**Thiolactone-based Polymers for Formaldehyde Scavenging Coatings**

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**ABSTRACT**

A novel, straightforward chemical platform to prepare polymers with covalently bound amine functional groups has been developed for applications as coatings that scavenge formaldehyde emissions. For the polymer preparation, an amine-thiol-ene conjugation process was used to combine N-(allyloxy)carbonyl homocysteine thiolactone monomer with different amines, which simultaneously released a thiol group for subsequent thiol-ene radical polymerization. Results of the European standard formaldehyde release test by the flask method indicated that the obtained polymers with higher amine loadings resulted in a greater reduction in formaldehyde concentration. Urea-formaldehyde adhesive was overcoated with scavenging polymers, which resulted in a significant reduction in formaldehyde emissions. The amine-functionalized polymers were characterized by NMR and DSC before and after exposure to formaldehyde. After exposure to formaldehyde, polymers exhibited additional proton peaks in the NMR spectra and their glass transition temperature increased, which implied that formaldehyde was bound to the polymers.

Keywords: thiolactone, thiol-ene, polymer coatings, formaldehyde scavenging

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1. **Introduction**

Smart coatings comprise a broad range of advanced coatings with multifunctional properties, such as self-healing, self-cleaning, superhydrophobic, stimuli-responsive, and antifouling.[1](#_ENREF_1) Traditional protective coatings form a passive barrier that shields the substrate from environmental damage. In contrast, smart coatings typically contain active components in the polymer resin or additives that impart additional properties to coatings. The active components in coatings enable them to interact with environmental stimuli, such as pH, UV light, temperature, mechanical impact, or oxygen.[2](#_ENREF_2) For example, smart barrier coatings in food packaging contain oxygen scavengers that actively trap oxygen, which prevents food spoilage and extends shelf-life.[3](#_ENREF_3) Scavenging coatings are valuable in many applications for the reduction of undesired chemical species, such as volatile compounds,[4](#_ENREF_4) radicals,[5](#_ENREF_5) corrosive agents,[6](#_ENREF_6) and moisture.[7](#_ENREF_7) For the development of advanced coatings, techniques for introducing different scavenging functionalities into polymers are necessary.

Formaldehyde is an indoor air pollutant that can cause respiratory irritation and cancer after long-term exposure.[8](#_ENREF_8) The International Agency for Research on Cancer (IARC) classified formaldehyde as carcinogenic to humans,[9](#_ENREF_9) which led to stricter regulations on the emissions of formaldehyde. The recommended limit for formaldehyde in residential indoor air was established at 0.1 mg/m3 or about 0.08 ppm by the World Health Organization (WHO).[10](#_ENREF_10) Many countries, such as Japan and the United Kingdom, have also adopted the 0.1 mg/m3 limit.[8](#_ENREF_8) Mass production of urea formaldehyde adhesives for medium density fiberboard, particleboard, and plywood resulted in a need for formaldehyde abatement.

Research efforts have been directed towards reduction of formaldehyde by reformulation of resins and incorporation of formaldehyde scavengers. In this respect, different additives have been investigated for formaldehyde scavenging, including chemical agents (eg. sodium metabisulfite, ammonium bisulfite)[11](#_ENREF_11) and natural components (eg. wheat flour, tannin, rice husk and charcoal).[12](#_ENREF_12) Compounds with amine groups can be effective in scavenging formaldehyde, since amines undergo an addition reaction with formaldehyde forming methylol groups, which can react further to form methylene bridges.[13](#_ENREF_13) The effectiveness of amines in formaldehyde scavenging depends on several parameters, including the amount of amine groups in the matrix, the structure of the amine compound, and the morphology of the matrix.

Boran *et al.* determined that the emission of formaldehyde from medium density fiberboard panels, fabricated with urea formaldehyde resins, decreased with the addition of urea, propylamine, methylamine, ethylamine, or cyclopentylamine solution to the resin.[14](#_ENREF_14) Addition of amine compounds led to an increase in water absorption and thickness swelling values of fiberboard. Medium density fiberboard panels with added amines exhibited higher internal bond strength, modulus of rupture, and modulus of elasticity. Therefore, scavenging additives can have an impact on the properties of the resin, which may be undesirable for certain applications. Nomura *et al.* impregnated polymeric amines, such as branched poly(ethyleneimine), linear poly(ethyleneimine), poly(allylamine) into mesoporous silica for the adsorption of airborne formaldehyde.[15](#_ENREF_15) The formaldehyde adsorption capacity increased in proportion to the amount of amines, with maximum capacity corresponding to almost filled pores with slight residual porosity.

