Macromolecular Chemistry and Physics

Macromolecular Chemistry and Physics
www.mcp-journal.de

REVIEW OPEN ACCESS

Cationic Poly(2-oxazoline)s

Meike N. Leiske[1,2]

[1]Macromolecular Chemistry, University of Bayreuth, Bayreuth, Germany | [2]Bavarian Polymer Institute, Bayreuth, Germany

Correspondence: Meike N. Leiske (meike.leiske@uni-bayreuth.de)

Received: 9 January 2026 | **Revised:** 23 February 2026 | **Accepted:** 24 February 2026

Keywords: amino-functionalized polymer | cationic ring-opening polymerization | poly(2-oxazoline) | polycation | polyelectrolyte

ABSTRACT

In the past, cationic poly(2-oxazolines) (POx) have emerged as a promising class of polymers for biomedical applications. Cationic POx are intensely researched as antimicrobials as well as drug or gene delivery vectors. This review aims to summarize synthetic strategies for the design of cationic, amine-derived POx. It showcases previous approaches to synthesize chain-end and side chain functional POx and discusses obstacles that can arise during different synthetic routes. Finally, it will present examples of the application of cationic POx in the life science field. This review showcases cationic POx as a promising material with high potential for future applications and underlines future directions of this polymer class.

1 | Introduction

Cationic polymers represent a versatile class of macromolecules that have gained significant attention in biomedical applications due to their ability to interact electrostatically with negatively charged biological entities, including nucleic acids, proteins, cell membranes, and bacterial surfaces [1]. These interactions make cationic polymers particularly useful in drug delivery [2], gene therapy [3], antimicrobial coatings [4], and tissue engineering [5]. Their functional versatility arises from their tuneable physicochemical properties, such as charge density, molar mass, and hydrophilicity.

Structurally, cationic polymers are defined by the presence of positively charged functional groups along their backbone or within their side chains, typically comprising amine, quaternary ammonium, or guanidinium moieties [6]. Their electrostatic properties facilitate strong binding to anionic biomolecules, a feature that is crucial for applications such as gene delivery and antimicrobial therapies. The solubility and biocompatibility of these polymers vary depending on their charge density and chemical composition.

Cationic polymers can be broadly categorized into natural and (semi-)synthetic types. Among the naturally derived cationic polymers, chitosan, a polysaccharide derived from chitin, exhibits excellent biocompatibility and is widely explored for drug delivery, wound healing, and tissue engineering [7]. Besides, glycogen was extensively studied as a building block for advanced biological materials [8]. Synthetic cationic polymers, including poly(ethylene imine) (PEI), poly(β-amino ester)s (PBAEs), poly(2-dimethylaminoethyl methacrylate) (PDMAEMA), and polyquaternary ammonium compounds, are extensively employed in gene therapy, antimicrobial applications, and biomedical coatings due to their enhanced stability and functional tunability [9–12].

The biomedical potential of cationic polymers is vast, with gene delivery being one of their most prominent applications [1]. In non-viral gene therapy, cationic polymers facilitate the condensation of DNA or RNA into stable nanoparticles, allowing efficient cellular uptake and endosomal escape [13]. Synthetic polymers like PEI and PDMAEMA provide high transfection efficiency but may be associated with cytotoxicity at high molar mass [14]. PEI remains a gold standard for gene transfection,

although its cytotoxic effects have spurred the development of degradable alternatives such as biodegradable cationic PBAEs, which offer improved biocompatibility [11]. Similarly, chitosan- and PDMAEMA-based vectors have demonstrated promise for nucleic acid delivery in targeted therapies [10]. Additionally, polypeptides such as poly-L-lysine and polyarginine have demonstrated efficacy in gene delivery applications due to their strong nucleic acid condensation capabilities [15, 16].

Another critical application of cationic polymers is in drug delivery, where they serve as carriers for hydrophilic and hydrophobic drugs, enhancing their bioavailability and controlled release. pH-sensitive cationic polymers enable targeted drug release at specific physiological sites, such as tumours or inflamed tissues, by leveraging the acidic microenvironment for polymer degradation and cargo release [1, 2].

In addition to therapeutic delivery, cationic polymers exhibit strong antimicrobial properties, which are particularly useful in medical device coatings, wound dressings, and hospital surfaces [17]. Their mechanism of action typically involves electrostatic attraction to negatively charged bacterial membranes, leading to membrane disruption and bacterial cell death. Quaternary ammonium-based polymers have been extensively studied for their potent antimicrobial efficacy, making them ideal for infection-resistant biomedical materials.

Cationic polymers also play a pivotal role in tissue engineering and regenerative medicine [5, 18]. Their ability to support cell adhesion, proliferation, and differentiation has made them promising candidates for scaffold materials in wound healing, nerve regeneration, and three-dimensional tissue engineering constructs. The incorporation of cationic hydrogels in regenerative therapies further enhances tissue repair by providing a bioactive microenvironment conducive to cell growth and matrix deposition.

Despite their immense potential, many cationic polymers face challenges related to biocompatibility and cytotoxicity, particularly at high charge densities [14]. The development of novel cationic polymers with reduced cytotoxicity remains a key research focus.

Poly(2-oxazoline)s (POx) represent a versatile class of biomaterials that have garnered significant interest in biomedical applications due to their biocompatibility, tunable physicochemical properties (e.g., tailored hydrophilicity and temperature response in solution), and functionality [19, 20]. POx are widely regarded for their excellent biocompatibility, as they exhibit low immunogenicity and enhanced hemocompatibility, making them suitable for a wide range of biomedical applications [19–21]. The stealth-like properties of hydrophilic POx, similar to poly(ethylene glycol) (PEG), enable prolonged circulation times in drug delivery systems while reducing nonspecific protein adsorption [21–24]. Additionally, POx are chemically highly versatile and can be functionalized with bioactive groups [25–27], such as targeting ligands, to enhance cellular uptake and therapeutic efficacy. Their straightforward functionalization further renders them suitable for modifications of, e.g., nanoparticles or proteins via POxylation as compared to PEGylation [28].

Their synthesis via the living cationic ring-opening polymerization (CROP) of 2-oxazoline monomers enables precise control over molar mass, architecture, and composition [27]. Their amphiphilic nature, low cytotoxicity, and ability to form nanostructures make them attractive candidates for drug delivery, gene therapy, and tissue engineering.

POx is characterised by a poly(ethyleneimine) backbone with pendant side chains that determine their hydrophilic, hydrophobic, or amphiphilic properties. The polymerization of 2-oxazolines proceeds via a cationic mechanism initiated by electrophilic species such as alkyl tosylates or triflates, leading to a well-controlled molar mass distribution [29]. By varying their monomer composition, POx can be tailored to exhibit properties ranging from water solubility to thermoresponsiveness or even superhydrophobicity, allowing for the design of stimuli-responsive biomaterials [30].

Particularly, the synthesis of cationic POx presents unique challenges primarily due to the difficulty in introducing cationic functional groups without compromising polymerizability of the functional monomers, necessitating the use of protecting groups [31, 32]. In addition, post-polymerization modification (PPM) has come to the forefront as a useful tool to incorporate cationic moieties under mild conditions [33, 34].

In the following paragraph, an overview of the synthetic strategies yielding cationic POx will be provided before transitioning toward the applications of such polymers in the life science area.

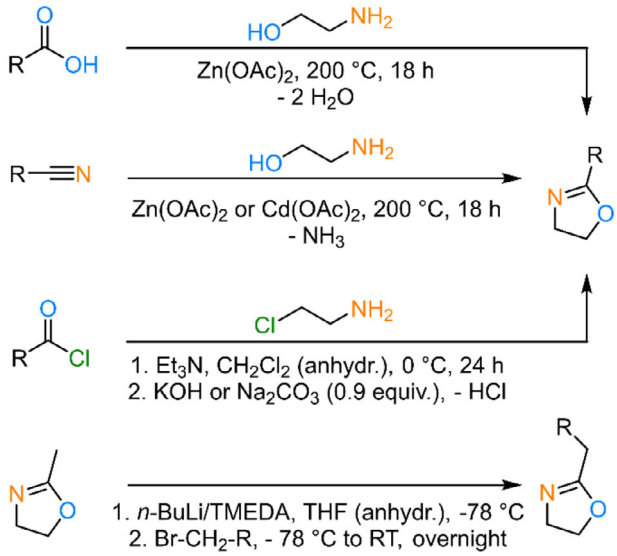
2 | Synthesis of Poly(2-oxazoline)s

2.1 | Synthesis of 2-oxazoline Monomers

As the application of POx is emerging, the most widely used 2-substituted-2-oxazolines, such as 2-methyl-2-oxazoline (MeOx), 2-ethyl-2-oxazoline (EtOx), 2-isopropyl-2-oxazoline (iPrOx), and 2-phenyl-2-oxazoline (PhOx), are commercially available. In addition, the growing interest in POx has led to the synthesis of a broad variety of different monomers and polymers thereof [25, 26]. Various synthetic strategies have been developed for preparing differently substituted 2-oxazolines. The most common methods in recent studies are outlined in Scheme 1.

One of the simplest and most direct approaches was introduced by Witte and Seeliger, involving the reaction of a substituted nitrile with a slight excess of 2-aminoethanol under Lewis acid catalysis (typically using zinc or cadmium acetate) [35, 36]. This strategy has become a preferred method due to its straightforward application for synthesizing a broad range of 2-substituted 2-oxazolines [37] and 2-oxazines [38, 39] using different amino alcohols. In general, this method is also compatible with the use of carboxylic acids instead of nitriles as starting materials, however, less explored. Introducing substituents at the 4- or 5-position of 2-oxazolines results in chiral systems [37, 40–42]. However, due to interference with the functional group, this approach is not suitable for the preparation of (protected) 2-amino-2-oxazolines.

Another widely utilized approach for synthesizing 2-substituted systems, particularly those containing functional groups incom-



SCHEME 1 | Strategies for the synthesis of 2-substituted-2-oxazolines.

patible with the nitrile-based method, starts from carboxylic acids and their activated derivatives, such as carboxylic halides and esters. In this two-step process, activated acids react with halogenethylene amine hydrochloride (e.g., a chloride) to yield the corresponding 2-halogenethylamide, which subsequently undergoes cyclisation in the presence of a base [32, 43, 44]. This method has enabled the synthesis of various 2-substituted-2-oxazolines and was previously reported for the preparation of amino-derived monomers [32, 45].

Additionally, modifying the 2-methyl group of commercially available MeOx via nucleophilic substitution has emerged as a popular strategy. In this method, the CH_3 group of MeOx is deprotonated using a strong base, such as n-butyllithium (*n*-BuLi), generating a nucleophilic intermediate that subsequently reacts with a substituted alkyl halide via nucleophilic substitution. This approach is particularly useful when the corresponding nitrile is unavailable, but the desired functional groups are compatible with strong bases (e.g., tertiary amines). By employing these three synthetic routes, numerous functional 2-oxazolines were successfully synthesized in the past [25, 26].

In summary, various techniques for the synthesis of 2-oxazolines were previously established. In particular, their demanding chemical properties (i.e., nucleophilicity of the amine) necessitate the use of protected precursors, which were shown to be most suitable with the synthesis of monomers via activated carboxylic acids.

2.2 | Polymerization of 2-oxazolines via Cationic Ring-opening Polymerization (CROP)

The polymerization of 2-oxazolines occurs through a living CROP mechanism, which allows for precise control over the propagation and the resulting polymer molar mass. The process consists of three main steps: initiation, propagation, and termination (Scheme 2) [29]. Polymerization begins with the activation of the 2-oxazoline monomer by an electrophilic initiator, typically alkyl tosylates, triflates, or other strong electrophiles. The nucleophilic attack by the 2-oxazoline nitrogen on the initiator leads to the formation of an oxazolinium ion, which serves as the active polymerization site. During propagation, the activated oxazolinium ion undergoes nucleophilic attack by additional monomer units, resulting in the sequential opening of 2-oxazoline rings and the formation of a growing polymer chain. This step continues in a controlled manner due to the living nature of polymerization, which ensures well-defined polymers featuring low dispersity. Controlled termination can be achieved by adding nucleophilic agents such as water, amines, or alcohols.

