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### Chain Extension of Boronic Esters with Lithiooxiranes Generated by Sulfoxide–Metal Exchange – Stereocontrolled Access to 2°/2°, 2°/3°, and 3°/3° Vicinal Diols and Related Compounds

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Keywords: Carbenoids / Epoxides / Diastereoselectivity / Metalation / Sulfoxide-metal exchange

Lithiooxiranes [LiCR<sup>1</sup>(O)CR<sup>2</sup>R<sup>3</sup>, R<sup>1</sup> = H, Me; R<sup>2</sup>/R<sup>3</sup> = H/Ph, H/ tBu, Me/Ph], generated by sulfoxide–lithium exchange from stereodefined sulfinyl epoxides (with use of PhLi or tBuLi, THF, at or below –90 °C), were employed for the stereospecific reagent-controlled homologation of boronic esters R<sup>0</sup>– Bpin (R<sup>0</sup> = BnCH<sub>2</sub>, allyl, cHex, Ph). Addition of TBSOTf to the intermediate ate complexes gave  $\beta$ -silyloxyboronates that were converted to vicinal diol monosilyl ethers by oxidative work-up with aq. NaOOH. The 2°/2° (4–32 %, dr >

#### Introduction

Any potentially unifying solution to the general problem of organic synthesis must address the need to finely control constitutional and stereochemical features during molecular assembly. The concept of stereospecific reagent-controlled homologation (StReCH) offers one strategy to negotiate this challenge and envisions a target molecule arising from the successive chain extension of a boronic ester, 1, by a series of stereodefined chiral carbenoid reagents 2 (Scheme 1).<sup>[1]</sup> The carbenoids<sup>[2]</sup> are the fundamental building blocks of the technique, and the order of their presentation to the boronate determines the nature of the synthesized compound. For StReCH to hold practical significance, access to an array of viable types of carbenoid that lead to desirable structural motifs is required. Of the classes of carbenoid reagents that have been successfully utilized for StReCH to date,<sup>[3-8]</sup> lithiated epoxides 5<sup>[9]</sup> are particularly noteworthy, because 1,2-metalate rearrangement of the relevant intermediate ate complexes 6 leads to synthetically versatile  $\beta$ -alkoxyboronates 7, which may be further elaborated to a variety of useful materials. Previously, Aggarwal et al. demonstrated that lithiooxiranes generated by direct metalation of terminal epoxides<sup>[10]</sup> react with boronic esters in the expected manner to yield stereodefined vicinal diols after oxidative work-up (Scheme 2).<sup>[6]</sup> It was further discovered that  $\beta$ -silvloxyboronates produced by conducting the

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□ Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/ejoc.201403105.

98:2), 2°/3° (21–66%,  $dr \ge 65:35$ ), and 3°/3° (59–68%,  $dr \ge$  95:5) contiguous stereodiad-containing compounds created in this manner were typically obtained in a highly stereocontrolled manner. In general, *cis*-sulfinyl epoxides afforded *anti*-like stereodiads, whereas *trans*-sulfinyl epoxides afforded *syn*-like stereodiads; however, as a result of its suspected configurational instability, LiCMe(O)CHPh gave *anti*-like 2°/3° motifs regardless of sulfinyl epoxide stereochemistry.

metalate rearrangement step in the presence of TESOTf can be subjected to additional StReCH cycles leading to contiguous stereotetrad-containing 1,2,4-triols.<sup>[6]</sup>



Scheme 1. Stereospecific reagent-controlled homologation (StReCH) of pinacol boronic ester 1 with generic carbenoid 2 and an illustration of the mechanism for the same process by using lithiated epoxide 5 as carbenoid.

The elegant work of Aggarwal et al. establishes the promise of lithiated epoxides for StReCH-based synthesis, but the deprotonation methods that were employed to access these carbenoids are restricted to the production of *trans*-2-alkyl-3-lithiooxiranes **8** from terminal alkyl epoxides<sup>[10a]</sup> and to 2-lithio-2-aryloxiranes (e.g. **10**) from styrene oxides.<sup>[10b]</sup> To unlock the full synthetic potential of lithiooxiranes for StReCH, a more versatile method for their generation, capable of producing any stereo- and regioisomer, is required. Significantly, Satoh and co-workers reported that treatment of sulfinyl epoxides **12** with organo-lithium compounds at low temperature produces transient

