# Synthesis and Photo Cross-Linking of Psoralen for 3D Printing

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## Utilizing Photo Crosslinking Abilities of Psoralen for 3D Printing

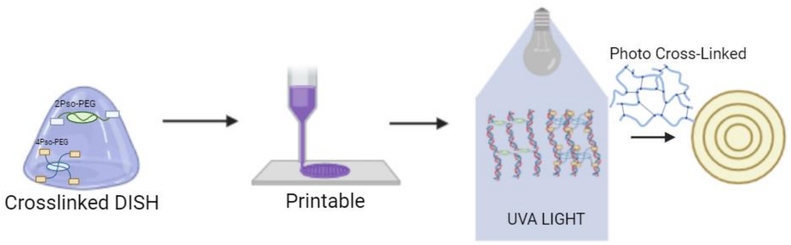



***Figure 1.*** *2-arm and 4-arm Pso-PEG hydrogels with an ideal viscosity that allows the gel to be printable. When UV-activated, they are photo-cross-linked and can hold a 3D design structure.*

Photo cross-linking hydrogels for 3D printing is a common practice for applications such as tissue scaffolding and drug delivery systems. In this project, we utilized DNA as the base of our hydrogels due to its biocompatibility and interaction with aromatic molecules via intercalation. If we can successfully 3D print with our DNA hydrogel, it would help prove the functionality of the gel, the control of cells, and most importantly the extracellular matrix. The main goal of this experiment is to be able to implant a familiar complex but also be able to manipulate what the complex can do. Intercalation is another key factor in this project. It is the reversible insertion of a molecule into that causes the unwinding of DNA and disruption in base pairs. In this project, we are utilizing Psoralen for its ability to interact with DNA via intercalation a its photo cross-linking abilities. This has been utilized in the treatment of skin conditions such as Psoriasis, Vitiligo, and Skin nodules of cutaneous T-cell lymphoma. The UV irradiation forms covalent, water-stable cross-links, making them ideal for hydrogel formation. A key function of cross-linking with psoralen is the retention of the DNA's double-stranded structure allowing for a stronger, uniform network. DNA hydrogels are known to have sheer-thinning behavior making these an attractive option for 3D printing applications. For this project, we hoped to explore the material properties of Psoralen as a cross-linker when attached to both 2-arm and 4-arm polyethylene glycol (PEG) (2-arm Pso-PEG and 4-arm Pso-PEG).

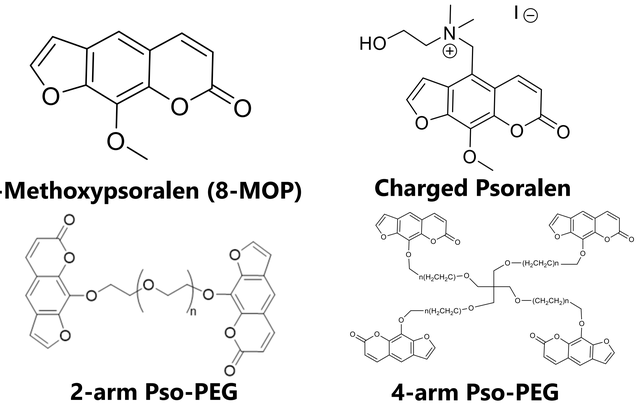



***Figure 2.*** *8-MOP is the Psoralen of interest in this study and has been attached to both 2-arm and 4-arm PEGs. We are also interested in the formation of a charged psoralen to explore the additional interaction with DNA's negatively charged phosphate backbone.*

## Increasing Stiffness of Hydrogels with UV Activation

Rheology is the study of matter deformation resulting from applying force. We utilized an oscillatory time sweep to determine the stiffness of both 2-arm and 4-arm Pso-PEG when being UV-activated. As the 4-arm Pso-PEG had a significant change in modulus when photo cross-linked, we chose to focus on this for 3D printing.