In contrast to the previous strategies of addition of formaldehyde scavengers to materials, our research aimed to use thiolactone chemistry for the covalent linkage of scavenging functional groups to a polymer backbone and the resulting polymer thin film. This strategy could be effective for formaldehyde abatement in a wide range of products and applications without the need to reformulate existing resins. In addition, incorporation of scavenging functionalities by covalent linking to the polymer backbone is expected to reduce undesired migration and loss of scavengers over long time periods.

Thiolactone chemistry has been established earlier as an effective method for one-pot multi-step synthesis of multifunctional polymers.[16](#_ENREF_16) In previous research, thiolactone chemistry has been demonstrated as an effective strategy for the preparation of isocyanate-free polyurethanes,[17](#_ENREF_17) diversely substituted polyamides,[18](#_ENREF_18) hyperbranched polymers,[19](#_ENREF_19) functionalized cyclic polymers,[20](#_ENREF_20) glycopolymer nanoparticles,[21](#_ENREF_21) poly(thioetherurethane)s[22](#_ENREF_22) and crosslinked chitosan polymers.[23](#_ENREF_23)

DL-homocysteine thiolactone hydrochloride is a renewable and commercially available heterocyclic thioester with a protected thiol group. An AB’ monomer containing a double bond and a thiolactone unit has been synthesized by the addition of allyl chloroformate to DL-homocysteine thiolactone hydrochloride to form N-(allyloxy)carbonyl homocysteine thiolactone (Alloc-TL) (Scheme 1). Polymers with different functional groups have been prepared from the Alloc-TL monomer, following the earlier described amine-thiol-ene conjugation.[16](#_ENREF_16) Addition of primary amine compounds to Alloc-TL results in thiolactone ring opening, which releases free thiol groups that can subsequently react via radical thiol-ene addition with double bonds (Scheme 1).



Scheme 1. Reaction of DL-homocysteine thiolactone hydrochloride and allyl chloroformate to form N-(allyloxy)carbonyl homocysteine thiolactone (Alloc-TL) monomer, followed by aminolysis and thiol-ene reaction in the presence of 2,2-dimethoxy-2-phenyl acetophenone (DMPA) photoinitiator and UV light.

The aim of this research was the application of thiolactone chemistry to the preparation of UV-cured clear coats for scavenging formaldehyde. Formaldehyde emissions in the presence of polymer films with different types and loadings of amine compounds were evaluated according to the European standard formaldehyde release test by the flask method.[24](#_ENREF_24) The amine-functionalized polymers were characterized by High Resolution Magic Angle Spinning Nuclear Magnetic Resonance (HR-MAS NMR) spectroscopy and Differential Scanning Calorimetry (DSC) in order to elucidate any changes in polymer structure after exposure to formaldehyde.

**2. Materials and methods**

**2.1 Materials**

## Allyl chloroformate (Sigma-Aldrich, 97%), DL-homocysteine thiolactone hydrochloride (Sigma-Aldrich, ≥99.0%), 2,2-dimethoxy-2-phenyl acetophenone (Sigma-Aldrich, 99%), 1-aminohexane (Sigma-Aldrich, 99%), tris(2-aminoethyl)amine (Sigma-Aldrich, 96%), 1,6-hexanediamine (Acros, 99.5+%), 2,2′-(ethylenedioxy)bis(ethylamine) (Sigma-Aldrich, 98%), 1,2-diaminoethane (Sigma-Aldrich, ≥ 99.5%), 1-propanol (Sigma-Aldrich, ACS reagent, ≥ 99.5%), formaldehyde in water, (Sigma-Aldrich, PE1380 Proficiency Testing Material) were used as received.

## 2.2 Methods

FT-ATR-IR spectra were recorded on Perkin-Elmer Spectrum1000 FTIR infrared spectrometer.

Thermal properties of the UV-cured polymer thin films were tested with TA Instruments 2920 Modulated DSC V2.6A under nitrogen gas flow of 19 mL/min. Measurements were performed in a temperature range of −20 to 150 °C with a rate of 10 °C/min over 2 cycles. Glass transition temperatures were determined from the midpoint of the step change in the second measurement cycle.