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Scheme 2. Previous work is limited to StReCH of boronic esters with *trans*-2-alkyl-3-lithiooxiranes **8** or 2-lithio-2-aryloxiranes **10**. Bpin =  $B[O(CMe_2)_2O]$ , Bneo =  $B[OCH_2CMe_2CH_2O]$ . See Aggarwal et al. ref.<sup>[6]</sup>

lithiated epoxides **5** [Equation (1)] that can be intercepted in good yield with a range of simple electrophiles.<sup>[11]</sup> Given that related sulfoxide–metal exchange phenomena<sup>[12]</sup> have been successfully employed to trigger other types of StReCH reactions,<sup>[1,3,13]</sup> we elected to investigate the chain extension of boronates using carbenoids derived from Satoh's method because of its potential to generate any type of lithiooxirane. Herein, we describe our findings and disclose that sulfoxide–lithium exchange from *cis-* or *trans*mono-, di-, and tri-substituted sulfinyl epoxides in the presence of boronic esters leads to chain-extended adducts with excellent diastereoselectivity in a majority of examples.



#### **Results and Discussion**

After evaluating many methods to access sulfinyl epoxides, a Darzens process via intermediate chlorohydrins<sup>[11b]</sup> was found to offer the greatest convenience and yielded the desired pairs of *cis*- and *trans*-epoxides 16–20 from  $\alpha$ chlorosulfoxides (Figure 1). Typically, this reaction afforded erythro-sulfinyl epoxide isomers; however, in one case it was established by single-crystal X-ray diffraction analysis<sup>[14]</sup> that the trans-epoxide produced (compound 18t) was of a threo-type. The Darzens approach was favored here for its ability to simultaneously generate both cis- and translithiooxirane precursors, but it should not be regarded as an optimal method if enantiopurity is paramount, because we discovered that partial racemization accompanies epoxide formation. Thus, for example, chlorosulfoxide 14 with 95% ee gave cis-epoxide 16c exhibiting only 81% ee by the illustrated route (ee data for other epoxides are given in the Supporting Information). Loss of stereochemical integrity in reactions involving  $\alpha$ -chlorosulfoxide carbanions has previously been observed, but the phenomenon is not well

understood.<sup>[3c,15]</sup> Alternate methods for sulfinyl epoxide synthesis are available that deliver higher *ee* and *dr* if required.<sup>[16]</sup>



[a] Stereochemistry determined by single-crystal X-ray diffraction analysis. [b] Relative stereochemistry about epoxide determined by  ${}^{3}J_{\rm HH}$  coupling constant analysis. [c] Relative stereochemistry about epoxide determined by NOE analysis. [d] Atypical *threo*-type stereochemistry observed.

Figure 1. Synthesis of *cis*- and *trans*-sulfinyl epoxides by a Darzens process.

Investigation of the utility of sulfinyl epoxides in StReCH began with evaluation of carbenoid precursors 16-17c/t that bear a-H-atoms and lead to cis- and trans-2-substituted-3-lithiooxiranes (Figure 2). After surveying a number of organolithium initiators (nBuLi, PhLi, tBuLi), solvents (THF, Et<sub>2</sub>O, PhMe), addition modes, additives (with and without TBSOTf), and reaction temperatures (-100 °C to -78 °C), the illustrated conditions were identified to be optimal for chain extension. Of note, StReCH failed if the boronate substrate was added after generation of the putative lithiooxirane 5, and it was found that the boronate and the sulfinyl epoxide must be premixed before the addition of the organolithium initiator (i.e., Barbier conditions) for a successful outcome. Negative results were likewise charted for reactions conducted in Et<sub>2</sub>O or PhMe or for those attempted above -90 °C. Unlike initiators PhLi and tBuLi, *n*BuLi was ineffective, presumably because the sulfoxideligand exchange adduct in this case (13, R = nBu) bears  $\alpha$ -H-atoms and so may quench the basic transient lithiooxirane 5 by proton transfer (n.b., this pathway has been used deliberately by Satoh et al. for the protodesulfinylation of sulfinyl epoxides).<sup>[11a]</sup> Regrettably, the yield of chain extension was low throughout (TBSOTf boosted yield by only 3-5%); however, in all cases the StReCH adducts isolated following oxidative work-up (21-25) were single diastereoisomers and where determined, their ee matched that of the sulfinyl epoxide employed. Stereochemically distinct 2°/2° vicinal diols (and related monosilylated adducts) were generated from epimeric sulfinyl epoxides, and it was verified by comparison to literature data for known compounds (21s, 22a/s, 24a, and 25a/s)<sup>[13,17]</sup> that, as anticipated, *cis*epoxides led to anti products while the trans-isomers gave

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instead the corresponding *syn* adducts. Monosubstituted sulfinyl epoxides **12** bearing simple alkyl groups in the  $\beta$ -position (R<sup>1</sup> = H, R<sup>2</sup>/R<sup>3</sup> = H/Me or H/*n*Pr, *cis*- and *trans*isomers) were likewise examined and gave similar results to those illustrated (i.e., yields 10–16% from **1**, R<sup>0</sup> = CH<sub>2</sub>Bn).



