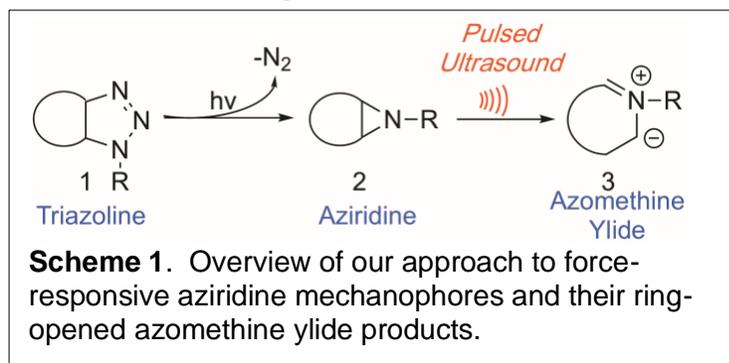


1. PRF #: 56464
2. Title: Unlocking the Rich Mechanochemistry of Aziridines Using Triazoline Synthons
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4. Co-PI: None

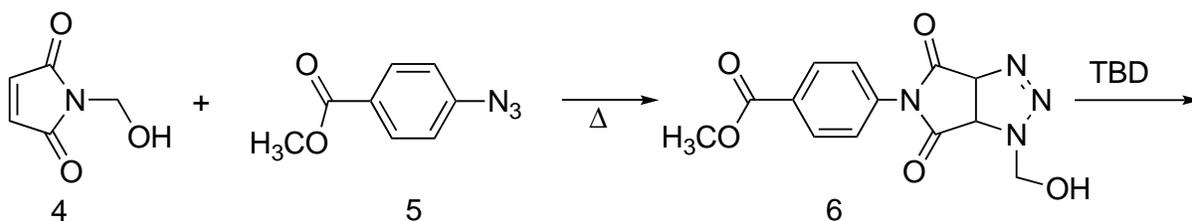
Introduction. The aim of this research program is to uncover the mechanochemical potential of aziridines and train the next generation of scientists. Aziridines are reactive three-member ring structures that, when embedded in a polymer main chain or side chain, function as cross-linking points. Accessing polyaziridines, however, is challenging and few examples exist. Our approach does not involve the direct synthesis of polyaziridines but rather an indirect route via the thermal or photochemical decomposition of polytriazolines. We intend to use triazolines as aziridine synthons. This approach circumvents the majority of synthetic challenges associated with synthesizing aziridines from other organic precursors and allows for a more comprehensive investigation of high density aziridine-containing polymers. Once the polyaziridines are in hand, we intend to probe how the application of mechanical force impacts the conversion of these strained three member rings into reactive intermediates (Scheme 1). We intend to



mechanochemically generate azomethine ylides (structure **3**, Scheme 1) from aziridine precursors (structure **2**, Scheme 1) and explore productive chemistries associated with these reactive intermediates including cross-linking (strengthening) as well as heterocycle formation (increase in structural complexity).

Year 3 Progress. A key lesson distilled out of years 1 and 2 was that aliphatic and aromatic azides produce triazolines with very different properties. Cycloadditions involving aliphatic azides proceed more smoothly than aromatic azides but the triazoline products cannot be photochemically denitrogenated easily. On the other hand, aromatic azides are slower to react with dipolarophiles and their triazoline products are less soluble than the analogous aliphatic products. Despite the more challenging road to arrive at the triazolines from aromatic azides, these heterocycles easily denitrogenate upon treatment with UV light. In order to produce a triazoline one reacts an azide with a dipolarophile. Andrew Saiz, an undergraduate working on this project during the academic year 3, synthesized key maleimide-based dipolarophile **4** shown in Scheme 2. Cycloaddition of maleimide **4** with aromatic azide **5** produces triazoline **6** in good yield. We envisioned triazoline **6** could serve as an A-B type monomer in a step-growth polymerization as it contains both an ester and an alcohol functionality. Typically, this type of polymerization would be done at high temperature. Unfortunately, we were limited thermally due to the propensity of triazolines to decompose (denitrogenation followed by ring-opening of the aziridine). We attempted the polymerization at 110°C in the presence of triazabicyclodecene (TBD). This guanidine base is a known and efficient catalyst for

transesterifications. Unfortunately, the TBD-catalyzed transesterification polymerization of triazoline **6** was unsuccessful.



Scheme 2. Year 3 synthesis of A-B type monomer **6** featuring a triazoline heterocycle. Polyester synthesis using a guanidine catalyst failed to return high molecular weight polymer.

We next turned our attention to the synthesis of diol **7** (Figure 1). Heating maleimide **4** in the presence of 1-azidoundecanol produces triazoline **7**. Although the cycloaddition reaction proceeded with high conversion, it was not quantitative. Disappointingly, chromatographic purification of triazoline **7** failed. It is unclear, at this point, why triazolines do not seem amenable to column chromatography. We attempted chromatographic purification under a variety of conditions but, as of yet, we have found a set of conditions that will reliably return pure material. This was one of the hardest lessons we learned in year 3. Despite having great success synthesizing polymer precursors such as **7**, these materials proved exceedingly challenging to purify. Our intention was to synthesize a polyurethane using diol **7**. Pure monomer is essential in these types of polymerizations. Considering the purification hurdles we faced with triazoline-containing monomers, we attempted to synthesize a triazoline main chain polymer using a different synthetic strategy. In this approach, a soluble bis-maleimide building block would be synthesized by reacting compound **4** with hexamethylene diisocyanate (HDI). The maleimide end-capped monomer then undergoes polymerization with an aliphatic bisazide. Unfortunately, the reaction product of **4** with HDI was a completely insoluble in all solvents. This route was a dead end.

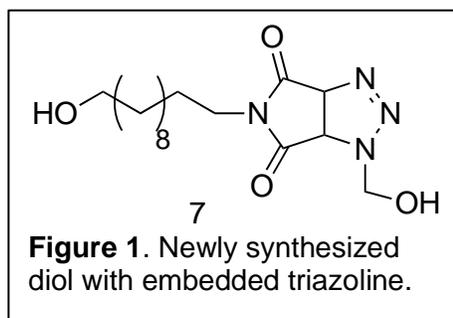


Figure 1. Newly synthesized diol with embedded triazoline.

In summary, we have learned a great deal of fundamental chemistry surrounding the synthesis of both aliphatic and aromatic triazolines. Unfortunately, we have not been successful at producing sufficient quantities of triazoline-rich polymer that could be used to probe the mechanochemical questions. This is not for a lack of effort. We do, however, have some promising synthetic leads that can potentially break this project open. We will continue to pull these threads and explore alternatives going forward.

Undergraduate Training. Andrew Saiz, joined my lab in the fall 2016 semester and graduated in May 2019. Andrew played a key role in this project although he was not part of the summer 2019 research group. The training he received on this project formed the nucleus of his senior honor's thesis. A second student, Jacob Hughes, joined the lab in the spring 2018 semester and will graduate in December 2019. Anna Zeman and Alyssa Miller were both paid stipends during the summer 2019 research period; they synthesized azide and maleimide-containing precursors.