While CROP is generally well-controlled, certain side reactions can occur, impacting polymer quality and yield. A detailed overview on the polymerization mechanism, including side reaction was provided by Hoogenboom and coworkers [29]. Unintended nucleophilic species present in the reaction medium can terminate polymer chains prematurely (i.e., chain transfer), leading to broader molar mass distributions. This drawback is particularly challenging when it comes to the design of cationic POx as they often feature amines, which need to be protected to avoid unwanted termination or side reactions [31, 32, 45].

3 | Cationic poly(2-oxazolines)

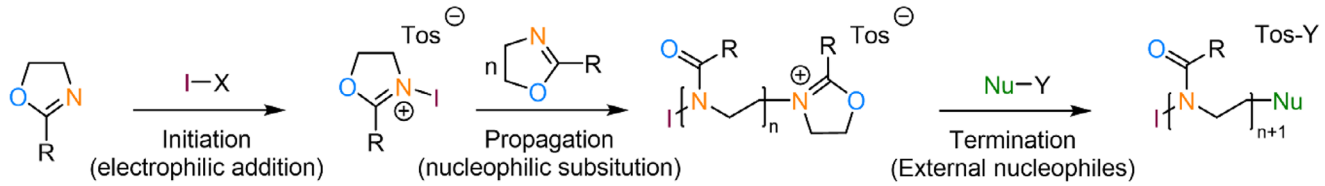
3.1 | Cationic End-groups

3.1.1 | Functional Initiators

Initiation of CROP using amine-functional initiators is rare due to interference with the propagation mechanism; however, such initiators can be used when appropriately protected. Kempe and coworkers investigated different initiators containing *tert*-butyloxycarbonyl (Boc) or phthalimide-protected amines and tosylate or bromide counterions for the polymerization of 2-ethyl-2-oxazolinen (Figure 1) [46]. Among these, the phthalimide-protected bromide initiator yielded well-defined PEtOx with superior polymerization efficiency despite a lower initiator efficiency compared to their Boc-protected pendants.

3.1.2 | Functional Termination Agents

A more intensely investigated method involves terminating the living polymer chains with primary, secondary, or tertiary amines (Scheme 3) [47]. Primary amines such as *n*-propylamine [48], nonylamine [49], and aniline [50], as well as various functionalized analogues, are commonly used to afford secondary amine termini. Secondary cyclic amines, such as piperidine [51–53] and piperazine derivatives [54], yield tertiary amine end groups. In contrast, sterically hindered tertiary amines like pyridine [55] and pyrrole [56] display lower reactivity, typically producing quaternary ammonium end groups [57]. Tiller and coworkers utilised *N*,*N*-dimethylalkylamines (C_4-C_{16}) to terminate poly(2-methyl-2-oxazoline) (PMeOx) and PEtOx, yielding quaternary ammonium-functionalized polymers [57]. To achieve a primary amine end group, ethylenediamine can be used; however, an excess is necessary to suppress chain coupling [58]. While this method yields POx with both primary and secondary amines at



SCHEME 2 | The cationic ring-opening polymerization of 2-oxazolines showing the (i) initiation, (ii) propagation, and (iii) termination steps.

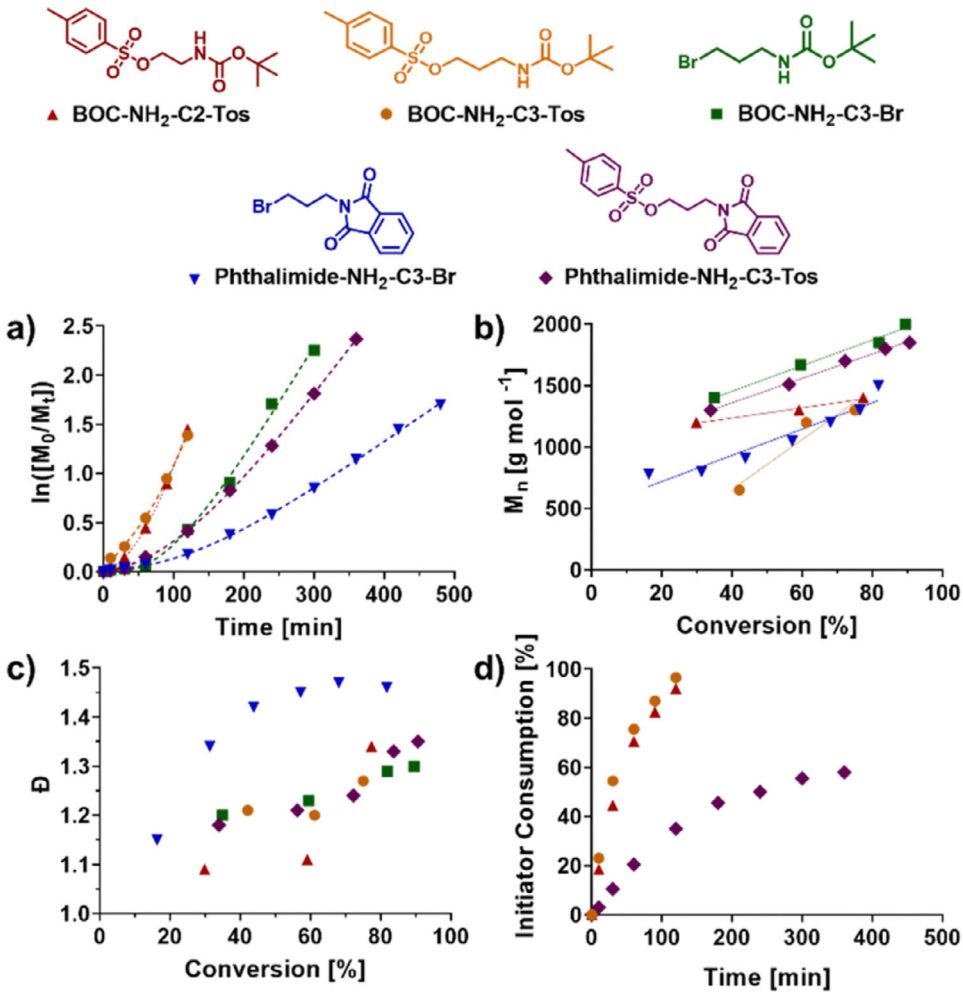
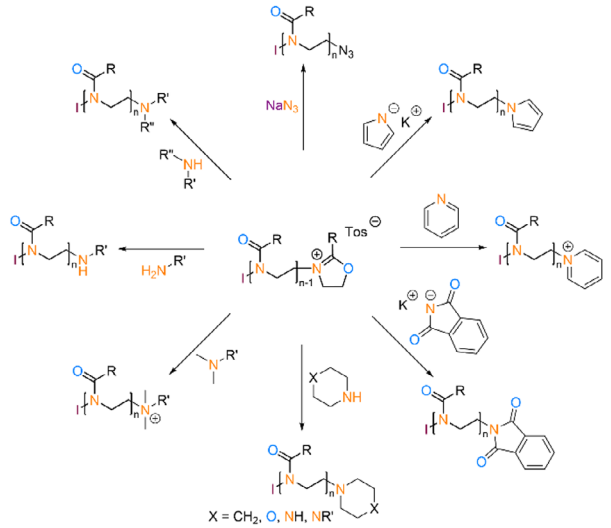


FIGURE 1 | Kinetics of EtOx polymerization initiated by protected amine initiators. (a) Kinetic plots determined by ^{1}H NMR spectroscopy (400 MHz, $CDCl_3$). The dotted lines are added for guidance only and do not represent actual data points. (b and c) M_n and dispersity ($Đ$) values as obtained from SEC measurements in DMAc (PS-cal.) against monomer conversion. CROP conditions: EtOx in MeCN using different amino initiators at $[M]_0/[I]_0$ ratio of 15 (T = 80°C, [M] = 2 M). (d) Evolution of the initiator consumption against time of the kinetic study. Reproduced from reference [46] with permission from the Royal Society of Chemistry.

the chain-end, termination with sodium azide and subsequent conversion to primary amines yields exclusively the latter. Osada and Kataoka terminated PEtOx with sodium azide, followed by Staudinger reduction with triphenylphosphine to yield amino-functional PEtOx [59]. This method as emerged as a widely applied technique to yield ω-end group amine functional POx as it can also be orthogonally applied to the reported α-end group functions mentioned above [60].

Schlaad et al. terminated the polymerization of 2-isopropyl-2-oxazoline (PiPrOx) with 4-(*N*-Boc-amino)-piperidine, leading to macromolecules with a single or, upon Boc deprotection, dual ammonium end groups [61]. Aguiar-Ricardo et al. reported a series of POx oligomers end-functionalized with various amines, including *N*,*N*-dimethyldodecylamine, *N*-methylcyclohexylamine, *N*-methyldioctylamine, and 1,4-diazabicyclo[2.2.2]octane [62].



SCHEME 3 | Overview of termination strategies yielding amine ω-end groups.

In summary, amine-mediated termination of POx during the CROP process represents a versatile and straightforward route to amino-end-functionalized polymers. A broad variety of amino compounds can be employed, allowing for tailored macromolecular structures and functionalities. Importantly, end-group selection allows modulation of polymer properties such as thermal responsiveness, while maintaining low overall amine content.

3.2 | Cationic Side Chains

The synthesis of side chain amino-functionalized POx can be broadly categorized into two principal strategies: (i) the direct approach, wherein amino functionalities are incorporated during the polymerization process, and (ii) the PPM approach, which entails chemical modification of pre-formed POx – either at the side chains or terminal groups – to introduce amino groups. An overview of different 2-amino-2-oxazoline-derived structures can be found in Table 1.

3.2.1 | Functional Monomers

Introducing functional groups into POx during polymer synthesis involves the CROP of 2-oxazoline monomers bearing amino functionalities. However, the direct polymerization of monomers with free amino groups has long been considered unsuitable due to the high likelihood of side and transfer reactions occurring during the propagation step [73–77].

To circumvent these issues, it is preferable to temporarily protect amino groups during polymerization and subsequently remove the protecting groups post-synthesis. One efficient route to protected 2-oxazoline monomers involves coupling N-protected α-amino acids with amino alcohols. Various protecting groups can be employed, including benzyl carbamate (Cbz), trifluoroacetamide, Boc, allyl carbamate (Alloc), and 9-fluorenylmethyloxycarbonyl (Fmoc). Among these, Boc-protected monomers are the most commonly used due to their stability under monomer synthesis and polymerization conditions and ease of removal under mild acidic treatment [78].

Boc-protected 2-oxazoline monomers have been polymerized using macroinitiators such as salts of *N*-methyl-2-methyl-2-oxazolinium triflate, *N*-methyl-2-ethyl-2-oxazolinium tosylate, or *N*-propargyl-2-methyl-2-oxazolinium tosylate. These systems afford (co)polymers bearing pendant primary (H_2NR) [31, 32] or secondary (HNR_2) [79] amines following deprotection. In contrast, polymerizations initiated by methyl triflate typically yielded undefined, low-molar-mass products [31].

Jordan and coworkers reported the homopolymerization of the Boc-protected monomer 2-[*N*-Boc-5-aminopentyl]-2-oxazoline (Boc-C5AmOx) as well as random copolymerization with EtOx via conventional heating [31]. Here, piperidine was used as the termination, introducing an additional secondary amine as the ω-end group.

Microwave-assisted CROP has also been applied to Boc-protected monomers. Schubert et al. synthesized homopolymers of 2-[*N*-Boc-4-aminobutyl]-2-oxazoline (Boc-C4AmOx) and its statistical copolymers with EtOx [32] as well as gradient copolymers with MeOx [80]. The polymerization showed hallmark characteristics of a living system: a constant concentration of propagating species, a linear relationship between molar mass and monomer conversion, narrow dispersity, and monomodal SEC profiles.