High Resolution Magic Angle Spinning Nuclear Magnetic Resonance (HR-MAS NMR) spectroscopy was performed on a Bruker Avance II 700 spectrometer (700 MHz). Samples were prepared by placing dry polymer into a 4 mm rotor and adding 30 µL of solvent (DMSO-d6) to allow the material to swell. 1H NMR spectra were recorded using a HR-MAS probe at spinning rate of 6 kHz and collecting 32 scans.

Formaldehyde testing was conducted according to the standard procedure for the determination of formaldehyde by the flask method[24](#_ENREF_24). UV-Vis spectra were obtained with AnalytikJena SPECORD 205 UV/Vis Spectrophotometer. A formaldehyde calibration curve was obtained using a standard solution of formaldehyde in water. Limit of detection of formaldehyde was determined from 20 blank samples and calculated by summation of the average value of the blank samples and the standard deviation multiplied by 3.

## 2.3 Synthesis of (N-allyloxy) carbonyl D,L-homocysteine thiolactone (Alloc-TL)[25](#_ENREF_25)

## DL-Homocysteine thiolactone hydrochloride (28 g, 0.1823 mol) was slowly added to a solution of NaHCO3 (76.44 g, 0.91 mol) in H2O/1,4-dioxane (1/1, 400 mL) and this mixture was stirred for 30 minutes. Allyl chloroformate (38.76 mL, 0,3644 mol) was added dropwise and the reaction mixture was stirred overnight at ambient temperature. The reaction mixture was diluted with brine (800 mL) and extracted with ethyl acetate (4 x 800 mL). The organic phase was dried with MgSO4. The drying agent was filtered, the solvent was evaporated under reduced pressure, and the product crystallized at 5°C after several days.

**2.4 Photopolymerization of polymer films prepared from Alloc-TL and 1-aminohexane**

A solution of N-(allyloxy)carbonyl homocysteine thiolactone (402 mg, 2 mmol) in 1-propanol (2 mL) was combined with 1-aminohexane (202 mg, 2 mmol). The reaction mixture was stirred for 4 hours at room temperature. DMPA (18 mg, 0.1 mmol) was added to the solution. The resulting formulation was dispensed by micropipette on microscope glass slides and spread with a 200 μm slot die, followed by drying for 1 hour. The thin film was irradiated with a 250 W mercury lamp (Hönle UVAHAND 250) at 1.4 J/cm2. Two samples were prepared for each formulation. Each sample was weighed on a microbalance. Average sample mass was 55 +/- 3 mg. Average dry film thickness was 25 μm. Polymer thin films with other amine compounds were prepared in a similar manner.

1. **Results and Discussion**

D,L-Homocysteine thiolactone hydrochloride is a cyclic thioester that was combined with allyl chloroformate to form N-(allyloxy)carbonyl homocysteine thiolactone (Alloc-TL) monomer according to a reported procedure.[25](#_ENREF_25) This Alloc-TL monomer was used to prepare different polymers following a two-step procedure. In the first step, Alloc-TL monomer reacted with a primary amine in solution, resulting in the release of the thiol functionality. The resulting solution was applied on substrates and the solvent was evaporated at ambient conditions. In the second step, polymer thin films were prepared by radical thiol-ene step growth addition that was triggered by UV irradiation in the presence of 2,2-dimethoxy-2-phenyl acetophenone (DMPA) radical photoinitiator. Four readily available diamines and triamines with primary amine groups, known to react with thiolactone groups, were chosen with the aim to obtain free amine groups that are available for scavenging formaldehyde (Figure 1). More specifically, aliphatic amine compounds with different chain length, composition, and branching were selected in order to investigate whether the structure of the amine compounds has an influence on the efficiency of formaldehyde scavenging.



Figure 1. Primary amine compounds used to prepare polymers for formaldehyde scavenging: 1,2-diaminoethane, 1,6-diaminohexane, tris(2-aminoethyl)amine, 2,2′-(ethylenedioxy)bis(ethylamine).

