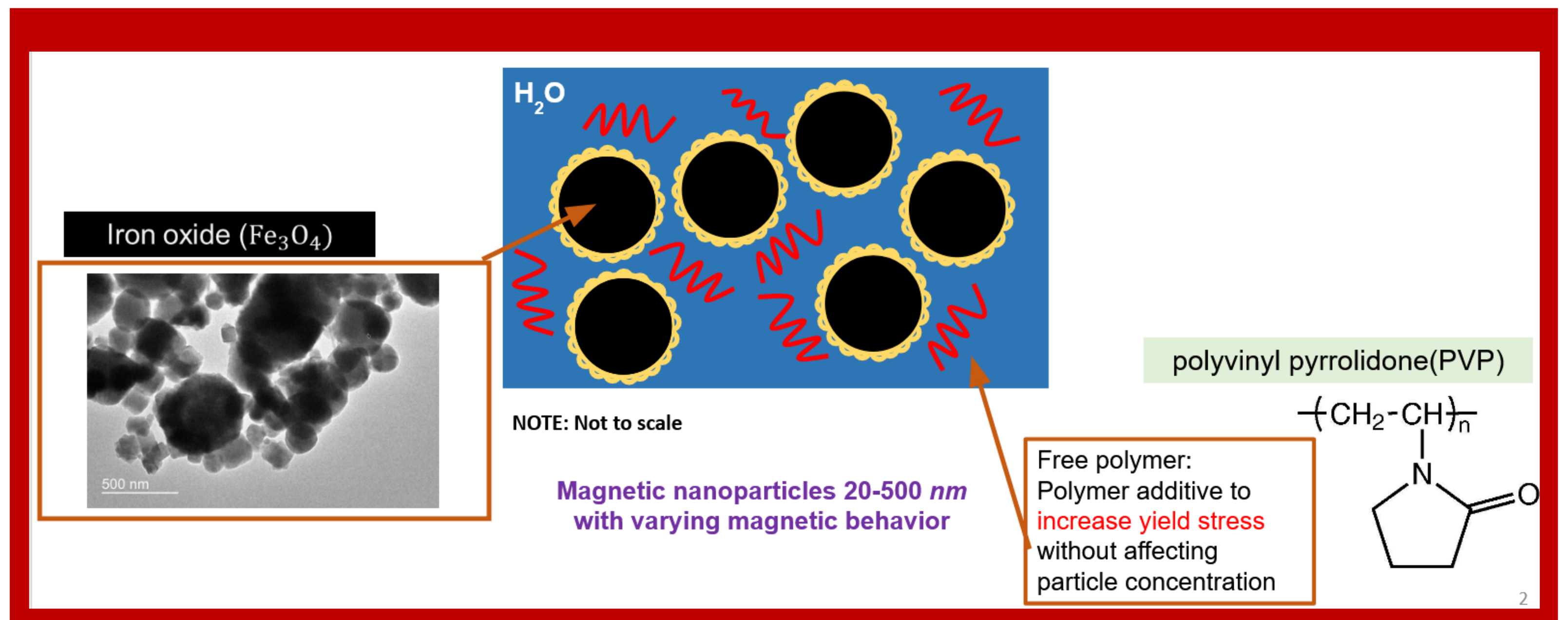


**Figure 2. A diagram by Rebecca Fedderwitz showing particle coating.**

The 420pvp samples, who's rheological and print data is shown below is coherent, with gel-like behavior in the frequency sweep and an amplitude sweep with a clear LVER. When printed, we can see clear print lines and great shape retention in the toroidal form. Not shown was the 280 and 350pvp print data which would show them lacking shape retention flowing across the build plate, and their rheological data which was wholly inconclusive for the 280pvp sample and was coherent for 350pvp but not indicative of the print data and therefore requires more testing to verify.