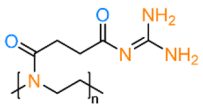
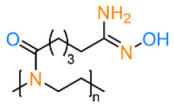
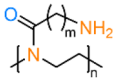
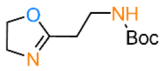
Further, block copolymers with low dispersity and resulting cross-linked structures were synthesized using these monomers [81, 82]. Copolymerization of Boc-C4AmOx with 2-nonyl-2-oxazoline via microwave-assisted CROP yielded amphiphilic block copolymers with narrow dispersity [83].

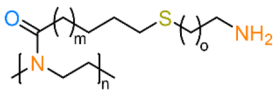
A combined synthetic strategy involving both microwave irradiation and conventional heating was employed by Luxenhofer and Kabanov to prepare block copolymers of 2-[*N*-methyl, *N*-Boc-aminomethyl]-2-oxazoline (Boc-MAMeOx) with MeOx [79]. The first block was synthesized in a microwave reactor using propargyl tosylate as the initiator, followed by conventional heating for the second, amino-functional block. Here, the lower reaction temperature was applied to suppress side-reactions and thermal deprotection during the polymerization of Boc-MAMeOx. The resulting polymers displayed narrow dispersity. Deprotection was attempted using a mixture of TFA, water, and triisobutylsilane (TIBS), but was not entirely successful.

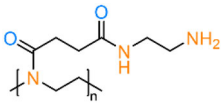
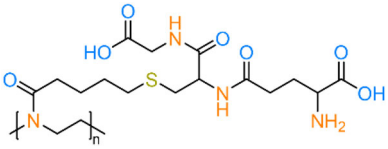
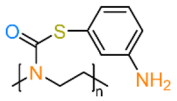
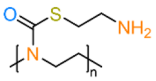
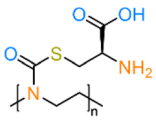
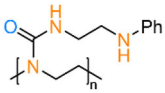
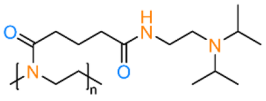
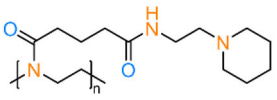
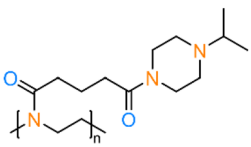
In a related study, Becer, Perrier, and coworkers employed the same monomer to synthesize homopolymers and random copolymers with EtOx or 2-*n*-propyl-2-oxazoline (nPrOx) via microwave-assisted CROP [65]. The resulting polymers exhibited symmetric, monomodal SEC profiles and dispersities between 1.25 and 1.40. Deprotection with TFA/DCM at elevated temperatures was performed, although desalting was not carried out, thereby limiting post-deprotection characterization.

Liu et al. also synthesized homopolymers from the same monomer [66]. However, SEC traces for $X_n = 40$ revealed tailing, suggestive of chain-transfer side reactions, consistent with earlier findings [31, 84].

TABLE 1 | Overview of various poly(2-amino-2-oxazoline)s. [a]Polymerization of functional monomer has not been reported to date.

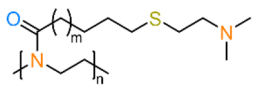
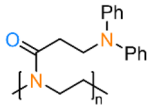
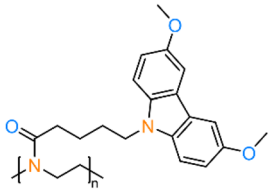
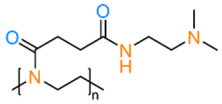
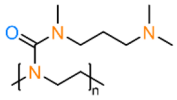
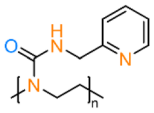
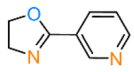
Nature of cation	Structure	Synthetic approach	Reference(s)
Guanidine		PPM	[63]
Amidoxime		PPM	[64]
Primary amine		Functional monomer	m = 1 [45, 65–67] m = 3 [67, 68] m = 4 [32] m = 5 [31]
		Functional monomer[a]	[69]

		PPM	m = 1, o = 1;
			m = 7, o = 1;
			m = 1, o = 5 [34]

		PPM	[70]
		PPM	[71]
		PPM	[72]
		PPM	[72]
		PPM	[72]
Secondary amine		PPM	[72]
Tertiary amine		PPM	[33]
		PPM	[33]
		PPM	[33]

(Continues)

TABLE 1 | (Continued)

Nature of cation	Structure	Synthetic approach	Reference(s)
		PPM	m = 1 [35] m = 7 [35]
		Functional monomer	[73]
		Functional monomer	[74]
		PPM	[70]
		PPM	[72]
Pyridine		PPM	[72]
		Functional monomer[a]	[69]

In summary, the use of Boc-protected 2-oxazoline monomers presents a reliable strategy for preparing amino-functionalized POx. Monomer synthesis is straightforward, and polymerizations proceed with good, however not excellent, control, typically producing molar masses consistent with theoretical expectations and narrow dispersity. The synthesis of cationic POx further allows for the introduction of quantitative α- or ω-end groups via functional initiators or termination agents, respectively. Importantly, reported examples generally exhibited comparably low X_n, likely due to steric hindrance from the Boc-groups and loss of control during the polymerization to yield longer polymers. Efficient deprotection is crucial and generally performed under acidic conditions, particularly using TFA. Lack of subsequent desalting hampers accurate molar mass determination and downstream application. Despite these limitations, many aspects of these polymers – including their solution behavior and physical properties – remain underexplored, highlighting opportunities for future investigation.

3.2.2 | Post-polymerization Modification (PPM)

A viable alternative to introducing amino groups into POx involves the PPM of side chains or chain termini. This method includes the functionalization of pendant groups [85] or terminal groups in pre-formed homo- or copolymers of 2-oxazolines [86]. Strategies such as ester-to-amide transformation [87] and thiol-ene "click" chemistry [88] have proven effective in this context, enabling the incorporation of NH_2, NHR_2, or NR_3 functionalities. Another route involves partial hydrolysis of the amide linkages in POx, which connect the substituents to the polymer backbone, leading to the formation of ethyleneimine units bearing secondary amines. [89] polyethylene imines were thoroughly reviewed in the past [9, 90] and will therefore not be discussed in detail here.

3.2.2.1 | Thiol-ene "Click" Functionalization.

Among the available techniques for POx side chain modification, the radical-mediated thiol-ene addition of aminothiols to vinyl side chains – commonly known as the "thio-click" reaction – is widely employed. This reaction requires the introduction of alkene groups into the side chains, typically achieved using monomers like 2-(3-butenyl)-2-oxazoline (ButEnOx) [34, 85, 91, 92] or 2-(9-decenyl)-2-oxazoline (DecEnOx) [34, 85]. The thiol-ene reaction proceeds with high regioselectivity and efficiency under mild, room-temperature conditions, often yielding functionalized products in quantitative amounts. Using this technique, POx containing primary [85]. secondary [92], or tertiary [34] amine side chains were successfully synthesized (Figure 2).

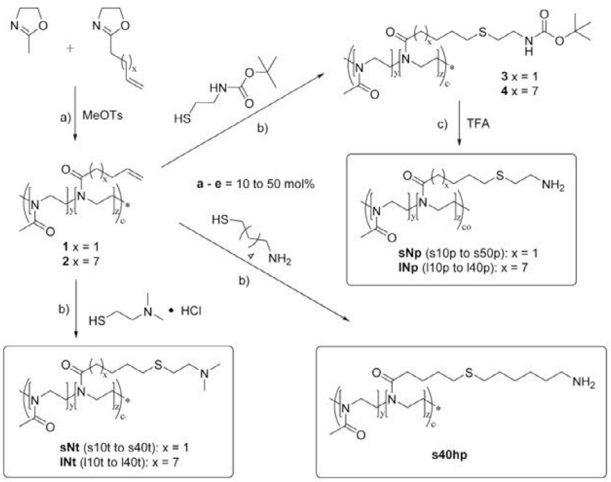


FIGURE 2 | Schematic representation of the synthesis of cationic poly(2-oxazoline)s. Reaction conditions: (a) 140 °C, microwave reactor, acetonitrile, (b) room temperature, overnight, methanol, catalyst: 0.1 mol% 2,2-dimethoxy-2-phenylacetophenone with respect to contained double bonds, (c) room temperature, overnight, DCM/TFA. Product terms: **s** = short butyl side chain, **l** = long decenyl side chain, N = amine content in mol%, **h** = hexamethylene spacer, **p** = primary amine, **t** = tertiary amine. Reproduced from reference [34] with permission. Copyright Wiley 2015.

Deng and Song utilized amphiphilic block copolymers of MeOx, BuOx, and ButEnOx for thiol-ene reactions with cysteamine to introduce primary amine groups [85]. The reaction was conducted in dry DMF at room temperature for 60 min, initiated with 2-hydroxy-4′-(2-hydroxyethoxy)-2-methylpropiophenone under UV irradiation (λ = 365 nm), leading to near-quantitative substitution of the vinyl groups. Similar modifications using ButEnOx-containing copolymers in tetrahydrofuran (THF):methanol mixtures were previously reported [88, 91].

Secondary amines were introduced into gradient copolymers based on iPrOx, MeOx, and ButEnOx via reaction with 2-(butylamino)ethanethiol [92]. This reaction, performed overnight in a 1:1 mixture of dry THF and methanol at room temperature, employed a tenfold molar excess of the aminothiol. Photosensitizers such as 2,2-dimethoxy-2-phenylacetophenone (DMPA) and benzophenone were used, with UV irradiation at λ = 254 nm. The maximum substitution yield for this reaction was reported at around 80%. Tertiary amino groups were incorporated into gradient copolymers of MeOx with ButEnOx or DecEnOx using similar thiol-ene protocols with DMPA and UV exposure at λ = 365 nm, resulting in full conversion of alkene functionalities [34].

3.2.2.2 | Ester-Amide Exchange Functionalization. Another prominent strategy for installing amino functionalities onto POx is the ester-to-amide exchange reaction [70]. It requires the presence of methyl ester groups in the polymer side chains, typically introduced through copolymerization with 2-methoxycarbonylethyl-2-oxazoline (MestOx) [87, 93–95]. Functionalization was achieved by reacting the ester-containing polymers with primary amines [94]. This method is particularly effective with small, liquid amines that readily dissolve the polymer and, thus, can be applied in access. The use of diamines yields polymers with cationic, amine-derived side-chains (Figure 3) [33]. Van Guyse et al. further showed the synthesis of guanidine-functionalized POx via this method [63].

Common diamines include ethylenediamine [87], diethylenetriamine (DET), and tris(2-aminoethyl)amine (TREN) [96]. When the polymer concentration is high and a large excess of diamine is employed, the reaction proceeds quantitatively at room temperature [93]. However, due to the risk of intermolecular crosslinking during the amidation process, mono-Boc-protected ethylenediamine has also been used as a safer alternative [93]. For instance, Van Hest and coworkers modified nPrOx/MestOx copolymers using a tenfold excess of ethylenediamine [87]. Highly functionalized polymers (>20% modification) exhibited crosslinking, resulting in insoluble materials. To mitigate this, mono-Boc-protected ethylenediamine was later employed [93].

In another study, DET and TREN were grafted onto MeOx or EtOx-based block copolymers containing MestOx [95]. The ester-amide exchange reaction was carried out at 40 °C over three days, enabling the efficient incorporation of multifunctional amine moieties.

In summary, PPM has emerged as a promising strategy for the design of side chain cationic POx circumventing the difficulties that functional monomers may bring. In particular, this approach allows for the introduction of tertiary or quaternary amines. A potential drawback of either strategy, thiol-ene click reactions or transamidations, may be the introduction of additional functional groups (i.e., a thioether or an amide bond) which significantly influence the properties of the resulting polymers. For this reason, PPM should be viewed as a complementary technique for the design of cationic POx while the synthesis via functional monomers should remain the main strategy to be further optimized in the future.