[a] Identity of StReCH adducts authenticated by comparison to literature data (21s ref.<sup>[17a]</sup> 22a/s ref.<sup>[17b]</sup> diol derived from 24a ref.<sup>[17c]</sup> 25a/s ref.<sup>[13]</sup>).
 [b] TBSOTf not added. [c] Isolated as diol after desilylation with TBAF.

Figure 2. Synthesis of syn and anti 2°/2° vicinal diols.

The data in Figure 2 prove that the sulfoxide–lithium exchange approach to lithiooxiranes can indeed produce StReCH adducts complementary to those obtainable by direct metalation (as in Scheme 2); however, the new method offers limited practical utility for  $2^{\circ}/2^{\circ}$  vicinal diol synthesis. The origin of the low yields encountered for this product class was traced to deleterious proton transfer between the carbenoid and its progenitor. Thus, treatment of epoxide **16c** as indicated with PhLi followed by deuterolysis with CD<sub>3</sub>OD returned the protonated form of the quenched lithiooxirane (styrene oxide) accompanied by the  $\alpha$ -deuterated form of **16c** and its epimer at sulfur [Equation (2)].



The proton-transfer pathway that compromised StReCH with monosubstituted sulfinyl epoxides 16-17 is not available to di- (18, 19) and tri- (20) substituted sulfinyl epoxides ( $R^1 = Me$ ), and we were delighted to find that sterically congested chain-extended adducts are realizable in good to excellent yield from such carbenoid precursors. Less pleasing, however, was the discovery that the stereochemical outcome for the reactions of disubstituted sulfinyl epoxides deviated significantly from ideal stereospecific behavior (Fig-

ure 3). Thus, *cis*-sulfinyl epoxide **18c** was observed to deliver the anticipated  $2^{\circ}/3^{\circ}$  *anti*-like stereodiad motifs (compounds **27a**, **31a**, and **32a**) with imperfect stereocontrol, while its *trans*-epimer **18t** was unexpectedly found to also produce *anti*-like adducts (n.b., the stereochemistry for **31a** and **32a** was established by XRD analysis<sup>[14]</sup> and that for other compounds in Figure 3 by NOE analysis of the corresponding acetonide derivatives).<sup>[18]</sup> The *t*Bu-group-substituted *cis*-sulfinyl epoxide **19c** favored generation of the expected *anti*-like compound **30a**, but the diastereoselectivity was particularly low. Throughout, omitting aq. NaOOH work-up enabled isolation of the StReCH products as boronic esters in a significantly higher yield than as carbinol derivatives, which reflects that oxidation of tertiary boronates is sluggish.



[a] Worked up with aq. NaOOH. [b] Relative stereochemistry determined by NOE analysis of the derived acetonide. [c] Stereochemistry determined by single-crystal X-ray diffraction analysis (ref.<sup>[14]</sup>).

Figure 3. Stereoconvergent synthesis of *anti*  $2^{\circ}/3^{\circ}$   $\beta$ -silyl-oxyboronates and related compounds.

Remarkably, "normal" (anticipated) stereochemical behavior was restored in a brace of experiments involving trisubstituted sulfinyl epoxides 20c/t. Thus, StReCH of boronate 1 ( $R^0 = CH_2Bn$ ) with 20c and 20t by the protocol shown in Figure 3 (with NaOOH work-up), resulted in impressive stereospecific transformations yielding anti- (33a) and syn-like (33s) 3°/3° vicinal diols, respectively (Scheme 3). In this case, presumably because of heightened steric hindrance, TBSOTf did not effectively interact with the oxiranyl oxygen atom during metalate rearrangement. The relative stereochemistry of each product was again established by NOE analysis of its acetonide derivative. Upon closer scrutiny of the StReCH reaction of sulfinyl epoxide 20c, it was discovered that the failure of TBSOTf to capture the developing alkoxide anion during ate complex rearrangement resulted in the formation of a significant quantity of the tetrasubstituted alkene 36 as a single (Z)isomer by the intervention of bora-Wittig elimination.<sup>[19]</sup>

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This process was not further explored; however, when suitably optimized it would hold synthetic value as a stereospecific connective synthesis of tetrasubstituted olefins.<sup>[20]</sup> Of particular note herein is the impressive overall net yield (91%) of products that derive from a StReCH process involving a reactive carbenoid atom center that is itself fully substituted and flanked by another fully substituted carbon atom.<sup>[21]</sup>



Scheme 3. Synthesis of syn and anti 3°/3° stereodiads.