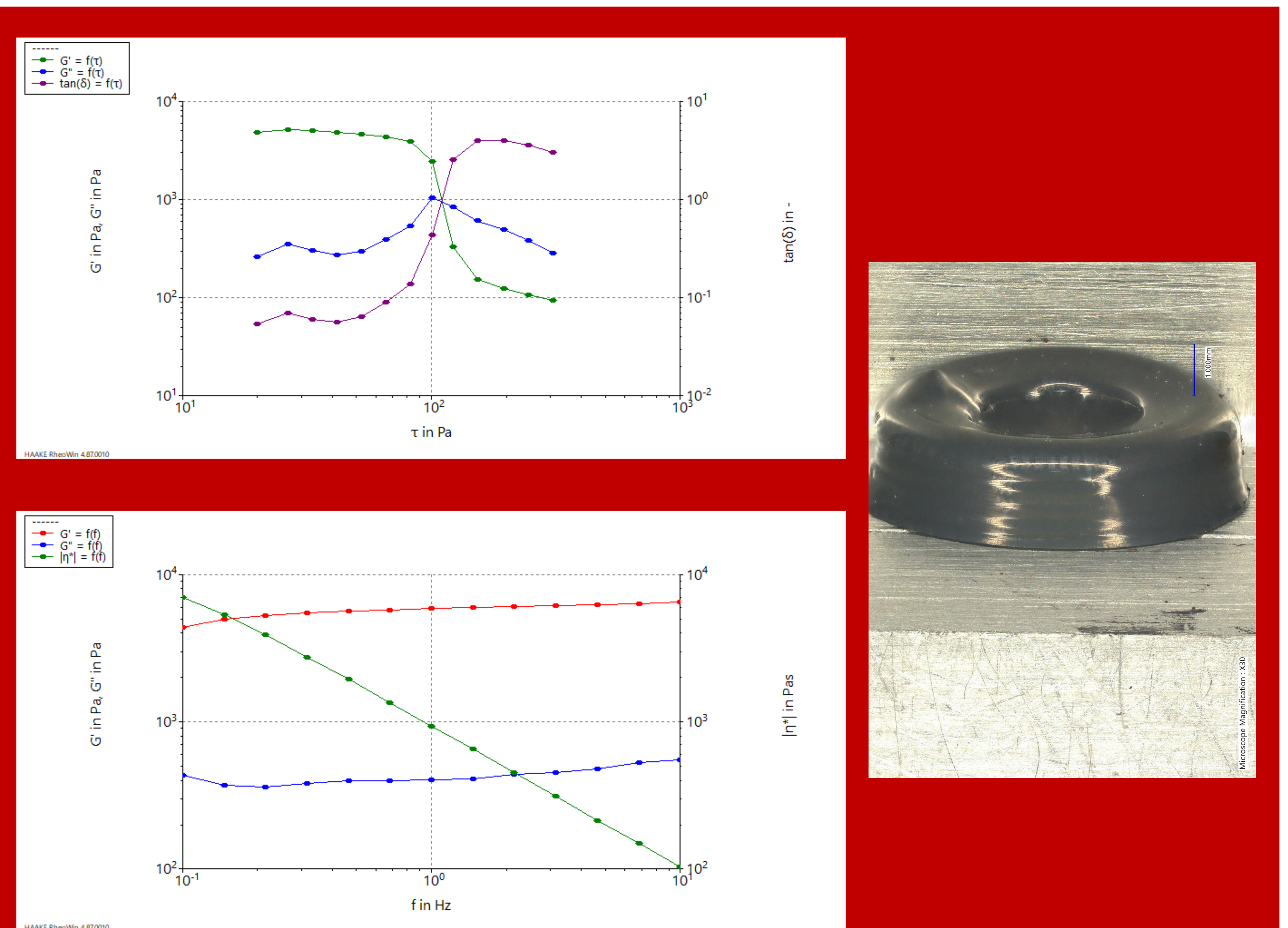


**Figure 3-5. Top left is the amplitude sweep of the 420pvp sample, bottom left is the frequency sweep of said sample, and the right is a 420pvp sample printed.**

## Conclusion

The 420pvp was a clear winner in print quality, as the other two samples have little to no shape retention, but the rheological data should have a higher yield and a more consistent LVER which prompts further testing. This concentration is believed to be advantageous because it increases the crowding effect to such a high degree that the coated iron oxide molecules are forced to pack together, increasing viscosity while decreasing void space. This must be done in an excess to reduce bridging, in which the PVP would attach to the surface of the iron oxide and connect to another PVP molecule on another iron oxide. This would decrease viscosity and increase the flow the particles had between each other, which is what we see when printing the 280pvp and 350 PVP samples. This does not happen in the 420 PVP samples as it breaches a critical threshold of crowding, and thus increases the viscosity and gives us the desired gel like behavior.

## Future Work

The future work of this project entails sintering the final prints to decrease the void space and increase mechanical properties as well as further testing on the 420 PVP samples, changing concentration of other components to optimize each of its properties.

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