3.3 | Applications

3.3.1 | Drug Delivery

Cationic POx have recently attracted significant interest as biocompatible and stealthy carriers for drug and nucleic acid delivery. Their amphiphilic architecture leverages electrostatic, hydrophobic, and steric interactions to facilitate loading, stabilization, targeted delivery, and controlled release. POx, particularly the hydrophilic PMeOx and PEtOx, function as PEG alternatives [21–23, 28]. In lipid nanoparticle formulations for mRNA vaccines, POx-lipid conjugates exhibited comparable or superior delivery efficacy with reduced immunogenicity and diminished liver uptake relative to PEG systems [96]. Core cross-linked star POx synthesized via an “arm-first” CROP encapsulated doxorubicin in their hydrophobic cores. These materials demonstrated pH-responsive release – accelerating at pH 5.2 compared to 7.1 – and selective cytotoxicity in HeLa cells only upon drug loading, while remaining non-toxic when unloaded [97]. pH-responsive POx nanogels chemically loaded with doxorubicin via imine linkages released the drug selectively under acidic conditions, suppressing tumour growth in vivo with low off-target toxicity [98]. Triblock POx micelles achieved

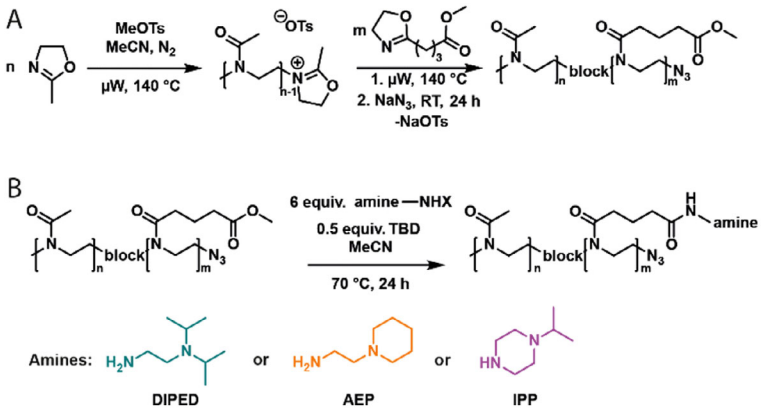


FIGURE 3 | Preparation of polymers used in this study. (A) Synthesis of PMeOx$_n$-*b*-PC3MestOx$_m$ *via* cationic ring-opening polymerization of MeOx (first block) and sequential addition of C3MestOx (second block), followed by termination with sodium azide. (B) Post-polymerization modification of PMeOx$_n$-*b*-PC3MestOx$_m$, yielding different tertiary-amine-modified polymers. Reproduced from reference [33] with permission from the Royal Society of Chemistry.

remarkably high (≤50 wt%) encapsulation of paclitaxel, demonstrating excellent stability (<100 nm) and enhanced efficacy in multidrug-resistant cancer models – outperforming conventional formulations [99]. POx-based systems exhibit multifunctionality: folate-targeted PEtOx–PLA micelles co-delivering doxorubicin and tocopheryl PEG-succinate reversed multidrug resistance via pH-triggered behavior [96]. Hoogenboom and coworkers prepared cationic block copolymers with pH-dependent lower-critical solution temperature (LCST). These polymers formed micelles upon temperature change and encapsulated paclitaxel. Application of the derived nanostructures showed increased cytotoxicity toward MDA-MB-231 breast cancer cells [33]. Schubert and Meinel and coworkers further demonstrated the application of cationic copolymers for the POxylation of IL-4 and subsequent delivery to monocytes in vitro (Figure 4) [28].

3.3.2 | Gene Delivery

Amino-functionalization is essential for polymer-based vectors used in gene delivery, enabling electrostatic interactions between the polymer and nucleic acid backbones to form nanosized polyelectrolyte complexes (polyplexes). Given the excellent biocompatibility of POx, their amino-functionalized derivatives have shown great promise as gene delivery agents.

The most commonly used method for introducing amino functionalities into POx is partial hydrolysis, which yields linear polyethylene imine – considered the "gold standard" for gene delivery, which was comprehensively reviewed in the past [9, 90].

Polymers with amino groups in the side chains have also shown promise in gene delivery, allowing for the introduction of primary, secondary, and tertiary amines. For instance, cationic P(EtOx-*b*-AmOx) block copolymers containing 10–33% primary amines were tested for DNA complexation via ethidium bromide displacement [32]. While 10% amine content was insufficient, increasing to 15% reduced fluorescence by 10%, with further decreases at higher amine levels. In contrast, nanogels formed from these same copolymers quenched fluorescence regardless of amine content, indicating effective DNA binding. Moreover, nanogels allowed for DNA release, albeit incompletely (~60% fluorescence recovery), and their crosslinking density influenced cellular uptake without affecting biocompatibility [81].

Schubert and coworkers synthesized well-defined P(MeOx-*co*-ButEnOx) and P(MeOx-*co*-DecEnOx) copolymers and modified them with primary and tertiary amines (10–40 mol%) to assess the influence of amine type, content, and hydrophobicity on gene delivery [34]. Copolymers with 10 mol% amines failed to form polyplexes. Primary amines bound DNA more effectively than tertiary ones, and increased side chain hydrophobicity enhanced condensation but also led to greater cytotoxicity and haemolysis. Oleszko–Torbus and Kowalczuk et al. examined iPrOx copolymers with MeOx and ButEnOx functionalized with primary or secondary amines (≤ 20 mol%) located either on substituents or within the backbone [92]. Copolymers with pendant primary amines showed weaker DNA binding due to hydrogen bonding, while those with secondary amines—regardless of location—demonstrated stronger complexation and good transfection. The secondary amine-containing substituent copolymers also showed excellent biocompatibility in human fibrosarcoma cell lines. In contrast, copolymers of MeOx or EtOx and C4AmOx, synthesized via the functional monomer approach, did not transfect cells in vitro successfully [80]. It can be assumed that hydrophobicity, as well as the thioether, plays a role in the success of the transfection vector. The role of hydrophobicity was further confirmed by the application of block copolymers of 2-nonyl-2-oxazoline and C4AmOx (PNonOx-*b*-C4AmOx), which revealed increased transfection ability compared to the purely hydrophilic POx [83]. Becer and coworkers showed the successful gene complexation and transfection with glycine-derived cationic POx (Figure 5) [45], demonstrating the move toward biologically derived structures. Glutathione-Functionalization of cationic POx further showed promising results in crossing the blood-brain-barrier in vitro [71].

Furthermore, cationic POx derivatives bearing pendant secondary amines (e.g., PEtOx-*b*-MAMeOx) condensed plasmid DNA into <100 nm polyplexes exhibiting low protein adsorption and minimal cytotoxicity, comparable to PEG–PLL systems. These were effective in transfecting macrophages and certain cancer cells [96].

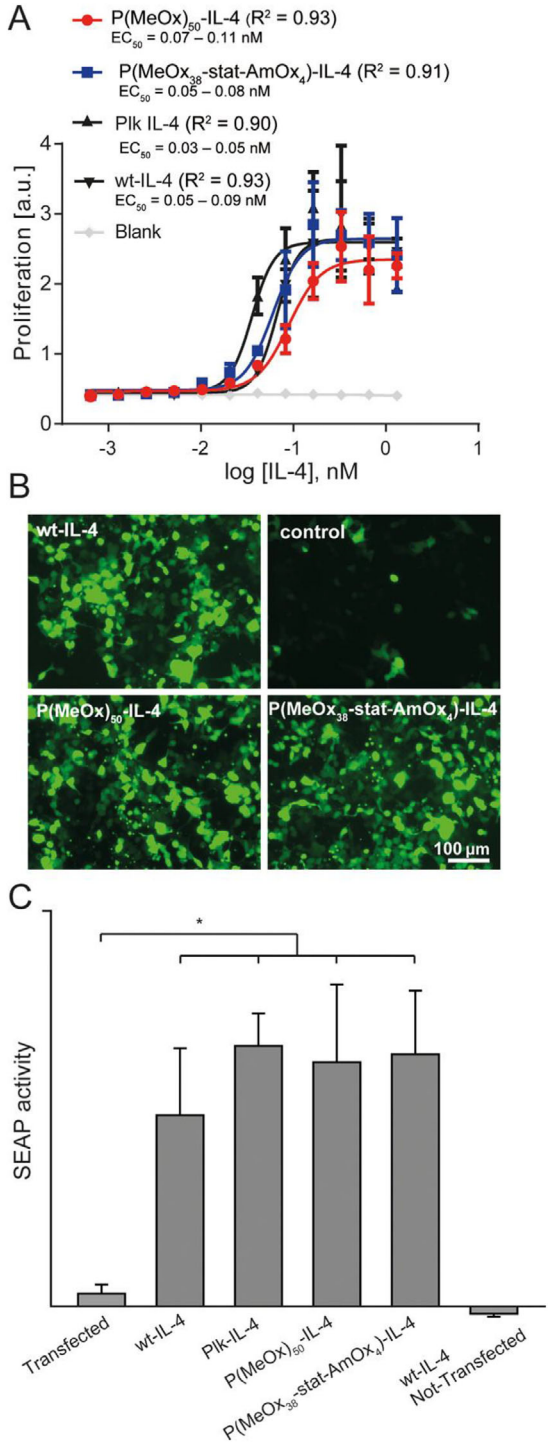


FIGURE 4 | (a) TF-1 proliferation assay of wt-IL-4, Plk-IL-4, and polymer conjugated IL-4 derivatives (mean ± standard deviation, $n = 3$). R^2 values of the nonlinear fitting, as well as the 95% confidence intervals of the estimated EC_{50} values, are given. (b) eYFP reporter gene assay of HEK 293 T cells transfected with pSTAT6–eYFP and pSTAT6 after stimulation with 1.3 nM wt-IL-4, Plk-IL-4, and polymer-conjugated IL-4 species. The control shows transfected but unstimulated cells. (b) SEAP reporter gene assay of HEK293 T cells transfected with pSTAT6-SEAP and pSTAT6 after stimulation with 1.3 nM wt-IL-4, Plk-IL-4 and polymer conjugated IL-4 species. Asterisks indicate statistically significant differences among groups ($p \leq 0.05$ (*), $n = 5$). Reproduced with permission from reference [28]. Copyright American Chemical Society 2017.

Recent developments include PEtOx–lipid conjugates for mRNA delivery, forming lipid nanoparticles that match PEG-based vaccines in hepatic transfection and overall immunogenic performance [97].

The past studies showed that side chain functionalization provides a promising alternative route to the (partial) hydrolysis of POx to polyethylene imine and enables the corporation of primary, secondary, or tertiary amines—enabling improved DNA interaction without the disadvantageous toxicity known for polyethylene imine. The nature and location of amines, as well as hydrophobicity, significantly impact nucleic acid binding, release, and biological performance, underscoring the importance of fine-tuning structure–property relationships for optimal gene delivery.

3.3.3 | Surface Coatings / Anti Fouling / Antimicrobials

Recent research has demonstrated that polymers bearing positively charged functionalities, such as amino or quaternary ammonium groups, can exhibit intrinsic antibacterial activity themselves [100, 101]. Amine end-functionalized POx were applied as surface coatings [102] or in solution. In this regard, Waschinski and Tiller investigated the antimicrobial properties of telechelic homopolymers of MeOx and EtOx, end-functionalized with quaternary alkylamines, against the Gram-positive bacterium *Staphylococcus aureus* [57]. These polymers varied in end-group composition – hydrogen, methyl, Boc-protected aromatic amines, and free aromatic NH_2 groups – and had an X_n ranging from 20 to 132. Their study revealed that a minimum of 12 carbon atoms in the quaternary ammonium alkyl chain was necessary to exhibit antibacterial activity. Furthermore, the nature of the terminal groups was shown to significantly influence bioactivity. The polymer backbone also played a role, with PEtOx-based materials displaying twice the antibacterial activity compared to analogous PMeOx derivatives. In subsequent work, the same authors further explored how the structure of the terminal, non-antimicrobial moiety – referred to as the "satellite group" – affects antibacterial efficacy [103]. They introduced a quaternary *N*,*N*-dimethyldodecylammonium (DDA) group at one chain end and various alkyl, aminoalkyl, or PPhOx groups at the opposite end, yielding telechelic polymers. The resulting polymers were evaluated against both Gram-positive (*Staphylococcus aureus*) and Gram-negative (*Escherichia coli*) bacteria. Notable differences in antibacterial activity were observed, depending on the structure of the satellite group. The authors proposed that even non-bioactive terminal groups could synergistically enhance antibacterial function when positioned distal to the active DDA group. Additionally, certain POx derivatives bearing hydrophobic satellite groups were found to form unimolecular micelles, improving membrane penetration and contributing to antibacterial efficacy.