Fourier Transform Infrared (FTIR) spectroscopy was used to confirm the formation of an amide adduct from Alloc-TL and an amine. The infrared spectrum of the Alloc-TL contains a carbonyl absorbance peak at 1685 cm-1 that corresponds to the thioester group (Figure 2). Following the addition of an amine to Alloc-TL, a new carbonyl peak is observed at 1660 cm-1, which corresponds to the amide product. An overlapping carbonyl peak at 1700 cm-1 is associated with the urethane functional group of Alloc-TL. The thiol-ene addition reaction results in the disappearance of the absorption at 995 cm-1, which corresponds with the alkene C=C–H bending vibration. The overall conversion has been calculated from the integration of the alkene absorption peak before and after UV irradiation (Table 1).

Figure 2. Fourier Transform Infrared (FTIR) spectra of Alloc-TL monomer (bottom), formulation of Alloc-TL and 1,6-diaminohexane (middle), and the resulting UV-cured polymer (top).

Systematic testing of polymers with different amine loadings was conducted in order to determine if they are effective in scavenging formaldehyde. The amine loading in dry polymers was calculated based on the molar ratio of the Alloc-TL monomer and amine compounds in order to distinguish polymers with varying quantities of primary amine groups that could react with formaldehyde. A series of UV-cured polymer films with progressively increasing molar loadings of residual amine groups were prepared by varying the ratio of monofunctional 1-aminohexane and difunctional 1,6-diaminohexane (formulations # 1-6). Formulation #1 contained only 1-aminohexane that reacted completely with Alloc-TL and resulted in the absence of residual amine groups. This formulation was used as a reference sample, which is not expected to scavenge formaldehyde. On the other hand, formulations prepared with the difunctional 1,6-diaminohexane contain residual amine groups, as indicated by the molar amine loading in Table 1. In most formulations, linear polymers are formed with pendant primary amine groups, while in formulation #10 cross-linked polymers are formed, since the trifunctional amine reacts with 2 equivalents of the Alloc-TL monomer.

Table 1. Formulations prepared from N-(allyloxy)carbonylhomocysteine thiolactone (Alloc-TL) and different amine compounds.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Formulation | Molar ratio of components | Amine loading in polymer (mmolN g-1) | % Conversion (C=C-H absorption) |
| 1 | Alloc-TL: 1-aminohexane : 1,6-diaminohexane | 1.00 : 1.00 : 0 | 0.0 | 92 |
| 2 | Alloc-TL: 1-aminohexane : 1,6-diaminohexane | 1.00 : 0.85 : 0.15 | 0.5 | 89 |
| 3 | Alloc-TL: 1-aminohexane : 1,6-diaminohexane | 1.00 : 0.67 : 0.33 | 1.1 | 81 |
| 4 | Alloc-TL: 1-aminohexane : 1,6-diaminohexane | 1.00 : 0.50 : 0.50 | 1.6 | 88 |
| 5 | Alloc-TL: 1-aminohexane : 1,6-diaminohexane | 1.00 : 0.33 : 0.67 | 2.1 | 81 |
| 6 | Alloc-TL: 1-aminohexane : 1,6-diaminohexane | 1.00 : 0 : 1.00 | 3.2 | 89 |
| 7 | Alloc-TL: 1,2-diaminoethane | 1:1 | 3.8 | 81 |
| 8 | Alloc-TL: 2,2′-(ethylenedioxy) bis(ethylamine) | 1:1 | 2.9 | 97 |
| 9 | Alloc-TL: tris(2-aminoethyl) amine | 1:1 | 5.8 | 88 |
| 10 | Alloc-TL: tris(2-aminoethyl) amine | 2:1 | 3.6 | 88 |

The average mass of the polymer samples that were tested for formaldehyde scavenging was 55 +/- 3 mg. The total quantity of amine groups per sample ranged between 0.0275 mmol (0.5 mmolN g-1) and 0.319 mmol (5.8 mmolN g-1). The initial concentration of formaldehyde in solution that was added to each test flask was 0.2 ppm, which corresponded to the total amount of formaldehyde of 0.00004 mmol per flask. The concentration of amine groups in the polymer was varied in different samples, while the total amount of amine groups in each sample was in a large excess of formaldehyde. An excess of scavenging groups is necessary to trap trace quantities of volatile compounds, otherwise it would take a very long time for the scavenging reaction to take place, which would not be useful for potential applications. Since the total amount of amine groups in the tested samples was in a large excess compared to the total amount of formaldehyde in the test flask, small variations in the mass of the polymers are not going to affect the total amount of formaldehyde scavenged.

