



# Use of High Intensity Ultra-Violet Light to Cross-link Penta-block Polymers

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## Abstract

Polymers can be constructed that show various properties. Dr. Mallapragada's work with temperature-sensitive polymers<sup>1</sup> that gel at body temperatures has shown promise in biomedical applications including timed drug and gene delivery. A new application, co-sponsored by Ames Lab and the University of Iowa, would use temperature reactive polymers to stabilize and help medicate traumatized cartilage. To be effective the polymers must first "cross-link", usually under ultra-violet light, to form stable bonds within itself. The polymer PDEAM<sub>15</sub>-PEG<sub>1000</sub> has been shown to cross-link under low wattage UV light. This project was an attempt to determine what effect distance, intensity and duration of a high intensity UV light would have on the cross-linking of this polymer.

## Research Question

What parameters of ultra-violet light exposure will induce a self assembling penta-block polymer to form cross-links?

## Method

Polymers were constructed by dissolving a mixture of (PDEAM<sub>15</sub>-PEG<sub>1000</sub>)<sup>2</sup> (5:1 ratio) in a solution of a photo initiator (.65g Irgacure/10 ml de-ionized water) to form a 20% solution by weight.

The mixture was covered with foil to protect it from ambient light and placed in a refrigerator overnight to complete dissolving.

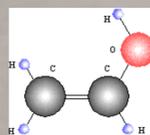
The polymer solution was then separated into vials of .30ml samples, covered and again refrigerated.

Covered vials were removed 10 minutes prior to UV exposure<sup>3</sup> to allow it to reach room temperature and begin self-assembling.

A sample was then placed under the UV light for either 5 or 10 minutes, at either 1%, 2%, or 5% intensity, at either 24cm, 18cm, 12cm, 6cm, or 1.5cm. The polymer was immediately examined for visual signs of cross-linking (viscosity) then covered with 2ml of de-ionized water to check for solubility. The polymers were checked 24 hours later to determine the rate of decomposition to solution.

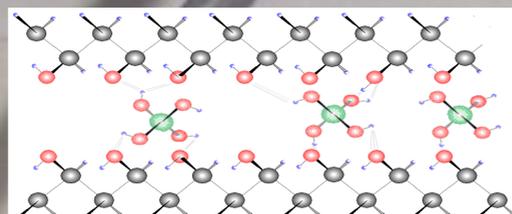
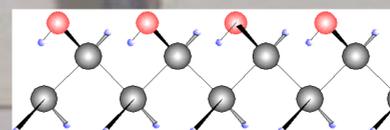


## Background



A monomer is a small molecule.

If we join many of these monomers we get a long "stringy" molecule, a polymer.



As you can see there are many points where these can assemble or bond. By adding energy you can often get them to make more bonds, or cross-link, in many places. By adding different kinds of polymers you can change the characteristics and properties of the final product.

One important characteristic is as the polymer bends around to assemble new bonds it will often surround a smaller molecule, trapping it. If this smaller molecule is a liquid, like water, the new polymer might have a gel-like consistency. But we could also have a small molecule of some other type, medicine or DNA for instance, that is surrounded and trapped by this polymer. Then this other molecule would be kept till the bonds of the polymer break down, releasing it at that time. The type and number of bonds can affect the rate at which the polymer breaks down. So if we can control the bonds we can influence the release of the trapped molecules. Dr. Mallapragada and her research team have been working on this last application<sup>1</sup>.

Penta-block polymers were constructed that showed self-assembly to both temperature and pH differences<sup>1</sup>. While a liquid at colder temperatures, the polymer would gel at body temperature. Further cross-linking could be achieved by introducing UV light to the polymer. The advantage of using UV light to cross-link is it can be turned on at the appropriate time and can be localized to a specific area.

A novel application of these bio-type polymers is in the treatment of traumatized cartilage. Damaged cartilage has difficulty repairing itself without some sort of intervention. Cross-linked polymers could be constructed to encapsulate medicine that would promote regeneration and at the same time provide structural support to the damaged area. Through proper construction of the polymer it would have the properties of dissolving and releasing the helpful agent at the same rate as the body is repairing the damage. The Ames Laboratory at Iowa State and the University of Iowa have begun a joint project to design such polymers.

Dr. Mallapragada and her research team have been constructing cross-linkable polymers consisting of a mixture of penta-block polymers using commercially available base polymers dissolved in a photo initiator agent (Irgacure 2959) to facilitate its reactivity to UV light. These polymers have been cross-linked under low wattage UV light in as little as ten minutes. However these polymers did not have the necessary mechanical properties and dissolution rate to be effective in cartilage therapy. The decision was made to investigate the use of a high intensity UV light source. It is then necessary to re-examine the properties of the polymers under different conditions of high intensity UV light.



## Results

Under no conditions did the polymers exhibit signs of cross-linking. When attaining room temperature and reaching maximum self-assembly the polymer was in a thicker, but still viscous state. After exposure to the UV light the polymer was still viscous. Successful cross-linking would have yielded a solid with a measurable compression coefficient. When covering with water to check for solubility it was apparent that the polymer was turning to solution within minutes. When checked the next day the samples were again in complete solution.



## Discussion

It was not unexpected that the results would be negative. Of all the possible parameters, we had time to test only a few. But cross-linking is possible with UV light as demonstrated by prior results under low wattage UV. When our first negative result occurred our first thought was, "More light!" either by longer exposure, shorter distance, or higher intensity. But after further discussion with C.Paul and U.Kanapathipillai we learned that the polymers have a very narrow band of sensitivity. Too little or too much would yield negative results. It appears the optimal range for cross-linking this polymer would lie between these two methods. Further investigations are needed to determine the appropriate parameters of UV light.

## References

- <sup>1</sup>Michael D. Determan,, Soenke Seifert, P. Thiyagarajan, James P. Cox, and Surya K. Mallapragada. *Synthesis and characterization of temperature and pH-responsive pentablock copolymers*. *Polymer*, Volume 46, Issue 18, 23 August 2005, Pages 6933-6946
- <sup>2</sup>PDEAM - poly-(N,N-diethylacrylamide) ; PEG -Polyethelene glycol
- <sup>3</sup>OmniCure 1000 100 watt, 18w/cm<sup>2</sup>

## Acknowledgements

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