The type and structure of POx functionalities appear to be crucial in determining their antimicrobial properties. For example, oligo(MeOx) and oligo(2-bisoxazoline) terminated with *N*,*N*-dimethyldodecylamines showed rapid bactericidal activity against both *Escherichia coli* and *Staphylococcus aureus* [62]. In contrast, oligomers terminated with cyclic or aromatic amines were less effective at integrating into bacterial membranes,

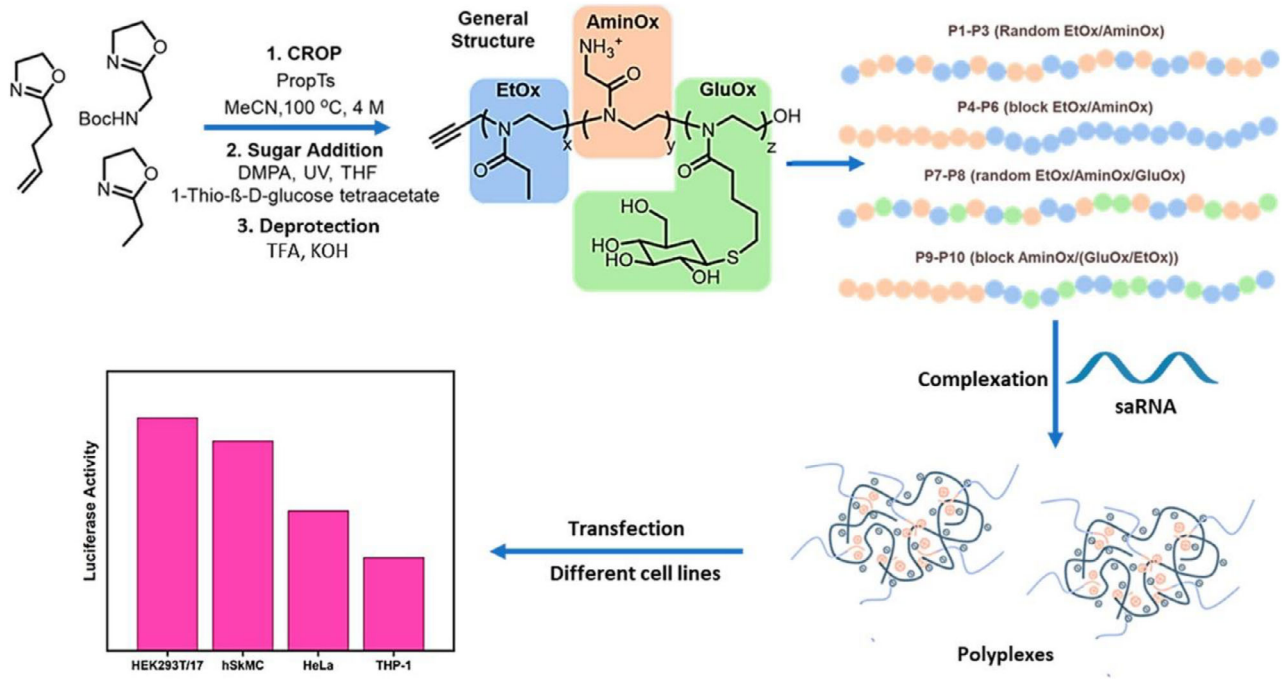


FIGURE 5 | Schematic Illustration of the Synthesis of Glycosylated Cationic Poly(2-oxazoline)s in Different Structures and the Formed Polyplexes with saRNA for Transfection Experiments in Different Cell Lines by Luciferase Assay. Reproduced with permission from open access reference [45] under CC-BY 4.0 license.

yielding higher minimum inhibitory concentrations (MIC) and diminished activity. Conversely, oligomers terminated with linear alkyl amines demonstrated enhanced antimicrobial effects, emphasizing the importance of hydrophobic, flexible chains in disrupting bacterial membranes through insertion or pore formation.

The role of hydrophobicity was further confirmed in a study involving copolymers based on Boc-protected amino-2-oxazolines with EtOx or nPrOx [65]. Homopolymers and random copolymers, with cationic content ranging from 30% to 100% and hydrophobic segments having an X_n between 6 and 14, were synthesized. Their antimicrobial properties were evaluated both in vitro against five *Staphylococcus aureus* strains and in vivo using an insect model. A higher proportion of cationic units corresponded to lower MIC values and improved antibacterial activity. Importantly, the materials exhibited no cytotoxicity toward human keratinocyte (HaCaT) and fibroblast (3T3) cell lines. These findings support the potential of amino-functionalized POx as effective, broad-spectrum antimicrobial agents with rapid killing rates and low cytotoxicity. Zhou et al. applied glycine-derived cationic POx for the treatment of methicillin-resistant *Staphylococcus aureus* (MRSA, Figure 6) [66]. While the polymers were antimicrobially active, the authors did not observe and antimicrobial resistance. Dai et al. confirmed these results and further investigated a C3AmOx derivative [67]. Both polymers furthermore revealed excellent haemocompatibility.

3.3.4 | Hydrogels

Cationic POx hydrogels, formed through gelation of amino-functional or cross-linkable POx precursors (Figure 7), are emerging as highly versatile platforms for controlled drug release, gene complexation, tissue engineering, and stimuli-responsive biomaterials.

Hartlieb et al. introduced hydrogels derived from Boc-protected amino-POx (Boc-C4AmOx) copolymerized with EtOx. Following deprotection and cross-linking with epichlorohydrin, these hydrogels demonstrated reversible DNA binding – with adsorption capacity confirmed via ethidium bromide assays and controlled heparin-triggered DNA release [32]. They were applied in a polymerase chain-reaction lab-in-a-tube setup [104]. Their swelling behavior and DNA capture furthermore suggest potential utility in gene delivery or sensing applications.

Blöhbaum et al. functionalized ButEnOx-containing POx copolymers in a PPM reaction with cysteine-derived thiols, enabling UV-initiated thiol–ene cross-linking [105]. The resulting hydrogels exhibited adjustable thermo-responsive behavior, swelling characteristics, mechanical strength, and positive charge density—allowing tuneable interactions with charged molecules like methylene blue or fluorescein. Cytocompatibility was confirmed via cell culture assays.

In a biohybrid system, POx was cross-linked with heparin to create hydrogels with customizable stiffness and growth factor release profiles [106]. These hydrogels modulate growth factor delivery and demonstrate favorable hemocompatibility when benchmarked against PEG-based materials.

Magnetic POx hydrogels were further developed by entrapping carbonyl iron particles within a PEtOx matrix synthesized via living CROP. These gels maintain excellent fibroblast biocompatibility and exhibit magneto-mechanical responsiveness—a

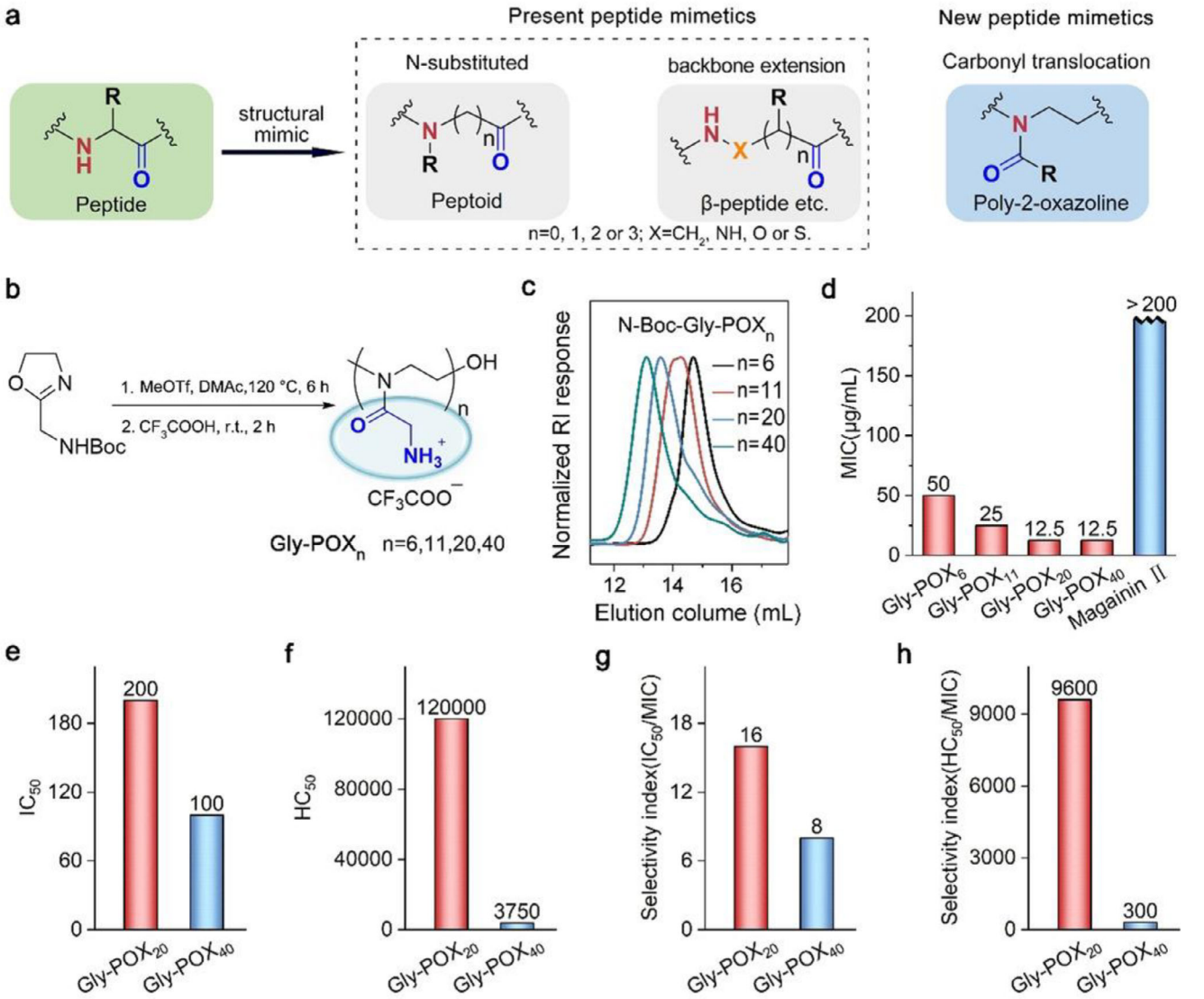


FIGURE 6 | (a) Structural design of peptides and peptide mimetics. (b) Synthesis of the HDP mimetics Gly-POX$_n$. (c) SEC traces of representative *N*-Boc-protected Gly-POX$_n$. (d) MIC values of Gly-POX$_n$, with variable chain lengths, against *Staphylococcus aureus* using representative HDP magainin II as the control. (e) Cytotoxicity of Gly-POX$_{20}$ and Gly-POX$_{40}$ with 3T3 fibroblast cells. (f) Haemolysis of Gly-POX$_{20}$ and Gly-POX$_{40}$ for hRBCs. (g) Selectivity index calculated from IC$_{50}$/MIC. (h) Selectivity index calculated from HC$_{50}$/MIC. Reproduced with permission from reference [66]. Copyright Wiley VCH 2020.

promising feature for mechanobiology or targeted delivery systems enabled by external magnetic fields. Hoelzer and Leiske et al. reported core-cross-linked POx nanogels with a cationic C4AmOx core and PEtOx shell, cross-linked via glutaraldehyde and loaded with doxorubicin through imine bonds [98]. These nanogels enabled pH-sensitive doxorubicin release and exhibited significant tumour growth inhibition in vivo, outperforming free doxorubicin and enhancing animal survival – with minimal systemic toxicity.