Formaldehyde scavenging was investigated according to the EN 717-3 European standard flask method for the determination of formaldehyde release.[24](#_ENREF_24) Polymer films with amine functional groups were suspended at the top of the flask containing 0.2 ppm formaldehyde solution in water and samples were withdrawn over time (Scheme 2A). The samples with formaldehyde solution were combined with ammonium acetate and acetyl acetone, resulting in the formation of a UV-absorbing compound (Scheme 2B), which was analyzed by UV/Vis spectrophotometry.



Scheme 2. Schematic representation of the formaldehyde test in a flask [A]; reaction scheme of formaldehyde with acetyl acetone and ammonium acetate [B]. [24](#_ENREF_24)

Figure 3 illustrates the change in the concentration of formaldehyde over time in the presence of polymer films with different molar loadings of primary amine groups. Reduction of formaldehyde concentration was observed in the presence of the polymers with residual amine groups, as opposed to the reference sample. The concentration of formaldehyde was reduced to a greater extent in the presence of polymer samples with higher loadings of primary amines.

Figure 3. Formaldehyde concentration over time in the presence of 55 mg of polymer films with different molar quantities of primary amine groups prepared from Alloc-TL, 1-aminohexane and 1,6-diaminohexane in different molar ratios.

Various amine compounds were incorporated into polymers and their effect on formaldehyde concentration in a flask was investigated. Figure 4 illustrates the increase in the quantity of scavenged formaldehyde for a specific polymer film over time from a solution with 1.2 μg of formaldehyde. We observed a difference in the amount of formaldehyde scavenged by polymer films with different amines in the time period of 24 to 72 hours. The difference in scavenging was reduced over a longer time period, which suggests that at first, the orientation of the different amine molecules on the surface of the polymer film affected interactions with gaseous formaldehyde.

After 120 hours, the total amount of formaldehyde scavenged was the highest for amine compounds with linear aliphatic chains, compared to branched amine compounds. For example, formulations # 9,10 with the branched tris(2-aminoethyl)amine at amine loading of 5.8 and 3.6 mmol g-1 resulted in a similar percentage of formaldehyde scavenged after 120 hours (respectively 90% and 91%). Formulation #10 had a higher ratio of monomer to amine than formulation #9, resulting in greater cross-link density and lower amine loading. The results of formaldehyde scavenging indicated that branched amines with different loadings and cross-link densities are overall less effective than linear amines. Formulations # 6,7 with linear aliphatic chain amines, 1,6-diaminohexane and 1,2-diaminoethane resulted in a higher percentage of formaldehyde scavenged after 120 hours (respectively 99% and 97%). The difference between the formaldehyde scavenged by polymers with 1,6-diaminohexane and tris(2-aminoethyl)amine was 0.10 µg, while the standard error corresponded to 0.01 µg. Therefore, the difference in the amount of formaldehyde scavenged is related to the effect of polymers, rather than to differences in sample preparation or testing. The reactivity of all the primary amine compounds used in this study with formaldehyde is expected to be the same. The difference in formaldehyde scavenging could be attributed to several secondary factors, such as the conformational constrains of the amine groups in the polymer and diffusion of formaldehyde through the polymer matrix.

Figure 4. Formaldehyde scavenged by 55 mg of polymer films: ◊ Alloc-TL : 1,2-diaminoethane (1:1), ■ Alloc-TL : 2,2′-(ethylenedioxy)bis(ethylamine) (1:1), ○ Alloc-TL: tris(2-aminoethyl)amine (1:1), ▲ Alloc-TL: tris(2-aminoethyl)amine (2:1), ♦ Alloc-TL: 1,6-diaminohexane (1:1).

The chemical change in the polymer structure after exposure to formaldehyde was elucidated by HR-MAS NMR spectroscopy. The spectrum of the polymer prepared from Alloc-TL and 1,2-diaminoethane exhibited new peaks at 4.71 ppm and 4.82 ppm after exposure to formaldehyde (Figure 5). The new peaks were expected from the methylene and methylol protons that are incorporated into the polymer after reaction of amine groups in the polymer with formaldehyde.

Similar results were obtained by Slonim *et al.* during an investigation of the structure of urea-formaldehyde resins by NMR, which revealed peaks at 4.39 ppm and 4.60 ppm corresponding to methylene diurea and methylol urea. [26](#_ENREF_26) The difference in the chemical shift of the methylol and methylene peaks in the formaldehyde scavenging polymers compared to the urea-formaldehyde resins could be attributed to the influence of the urea functionality as opposed to aliphatic amines and the effect of solvent interactions, such as hydrogen bonding in the case of deuterated water.