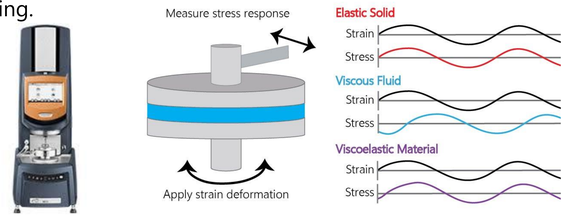



***Figure 3.*** *The comparison of the amount of stress applied to the amount of strain applied to the hydrogel.*

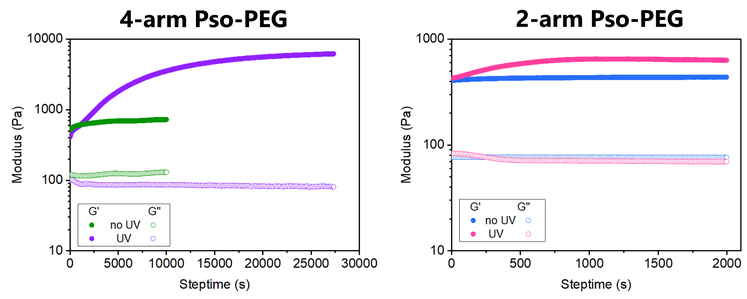
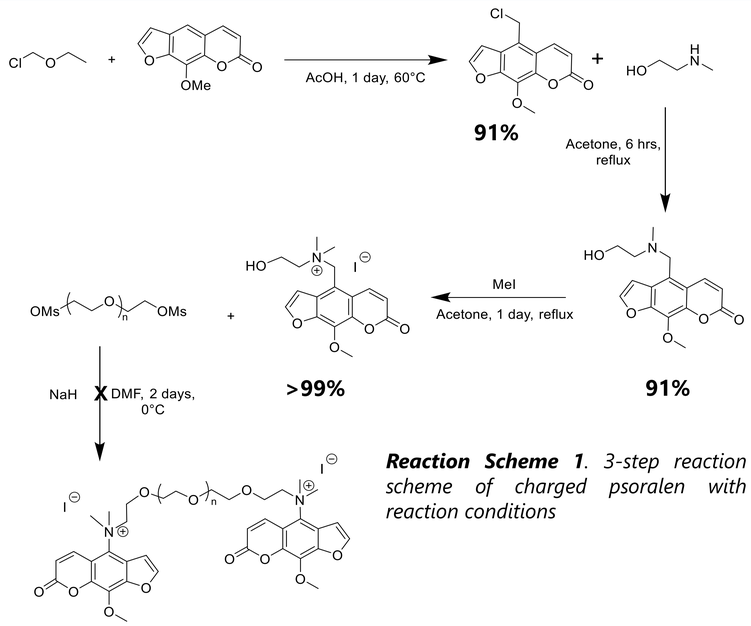



***Figure 4.*** *Time sweep comparisons of 2-arm and 4-arm Pso-PEG when being UV-activated.*

## Synthesis of Charged Psoralen




***Reaction Scheme 1****. 3-step reaction scheme of charged psoralen with reaction conditions*

## 3D Printing of 4 Arm Pso-PEG

The first step in 3D printing is loading the gel into the syringe. Then we tested the ideal pressure needed to push the gel out of the needle. The gel is excreted from a small needle, so we had to keep adjusting the amount of pressure applied to help push the gel out. In the end, 85 psi was applied to the gel. Once this step was completed and the printer was calibrated the printing began. While it's printing there is a UV light that is being applied to the gel. In Figure B the UV photo cross-linking properties are occurring. When the gel is being released from the needle it must be fluid enough to be released but with the UV activation, it is curing under that light. That way it can hold its structure and create the 3D design. Figure 6 C is our DNA hydrogel this gel is the second successful gel printed and the first one holding its structure. We created a circle with ridged circles within. We are optimizing the process to print out a larger design.

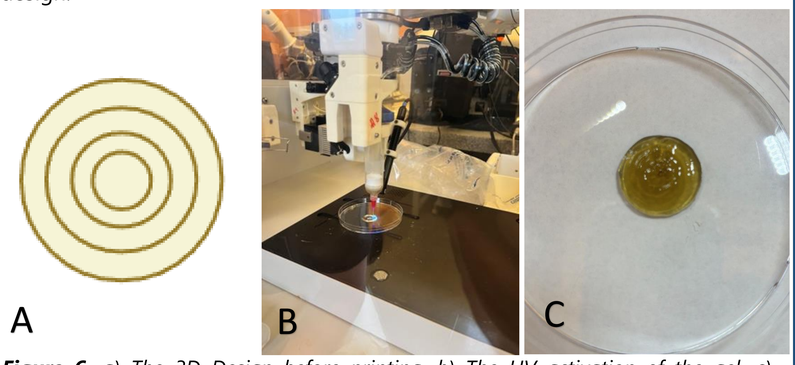



***Figure 6.*** *a) The 3D Design before printing. b) The UV activation of the gel. c) Hydrogel with a 2.5 wt% DNA and 3mM crosslinker.*

## Future Work

We are working on the attachment of the charged Psoralen to $PEG_{2K}$ and will continue to brainstorm new reaction conditions to help this attachment. Also, continue running more hydrogels on the rheometer to understand the correct viscosity needed. Lastly, make a new 3D design that will work better with the gel.

## Acknowledgments

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