4 | Conclusions and Future Directions

Over the last decades, cationic POx have emerged as promising materials with versatile applications in the biomedical area. Synthetic strategies include the preparation of chain-end or side chain functional polymers, which can be prepared directly during the polymerization process or via post-polymerization modifications.

This combination of strategies facilitates the design of a broad series of cationic POx bearing different amines (e.g., primary or secondary). Copolymerization with non-ionic monomers enables a fine-tuning of the polymer properties, such as hydrophobicity and charge density. Future design strategies may investigate the chemical versatility of cationic POx in more detail to yield structures comparable to vinylic polymers such as Eudragits. Applications of these polycations range from antimicrobials to drug and gene delivery vectors. While results in the drug and gene delivery area to date are very preliminary, potentially owed to the increased cytotoxicity of the yielded polymers, they have shown great promise as antimicrobials in vitro and in vivo. Yet, applications that do not necessitate biocompatibility (e.g., antimicrobial coatings or cationic gels for DNA purification purposes) may have

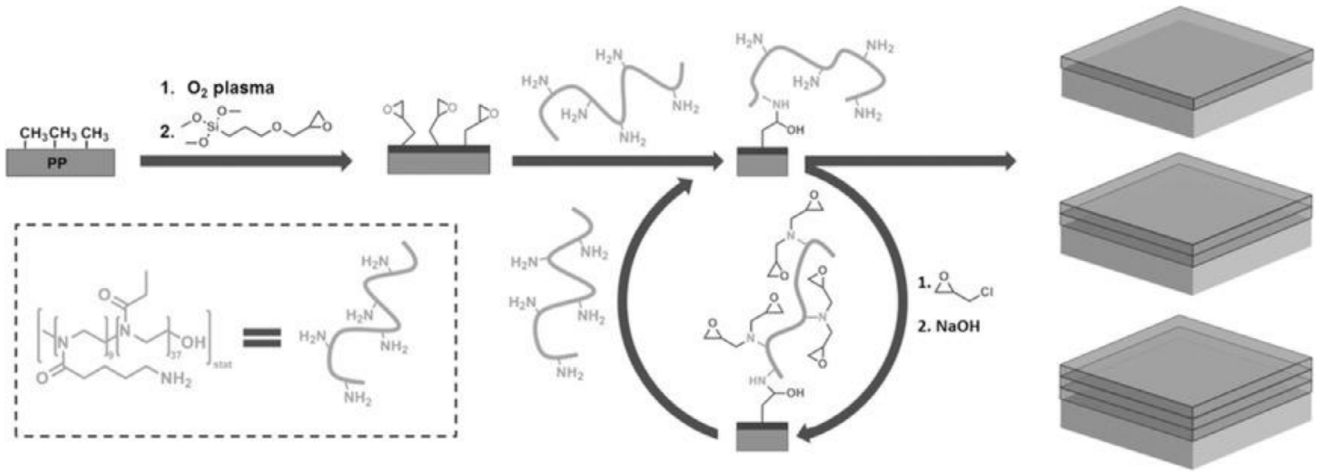


FIGURE 7 | Schematic representation of the deposition of P($EtOx_{37}$-*stat*-$AmOx_9$) on substrates by layer-by-layer immobilization. Reproduced with permission from reference [104]. Copyright Wiley VCH 2015.

the greatest potential to find timely applications. The reported studies paved the way for future investigations, which will likely focus on the improved design of novel POx-derived polycations, polymer nanostructures, and stimuli-responsive delivery systems with improved biocompatibility.

Acknowledgements

This work was generously supported by the German Research Foundation (DFG; project number 563027621). The graphical abstract image was partly created with BioRender.com.

Open access funding enabled and organized by Projekt DEAL.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. S. K. Samal, M. Dash, S. van Vlierberghe, et al., "Cationic Polymers and Their Therapeutic Potential," *Chemical Society Reviews* 10 (2012): 7147–7194, https://doi.org/10.1039/c2cs35094g.

2. M. Farshbaf, S. Davaran, A. Zarebkohan, N. Annabi, A. Akbarzadeh, and R. Salehi, "Carbon Quantum Dots: Recent Progresses on Synthesis, Surface Modification and Applications," *Artificial Cells, Nanomedicine, and Biotechnology* 46 (2018): 1331–1348, https://doi.org/10.1080/21691401.2017.1395344.

3. M. C. Garnett, "Gene-Delivery Systems Using Cationic Polymers," *Critical Reviews™ in Therapeutic Drug Carrier Systems* 16 (1999): 61, , https://doi.org/10.1615/CritRevTherDrugCarrierSyst.v16.i2.10.

4. A. Jain, L. S. Duvvuri, S. Farah, N. Beyth, A. J. Domb, and W. Khan, "Antimicrobial Polymers," *Advanced Healthcare Materials* 3 (2014): 1969–1985, https://doi.org/10.1002/adhm.201400418.

5. S. K. Samal and P. Dubruel, *Cationic Polymers in Regenerative Medicine*. (Royal Society of Chemistry, 2014).

6. A. Traeger and M. N. Leiske, "The Whole Is Greater than the Sum of Its Parts – Challenges and Perspectives in Polyelectrolytes," *Biomacromolecules* 26 (2025): 5–32, https://doi.org/10.1021/acs.biomac.4c01061.

7. C. Thambiliyagodage, M. Jayanetti, A. Mendis, G. Ekanayake, H. Liyanaarachchi, and S. Vigneswaran, "Recent Advances in Chitosan-Based Applications—A Review," *Materials* 16 (2023): 2073, https://doi.org/10.3390/ma16052073.

8. Q. A. Besford, F. Cavalieri, and F. Caruso, "Glycogen as a Building Block for Advanced Biological Materials," *Advanced Materials* 32 (2020): 1904625, https://doi.org/10.1002/adma.201904625.

9. S. Taranejoo, J. Liu, P. Verma, and K. Hourigan, "A Review of the Developments of Characteristics of PEI Derivatives for Gene Delivery Applications," *Journal of Applied Polymer Science* 132 (2015): 42096, https://doi.org/10.1002/app.42096.

10. S. Agarwal, Y. Zhang, S. Maji, and A. Greiner, "PDMAEMA Based Gene Delivery Materials," *Materials Today* 15 (2012): 388–393, https://doi.org/10.1016/S1369-7021(12)70165-7.

11. J. Karlsson, K. R. Rhodes, J. J. Green, and S. Y. Tzeng, "Poly(beta-amino ester)s as Gene Delivery Vehicles: Challenges and Opportunities," *Expert Opinion on Drug Delivery* 17 (2020): 1395–1410, https://doi.org/10.1080/17425247.2020.1796628.

12. J. Wei, L. Zhu, Q. Lu, et al., "Recent Progress and Applications of Poly(beta amino esters)-based Biomaterials," *Journal of Controlled Release* 354 (2023): 337–353, https://doi.org/10.1016/j.jconrel.2023.01.002.

13. T. Bus, A. Traeger, and U. S. Schubert, "The Great Escape: How Cationic Polyplexes Overcome the Endosomal Barrier," *Journal of Materials Chemistry B* 6 (2018): 6904–6918, https://doi.org/10.1039/C8TB00967H.

14. J. Cai, Y. Yue, D. Rui, Y. Zhang, S. Liu, and C. Wu, "Effect of Chain Length on Cytotoxicity and Endocytosis of Cationic Polymers," *Macromolecules* 44 (2011): 2050–2057, https://doi.org/10.1021/ma102498g.

15. C. Shi, Y. He, X. Feng, and D. Fu, "ε-Polylysine and next-generation Dendrigraft Poly-L-lysine: Chemistry, Activity, and Applications in Biopharmaceuticals," *Journal of Biomaterials Science, Polymer Edition* 26 (2015): 1343–1356, https://doi.org/10.1080/09205063.2015.1095023.

16. Y. Zhou, S. Han, Z. Liang, M. Zhao, G. Liu, and J. Wu, "Progress in Arginine-based Gene Delivery Systems," *Journal of Materials Chemistry B* 8 (2020): 5564–5577, https://doi.org/10.1039/D0TB00498G.

17. L. Timofeeva and N. Kleshcheva, "Antimicrobial Polymers: Mechanism of Action, Factors of Activity, and Applications," *Applied Microbiology and Biotechnology* 89 (2011): 475–492, https://doi.org/10.1007/s00253-010-2920-9.

18. C.-G. Wang, N. E. B. Surat'man, J. J. Chang, et al., "Polyelectrolyte Hydrogels for Tissue Engineering and Regenerative Medicine," *Chemistry – An Asian Journal* 17 (2022): 202200604, https://doi.org/10.1002/asia.202200604.

19. R. Hoogenboom, "Poly(2-oxazoline)s: A Polymer Class with Numerous Potential Applications," *Angewandte Chemie International Edition* 48 (2009): 7978–7994, https://doi.org/10.1002/anie.200901607.

20. T. Lorson, M. M. Lübtow, E. Wegener, et al., "Poly(2-oxazoline)s Based Biomaterials: A Comprehensive and Critical Update," *Biomaterials* 178 (2018): 204–280, https://doi.org/10.1016/j.biomaterials.2018.05.022.

21. M. N. Leiske, M. Lai, T. Amarasena, et al., "Interactions of Core Cross-linked Poly(2-oxazoline) and Poly(2-oxazine) Micelles with Immune Cells in human Blood," *Biomaterials* 274 (2021): 120843, https://doi.org/10.1016/j.biomaterials.2021.120843.

22. G. Morgese, B. Verbraeken, S. N. Ramakrishna, et al., "Chemical Design of Non-Ionic Polymer Brushes as Biointerfaces: Poly(2-oxazine)s Outperform both Poly(2-oxazoline)s and PEG," *Angewandte Chemie International Edition* 57 (2018): 11667–11672, https://doi.org/10.1002/anie.201805620.

23. M. Grube, M. N. Leiske, U. S. Schubert, and I. Nischang, "POx as an Alternative to PEG? A Hydrodynamic and Light Scattering Study," *Macromolecules* 51 (2018): 1905–1916, https://doi.org/10.1021/acs.macromol.7b02665.

24. K. Knop, R. Hoogenboom, D. Fischer, and U. S. Schubert, "Poly(ethylene glycol) in Drug Delivery: Pros and Cons as Well as Potential Alternatives," *Angewandte Chemie International Edition* 49 (2010): 6288–6308, https://doi.org/10.1002/anie.200902672.

25. M. Glassner, M. Vergaelen, and R. Hoogenboom, "Poly(2-oxazoline)s: A Comprehensive Overview of Polymer Structures and Their Physical Properties," *Polymer International* 67 (2018): 32–45, https://doi.org/10.1002/pi.5457.

26. S. Jana and R. Hoogenboom, "Poly(2-oxazoline)s: A Comprehensive Overview of Polymer Structures and Their Physical Properties—An Update," *Polymer International* 71 (2022): 935–949, https://doi.org/10.1002/pi.6426.

27. G. Delaittre, "Telechelic Poly(2-oxazoline)s," *European Polymer Journal* 121 (2019): 109281, https://doi.org/10.1016/j.eurpolymj.2019.109281.

28. T. Lühmann, M. Schmidt, M. N. Leiske, et al., "Site-Specific POxylation of Interleukin-4," *ACS Biomaterials Science & Engineering* 3 (2017): 304–312, https://doi.org/10.1021/acsbiomaterials.6b00578.

29. B. Verbraeken, B. D. Monnery, K. Lava, and R. Hoogenboom, "The Chemistry of Poly(2-oxazoline)s," *European Polymer Journal* 88 (2017): 451–469, https://doi.org/10.1016/j.eurpolymj.2016.11.016.

30. R. Hoogenboom, "The Future of Poly(2-oxazoline)s," *European Polymer Journal* 179 (2022): 111521, https://doi.org/10.1016/j.eurpolymj.2022.111521.

31. S. Cesana, J. Auernheimer, R. Jordan, H. Kessler, and O. Nuyken, "First Poly(2-oxazoline)s with Pendant Amino Groups," *Macromolecular Chemistry and Physics* 207 (2006): 183–192, https://doi.org/10.1002/macp.200500495.