Figure 5. HR-MAS NMR spectra of a polymer film based on Alloc-TL monomer and 1,2-diaminoethane in d6-DMSO (δ=2.5 ppm) before and after exposure to formaldehyde (A); chemical structures associated with the observed NMR spectra (B).

The effect of formaldehyde exposure on the thermal properties of the polymer films was investigated by DSC. Figure 6 shows the glass transition temperature (Tg) before and after exposure to formaldehyde while the difference in Tg is indicated on the scatter plot. The Tg increased significantly by 10-19 °C after exposure to formaldehyde. The greatest increase in the Tg after formaldehyde exposure was observed for formulation #7 with 1,2-diaminoethane, which is a low-molecular weight aliphatic amine and was one of the most effective scavengers according to the formaldehyde testing (Figure 4). On the one hand, the formation of methylol groups upon addition of formaldehyde to amines can contribute to hydrogen bonding, resulting in a higher Tg of the polymer. On the other hand, methylene bridges formed by reaction of formaldehyde with several amine groups (Figure 5B) can increase the cross-link density and thus the Tg-value.

Figure 6. Glass transition temperature (Tg) of polymers before and after exposure to formaldehyde, represented by white and gray bars, respectively. Scatter plot represents the difference between the initial Tg and the final Tg after formaldehyde exposure. Polymers were prepared from Alloc-TL and different amines: 1,2-diaminoethane (ED), tris(2-aminoethyl)amine (TAEA), 1,6-diaminohexane (HD), 2,2’-(ethyenedioxy)bis(ethylamine) (EDEA) and 1-aminohexane (HA). Molar ratios of Alloc-TL and amines are indicated in brackets.

The feasibility of using formaldehyde scavenging polymers as top coats was investigated using a urea-formaldehyde adhesive. The adhesive was applied and dried, followed by the application of the scavenging polymers. The results of the formaldehyde release test by the flask method indicated that formaldehyde emissions were significantly reduced by the scavenging polymers in comparison to the urea-formaldehyde adhesive as reference material (Figure 7).

Figure 7. Formaldehyde emissions from urea- formaldehyde adhesive overcoated by polymers: **×** Alloc-TL: 1,6-diaminohexane (1:1), ∆ Alloc-TL : tris(2-aminoethyl)amine (1:1), ◊ Alloc-TL : tris(2-aminoethyl)amine (2:1), ● Alloc-TL : 1-aminohexane (1:1), ■ urea-formaldehyde adhesive.

The reduction in formaldehyde emissions is due to a combination of the barrier effect of the polymer, as well as the scavenging groups. The polymers composed of Alloc-TL and 1-aminohexane, without any residual amines for scavenging, was expected to only have a passive barrier effect in preventing formaldehyde emission. A reduction was indeed observed for this polymer but to a much lower degree compared to the active scavenging polymers. After incubation of the overcoated adhesive samples for 1 week at 40°C, the lowest concentration of emitted formaldehyde was 0.007 ppm in the presence of the polymer with 1,6-diaminohexane, while the highest formaldehyde concentration was 0.3 ppm in the presence of the polymer with tris(2-aminoethyl)amine. The limit of detection for formaldehyde was 0.002 ppm, based on 20 blank samples. These results are in agreement with the findings from the free standing polymer films with amine scavengers, which confirmed that linear aliphatic chain amines are more effective in scavenging formaldehyde than branched amines.

**4. Conclusion**

This work focused on the proof of concept that polymer films with amine side groups can react with formaldehyde and thereby reduce formaldehyde emissions. Multifunctional amine compounds were introduced into thiol-ene polymers via the Alloc-TL monomer, following a two-step amine-thiol-ene conjugation. Different ratios of monomer and amines resulted in branched or cross-linked polymers. Pendant amines in the polymer films reacted with formaldehyde, resulting in reduction of formaldehyde concentration in testing flasks. Reduction in formaldehyde emissions from coated urea-formaldehyde adhesive was demonstrated using the standard formaldehyde release test by the flask method. The versatility of the thiolactone chemistry enables efficient screening of functional groups in polymers for different applications of interest. Optimization of thiolactone-based polymers for coating applications will be described in a forth-coming publication.

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