32. M. Hartlieb, D. Pretzel, K. Kempe, et al., "Cationic Poly(2-oxazoline) Hydrogels for Reversible DNA Binding," *Soft Matter* 9 (2013): 4693–4704, https://doi.org/10.1039/c3sm00114h.

33. M. N. Leiske, R. Singha, S. Jana, B. G. de Geest, and R. Hoogenboom, "Amidation of Methyl Ester-functionalized Poly(2-oxazoline)s as a Powerful Tool to Create Dual pH- and Temperature-responsive Polymers as Potential Drug Delivery Systems," *Polymer Chemistry* 14 (2023): 2034–2044, https://doi.org/10.1039/D3PY00050H.

34. A. C. Rinkenauer, L. Tauhardt, F. Wendler, et al., "A Cationic Poly(2-oxazoline) with High in Vitro Transfection Efficiency Identified by a Library Approach," *Macromolecular Bioscience* 15 (2015): 414–425, https://doi.org/10.1002/mabi.201400334.

35. H. Witte and W. Seeliger, "Cyclische Imidsäureester aus Nitrilen und Aminoalkoholen," *Justus Liebigs Annalen der Chemie* 1974 (1974): 996–1009, https://doi.org/10.1002/jlac.197419740615.

36. H. Witte and W. Seeliger, "Simple Synthesis of 2-Substituted 2-Oxazolines and 5,6-Dihydro-4 H -1,3-Oxazines," *Angewandte Chemie International Edition in English* 11 (1972): 287–288, https://doi.org/10.1002/anie.197202871.

37. M. M. Bloksma, S. Rogers, U. S. Schubert, and R. Hoogenboom, "Secondary Structure Formation of Main-chain Chiral Poly(2-oxazoline)s in Solution," *Soft Matter* 6 (2010): 994–1003, https://doi.org/10.1039/b921467d.

38. M. M. Bloksma, R. M. Paulus, H. P. C. van Kuringen, et al., "Thermoresponsive Poly(2-oxazine)s," *Macromolecular Rapid Communications* 33 (2012): 92–96, https://doi.org/10.1002/marc.201100587.

39. P. A. de Jongh, A. Mortiboy, G. S. Sulley, et al., "Dual Stimuli-Responsive Comb Polymers from Modular N -Acylated Poly(aminoester)-Based Macromonomers," *ACS Macro Letters* 5 (2016): 321–325, https://doi.org/10.1021/acsmacrolett.5b00904.

40. M. M. Bloksma, M. M. Hendrix, U. S. Schubert, and R. Hoogenboom, "Ordered Chiral Structures in the Crystals of Main-Chain Chiral Poly(2-oxazoline)s," *Macromolecules* 43 (2010): 4654–4659, https://doi.org/10.1021/ma100128q.

41. M. M. Bloksma, S. Hoeppener, C. D'Haese, et al., "Self-assembly of Chiral Block and Gradient Copolymers," *Soft Matter* 8 (2012): 165–172, https://doi.org/10.1039/c1sm06595e.

42. R. Luxenhofer, S. Huber, J. Hytry, J. Tong, A. V. Kabanov, and R. Jordan, "Chiral and Water-Soluble Poly(2-oxazoline)s," *Journal of Polymer Science Part A: Polymer Chemistry* 51 (2013): 732–738, https://doi.org/10.1002/pola.26437.

43. K. Kempe, R. Hoogenboom, and U. S. Schubert, "A Green Approach for the Synthesis and Thiol-Ene Modification of Alkene Functio1489lized Poly(2-oxazoline)s," *Macromolecular Rapid Communications* 32 (2011): 1484–1489, https://doi.org/10.1002/marc.201100271.

44. R. Luxenhofer and R. Jordan, "Click Chemistry with Poly(2-oxazoline)s," *Macromolecules* 39 (2006): 3509–3516, https://doi.org/10.1021/ma052515m.

45. G. Hayes, B. Dias-Barbieri, G. Yilmaz, R. J. Shattock, and C. R. Becer, "Poly(2-oxazoline)/saRNA Polyplexes for Targeted and Nonviral Gene Delivery," *Biomacromolecules* 24 (2023): 5142–5151, https://doi.org/10.1021/acs.biomac.3c00683.

46. Z. A. I. Mazrad, M. Lai, T. P. Davis, et al., "Protected Amine-functional Initiators for the Synthesis of α-amine Homo- and Heterotelechelic Poly(2-ethyl-2-oxazoline)s," *Polymer Chemistry* 13 (2022): 4436–4445, https://doi.org/10.1039/D2PY00649A.

47. B. Guillerm, S. Monge, V. Lapinte, and J.-J. Robin, "How to Modulate the Chemical Structure of Polyoxazolines by Appropriate Functionalization," *Macromolecular Rapid Communications* 33 (2012): 1600–1612, https://doi.org/10.1002/marc.201200266.

48. N. Oleszko-Torbus, A. Utrata-Wesołek, W. Wałach, and A. Dworak, "Solution Behavior of Thermoresponsive Random and Gradient Copolymers of 2-n-propyl-2-oxazoline," *European Polymer Journal* 88 (2017): 613–622, https://doi.org/10.1016/j.eurpolymj.2016.11.008.

49. S. Huber, N. Hutter, and R. Jordan, "Effect of End Group Polarity Upon the Lower Critical Solution Temperature of Poly(2-isopropyl-2-oxazoline)," *Colloid and Polymer Science* 286 (2008): 1653–1661, https://doi.org/10.1007/s00396-008-1942-7.

50. Y. Chujo, E. Ihara, H. Ihara, and T. Saegusa, "A Novel Silane Coupling Agent. 1. Synthesis of Trimethoxysilyl-terminated Poly(N-acetylethylenimine)," *Macromolecules* 22 (1989): 2040–2043, https://doi.org/10.1021/ma00195a003.

51. N. ten Brummelhuis and H. Schlaad, "Stimuli-responsive Star Polymers through Thiol–yne Core Functionalization/Crosslinking of Block Copolymer Micelles," *Polymer Chemistry* 2 (2011): 1180–1184, https://doi.org/10.1039/C1PY00002K.

52. S. Huber and R. Jordan, "Modulation of the Lower Critical Solution Temperature of 2-Alkyl-2-oxazoline Copolymers," *Colloid and Polymer Science* 286 (2008): 395–402, https://doi.org/10.1007/s00396-007-1781-y.

53. A. Gress, A. Völkel, and H. Schlaad, "Thio-Click Modification of Poly[2-(3-butenyl)-2-oxazoline]," *Macromolecules* 40 (2007): 7928–7933, https://doi.org/10.1021/ma071357r.

54. F. C. Gaertner, R. Luxenhofer, B. Blechert, R. Jordan, and M. Essler, "Synthesis, Biodistribution and Excretion of Radiolabeled Poly(2-alkyl-2-oxazoline)s," *Journal of Controlled Release* 119 (2007): 291–300, https://doi.org/10.1016/j.jconrel.2007.02.015.

55. M. Einzmann and W. H. Binder, "Novel Functional Initiators for Oxazoline Polymerization," *Journal of Polymer Science Part A: Polymer Chemistry* 39 (2001): 2821–2831, https://doi.org/10.1002/pola.1262.

56. A. Cirpan, S. Alkan, L. Toppare, G. David, and Y. Yagci, "Synthesis and Electroactivity of Pyrrole End-functionalized Poly(2-methyl-2-oxazoline)," *European Polymer Journal* 37 (2001): 2225–2229, https://doi.org/10.1016/s0014-3057(01)00103-3.

57. C. J. Waschinski and J. C. Tiller, "Poly(oxazoline)s with Telechelic Antimicrobial Functions," *Biomacromolecules* 6 (2005): 235–243, https://doi.org/10.1021/bm049553i.

58. C. P. Fik, C. Krumm, C. Muennig, et al., "Impact of Functional Satellite Groups on the Antimicrobial Activity and Hemocompatibility of Telechelic Poly(2-methyloxazoline)s," *Biomacromolecules* 13 (2012): 165–172, https://doi.org/10.1021/bm201403e.

59. S. Osawa, T. Ishii, H. Takemoto, K. Osada, and K. Kataoka, "A Facile Amino-functionalization of Poly(2-oxazoline)s″ distal End through Sequential Azido End-capping and Staudinger Reactions," *European Polymer Journal* 88 (2017): 553–561, https://doi.org/10.1016/j.eurpolymj.2016.11.029.

60. Z. A. I. Mazrad, M. N. Leiske, R. F. Tabor, J. A. Nicolazzo, and K. Kempe, "Comparison of the Anti-inflammatory Activity and Cellular Interaction of Brush Polymer– N -Acetyl Cysteine Conjugates in Human and Murine Microglial Cell Lines," *Molecular Pharmaceutics* 20 (2023): 2686–2701, https://doi.org/10.1021/acs.molpharmaceut.3c00140.

61. M. Meyer, M. Antonietti, and H. Schlaad, "Unexpected Thermal Characteristics of Aqueous Solutions of Poly(2-isopropyl-2-oxazoline)," *Soft Matter* 3 (2007): 430–431, https://doi.org/10.1039/B616678D.

62. V. G. Correia, V. D. B. Bonifácio, V. P. Raje, et al., "Oxazoline-Based Antimicrobial Oligomers: Synthesis by CROP Using Supercritical CO_2," *Macromolecular Bioscience* 11 (2011): 1128–1137, https://doi.org/10.1002/mabi.201100126.

63. J. F. R. van Guyse, X. Xu, and R. Hoogenboom, "Acyl Guanidine Functional Poly(2-oxazoline)s as Reactive Intermediates and Stimuli-Responsive Materials," *Journal of Polymer Science Part A: Polymer Chemistry* 57 (2019): 2616–2624, https://doi.org/10.1002/pola.29542.

64. Z. A. I. Mazrad, B. Schelle, J. A. Nicolazzo, M. N. Leiske, and K. Kempe, "Nitrile-Functionalized Poly(2-oxazoline)s as a Versatile Platform for the Development of Polymer Therapeutics," *Biomacromolecules* 22 (2021): 4618–4632, https://doi.org/10.1021/acs.biomac.1c00923.

65. M. Concilio, R. Garcia Maset, L. P. Lemonche, et al., "Mechanism of Action of Oxazoline-Based Antimicrobial Polymers against Staphylococcus aureus : In Vivo Antimicrobial Activity Evaluation," *Advanced Healthcare Materials* 12 (2023): 2301961, https://doi.org/10.1002/adhm.202301961.

66. M. Zhou, Y. Qian, J. Xie, et al., "Poly(2-Oxazoline)-Based Functional Peptide Mimics: Eradicating MRSA Infections and Persisters while Alleviating Antimicrobial Resistance," *Angewandte Chemie International Edition* 59 (2020): 6412–6419, https://doi.org/10.1002/anie.202000505.

67. C. Dai, M. Zhou, W. Jiang, et al., "Breaking or Following the Membrane-targeting Mechanism: Exploring the Antibacterial Mechanism of Host Defense Peptide Mimicking Poly(2-oxazoline)s," *Journal of Materials Science & Technology* 59 (2020): 220–226, https://doi.org/10.1016/j.jmst.2020.06.006.

68. N. Engel, T. Hoffmann, F. Behrendt, et al., "Cryogels Based on Poly(2-oxazoline)s through Development of Bi- and Trifunctional Cross-Linkers Incorporating End Groups with Adjustable Stability," *Macromolecules* 57 (2024): 2915–2927, https://doi.org/10.1021/acs.macromol.3c02030.

69. J. Zhu, M. Zhou, W. Jiang, Y. Zhou, G. Song, and R. Liu, "Facile One-pot Synthesis of 2-oxazoline," *Tetrahedron Letters* 91 (2022): 153637, https://doi.org/10.1016/j.tetlet.2022.153637.

70. M. A. Mees and R. Hoogenboom, "Functional Poly(2-oxazoline)s by Direct Amidation of Methyl Ester Side Chains," *Macromolecules* 48 (2015): 3531–3538, https://doi.org/10.1021/acs.macromol.5b00290.

71. C. Englert, A.-K. Trützschler, M. Raasch, et al., "Crossing the Blood-brain Barrier: Glutathione-conjugated Poly(ethylene imine) for Gene Delivery," *Journal of Controlled Release* 241 (2016): 1–14, https://doi.org/10.1016/j.jconrel.2016.08.039.

72. Y.-C. M. Wu and T. M. Swager, "Living Polymerization of 2-Ethylthio-2-oxazoline and Postpolymerization Diversification," *Journal of the American Chemical Society* 141 (2019): 12498–12501, https://doi.org/10.1021/jacs.9b06009.

73. C. I. Simionescu, I. Rabia, and I. Harfas, "Synthesis and Polymerization of 2-(β-N-ethylenediphenylamine)-2-oxazoline," *Polymer Bulletin* 7-7 (1982): 129–135, https://doi.org/10.1007/BF00265463.

74. B. R. Hsieh and M. H. Litt, "Poly(N-acylethylenimines) with Pendant Carbazole Derivatives. 2. Synthesis of 3,6-dimethoxy-, 3,6-dihydroxy-, and 2,7-dihydroxycarbazole-containing Polymers," *Macromolecules* 19 (1986): 516–520, https://doi.org/10.1021/ma00157a003.

75. O. Nuyken, G. Maier, A. Groß, and H. Fischer, "Systematic Investigations on the Reactivity of Oxazolinium Salts," *Macromolecular Chemistry and Physics* 197 (1996): 83–95, https://doi.org/10.1002/macp.1996.021970106.

76. J. Kronek, J. Luston, Z. Kroneková, et al., "Synthesis and Bioimmunological Efficiency of Poly(2-oxazolines) Containing a Free Amino Group," *Journal of Materials Science: Materials in Medicine* 21 (2010): 879–886, https://doi.org/10.1007/s10856-009-3949-0.

77. B. M. Culbertson and Y. Xue, "Synthesis of 2-(p-Aminophenyl)oxazoline and Its Cationic Polymerization Studies by Differential Scanning Calorimetry," *Journal of Macromolecular Science, Part A* 34 (1997): 1737–1746, https://doi.org/10.1080/10601329708010039.

78. J. J. Miller, S. Rajaram, C. Pfaffenroth, and M. S. Sigman, "Synthesis of Amine Functionalized Oxazolines with Applications in Asymmetric Catalysis," *Tetrahedron* 65 (2009): 3110–3119, https://doi.org/10.1016/j.tet.2008.11.046.

79. Z. He, L. Miao, R. Jordan, D. S-Manickam, R. Luxenhofer, and A. V. Kabanov, "A Low Protein Binding Cationic Poly(2-oxazoline) as Non-Viral Vector," *Macromolecular Bioscience* 15 (2015): 1004–1020, https://doi.org/10.1002/mabi.201500021.

80. D. Hertz, M. N. Leiske, T. Wloka, et al., "Comparison of Random and Gradient Amino Functionalized Poly(2-oxazoline)s: Can the Transfection Efficiency be Tuned by the Macromolecular Structure?," *Journal of Polymer Science Part A: Polymer Chemistry* 56 (2018): 1210–1224, https://doi.org/10.1002/pola.29000.

81. M. Hartlieb, T. Bus, J. Kübel, et al., "Tailoring Cellular Uptake and Fluorescence of Poly(2-oxazoline)-Based Nanogels," *Bioconjugate Chemistry* 28 (2017): 1229–1235, https://doi.org/10.1021/acs.bioconjchem.7b00067.

82. M. Hartlieb, D. Pretzel, C. Englert, et al., "Matrix Supported Poly(2-oxazoline)-Based Hydrogels for DNA Catch and Release," *Biomacromolecules* 15 (2014): 1970–1978, https://doi.org/10.1021/bm500236y.

83. M. N. Leiske, F. H. Sobotta, F. Richter, et al., "How To Tune the Gene Delivery and Biocompatibility of Poly(2-(4-aminobutyl)-2-oxazoline) by Self- and Coassembly," *Biomacromolecules* 19 (2018): 748–760, https://doi.org/10.1021/acs.biomac.7b01535.

84. B. D. Monnery, V. V. Jerca, O. Sedlacek, B. Verbraeken, R. Cavill, and R. Hoogenboom, "Defined High Molar Mass Poly(2-Oxazoline)s," *Angewandte Chemie International Edition* 57 (2018): 15400–15404, https://doi.org/10.1002/anie.201807796.

85. S. Dong, S. Ma, Z.-L. Liu, et al., "Functional Amphiphilic Poly(2-oxazoline) Block Copolymers as Drug Carriers: The Relationship between

Structure and Drug Loading Capacity," *Chinese Journal of Polymer Science* 39 (2021): 865–873, https://doi.org/10.1007/s10118-021-2547-6.

86. J. Li, Y. Zhou, C. Li, et al., "Poly(2-ethyl-2-oxazoline)–Doxorubicin Conjugate-Based Dual Endosomal pH-Sensitive Micelles with Enhanced Antitumor Efficacy," *Bioconjugate Chemistry* 26 (2015): 110–119, https://doi.org/10.1021/bc5004718.

87. M. A. Boerman, H. L. van der Laan, J. C. M. E. Bender, et al., "Synthesis of pH- and Thermoresponsive Poly(2- n -propyl-2-oxazoline) Based Copolymers," *Journal of Polymer Science Part A: Polymer Chemistry* 54 (2016): 1573–1582, https://doi.org/10.1002/pola.28011.

88. B. Mendrek, A. Kowalczuk, W. Wałach, M. Bochenek, and N. Oleszko-Torbus, "Microstructure-dependent Aggregation of Chelate-functionalized Poly(2-oxazoline)s," *Journal of Molecular Liquids* 428 (2025): 127540, https://doi.org/10.1016/j.molliq.2025.127540.

89. H. M. L. Lambermont-Thijs, J. P. A. Heuts, S. Hoeppener, R. Hoogenboom, and U. S. Schubert, "Selective Partial Hydrolysis of Amphiphilic Copoly(2-oxazoline)s as Basis for Temperature and pH Responsive Micelles," *Polymer Chemistry* 2 (2011): 313–322, https://doi.org/10.1039/C0PY00052C.

90. B. Demeneix and J.-P. Behr, "Polyethylenimine (pei)," *Advances in genetics* 53 (2005): 215–230, https://doi.org/10.1016/S0065-2660(05)53008-6.

91. M. Bochenek, B. Mendrek, W. Walach, et al., "Chelate-functionalized Poly(2-oxazoline) for the Destruction of Bacterial Cell Membranes," *Polymer Chemistry* 15 (2024): 2387–2396, https://doi.org/10.1039/D4PY00433G.

92. N. Oleszko-Torbus, B. Mendrek, W. Wałach, et al., "Amino-modified 2-oxazoline Copolymers for Complexation with DNA," *Polymer Chemistry* 15 (2024): 742–753, https://doi.org/10.1039/D3PY01313H.

93. G. Vancoillie, W. L. A. Brooks, M. A. Mees, B. S. Sumerlin, and R. Hoogenboom, "Synthesis of Novel Boronic Acid-decorated Poly(2-oxazoline)s Showing Triple-stimuli Responsive Behavior," *Polymer Chemistry* 7 (2016): 6725–6734, https://doi.org/10.1039/C6PY01437B.

94. J. F. R. van Guyse, M. N. Leiske, J. Verjans, Y. Bernhard, and R. Hoogenboom, "Accelerated Post-Polymerization Amidation of Polymers with Side-Chain Ester Groups by Intramolecular Activation," *Angewandte Chemie International Edition* 61 (2022): 202201781, https://doi.org/10.1002/anie.202201781.

95. D. N. Yamaleyeva, N. Makita, D. Hwang, M. J. Haney, R. Jordan, and A. V. Kabanov, "Poly(2-oxazoline)-Based Polyplexes as a PEG-Free Plasmid DNA Delivery Platform," *Macromolecular Bioscience* 2023, 23, 2300177, https://doi.org/10.1002/mabi.202300177.

96. C. Basham, M. Haney, Y. Zhao, et al., "PEG-Free Tunable Poly(2-Oxazoline) Lipids Modulate LNP Biodistribution and Expression in Vivo after Intramuscular Administration,", https://doi.org/10.1101/2025.06.05.657891.

97. N. Alkattan, N. Alasmael, V. Ladelta, N. M. Khashab, and N. Hadjichristidis, "Poly(2-oxazoline)-based Core Cross-linked Star Polymers: Synthesis and Drug Delivery Applications," *Nanoscale Advances* 5 (2023): 2794–2803, https://doi.org/10.1039/d3na00116d.

98. D. Hoelzer, M. N. Leiske, M. Hartlieb, et al., "Tumor Targeting with pH-responsive Poly(2-oxazoline)-based Nanogels for Metronomic Doxorubicin Treatment," *Oncotarget* 9 (2018): 22316–22331, https://doi.org/10.18632/oncotarget.24806.

99. J. F. R. van Guyse, S. Abbasi, K. Toh, et al., "Facile Generation of Heterotelechelic Poly(2-Oxazoline)s towards Accelerated Exploration of Poly(2-Oxazoline)-Based Nanomedicine," *Angewandte Chemie International Edition* 63 (2024): 202404972, https://doi.org/10.1002/anie.202404972.

100. A. Muñoz-Bonilla and M. Fernández-García, "Polymeric Materials with Antimicrobial Activity," *Progress in Polymer Science* 37 (2012): 281–339, https://doi.org/10.1016/j.progpolymsci.2011.08.005.

101. H. Luo, X.-Q. Yin, P.-F. Tan, Z.-P. Gu, Z.-M. Liu, and L. Tan, "Supramolecular Adenosine-based Skin Delivery System for Hair Regulation and Restoration," *Journal of Materials Chemistry B* 9 (2021): 2802–2815, https://doi.org/10.1039/d1tb00109d.

102. L. Tauhardt, M. Frant, D. Pretzel, et al., "Amine End-functionalized Poly(2-ethyl-2-oxazoline) as Promising Coating Material for Antifouling Applications," *J Mater Chem B* 2 (2014): 4883–4893, https://doi.org/10.1039/C4TB00193A.

103. C. J. Waschinski, V. Herdes, F. Schueler, and J. C. Tiller, "Influence of Satellite Groups on Telechelic Antimicrobial Functions of Polyoxazolines," *Macromolecular Bioscience* 5 (2005): 149–156, https://doi.org/10.1002/mabi.200400169.

104. M. N. Leiske, M. Hartlieb, C. Paulenz, et al., "Lab in a Tube: Purification, Amplification, and Detection of DNA Using Poly(2-oxazoline) Multilayers," *Advanced Functional Materials* 25 (2015): 2458–2466, https://doi.org/10.1002/adfm.201404510.

105. J. Blöhbaum, I. Paulus, A.-C. Pöppler, J. Tessmar, and J. Groll, "Influence of Charged Groups on the Cross-linking Efficiency and Release of Guest Molecules from Thiol–ene Cross-linked Poly(2-oxazoline) Hydrogels," *Journal of Materials Chemistry B* 7 (2019): 1782–1794, https://doi.org/10.1039/c8tb02575d.

106. D. Hahn, J. M. Sonntag, S. Lück, et al., "Poly(2-alkyl-2-oxazoline)-Heparin Hydrogels-Expanding the Physicochemical Parameter Space of Biohybrid Materials," *Advanced Healthcare Materials* 10 (2021): 2101327.

Biography

Meike N. Leiske is a Junior Professor in the department of Macromolecular Chemistry at the University of Bayreuth. She received her PhD in 2018 from the Friedrich Schiller University Jena. Afterwards, she was a postdoctoral research fellow at the Monash Institute of Pharmacy and Pharmaceutical Sciences (MIPS) and a visiting researcher at the University of Melbourne. In 2019, she received the prestigious Feodor-Lynen postdoc fellowship from the Alexander von Humboldt Foundation for her work on amino-acid-derived polyelectrolytes at MIPS. In 2021, she joined Ghent University as a postdoctoral researcher before starting her own group in Bayreuth in 2022. Her current research interests focus on the design of polyelectrolytes from 2-oxazolines and vinyls and their interaction with biological matter.