The observation of stereospecificity in chain extension reactions involving mono- (16c/t, 17c/t) and tri- (20c/t) substituted sulfinyl epoxides but the lack of this property for transformations involving disubstituted (18c/t, 19c) congeners, warrants comment. Arguably, the simplest explanation involves competition between lithiooxirane epimerization and ate complex formation; each process would be affected by substituent effects and only in those cases where the rate of epimerization surpasses that of ate complex formation might non-ideal behavior be expected. Stereoconvergence toward anti-like products in the reactions of 18c and 18t is understood on this basis (i.e., rapid epimerization) if one assumes that the reaction proceeds through the trans-like lithiooxirane 37t in both cases; 37t is formed directly from 18c and is accessible from 18t by epimerization of the initially generated higher-energy cis-like lithiooxirane 37c (Scheme 4).<sup>[22]</sup> Evidently, the rate of epimerization for 37c/ t is faster than that for the corresponding lithiated epoxides derived from either 16c/t or 20c/t. This fact can be rationalized, at least heuristically, if an  $\alpha$ -alkoxycarbene (compound 38) is considered to be the relevant vector for lithiooxirane epimerization.<sup>[23]</sup> Thus, when  $R^1 = H$  or  $R^2 \neq H$ , 38 is destabilized, and the rate of epimerization is consequently retarded, because in the first case the carbene center has 1° character while in the second case the alkoxide has 3° character. Conversely, when  $R^1 = Me$  and  $R^2 = H$ , the scenario for reactions involving 18c/t, an intermediate situation exists (2° carbene character and 2° alkoxide character in 38) that may facilitate epimerization. Finally, the poorly stereocontrolled reaction from 19c to 30a (dr = 65:35, Figure 3) can be understood by invoking the same principle and factoring that the more stable trans-like lithiooxirane in this case (i.e., 5,  $R^1 = Me$ ,  $R^2 = H$ ,  $R^3 = tBu$ ) will react more slowly than its epimer with the boronic ester because of severe steric hindrance of the C-Li bond by the tBu group.



Scheme 4. Stereoconvergence is explicable if the rate of lithiooxirane epimerization exceeds the rate of boronate capture.

#### Conclusions

In summary, Satoh's method for generating lithiooxiranes from sulfinyl epoxides has been interfaced with StReCH to prepare chain-extended adducts, many of which cannot be accessed by the direct metalation process used previously. While the new StReCH method did not provide synthetically useful yields of 2°/2° vicinal diols, it proved effective for the elaboration of 2°/3° and 3°/3° vicinal diols and related motifs via intermediate tertiary boronates. Significantly, the B-atom-bearing fully substituted stereogenic center derived from the process in this case is of a fairly generic type (i.e., not allylic or benzylic), which could be further converted in a stereospecific manner to other types of highly substituted stereogenic functional groups, such as tetrasubstituted alkenes or quaternary carbon atoms.<sup>[4f]</sup> An extension of the chemistry described herein to lithiated aziridines is conceivable, because such carbenoids (generated by deprotonation) have been employed successfully in StReCH before,<sup>[7]</sup> and sulfoxide-metal exchange has been demonstrated from sulfonylaziridines.<sup>[24]</sup>

#### **Experimental Section**

General Methods: All reactions requiring anhydrous and oxygenfree conditions were conducted in flame-dried glassware under Ar gas. Anhydrous THF was dispensed from a commercially available solvent purification system employing activated Al2O3 drying columns. Chromatographic separations were performed on silica gel 60 (35-75 µm), and reactions were followed by TLC analysis by using silica gel 60 plates (2-25 µm) with fluorescent indicator (254 nm) and visualized with UV or phosphomolybdic acid. All commercially available reagents were used as received unless otherwise noted. Melting points were determined from open capillary tubes with a melting point apparatus. Infrared (IR) spectra were recorded in the Fourier transform mode by using KBr disks for solids, while oils were supported between NaCl plates ("neat"). <sup>1</sup>H and <sup>13</sup>C NMR spectra were recorded in the Fourier transform mode at the field strength specified and from the indicated deuterated solvents in standard tubes having 5 mm diameter. Chemical shifts in ppm are quoted relative to residual solvent signals calibrated as follows: CDCl<sub>3</sub>  $\delta_{\rm H}$  (CHCl<sub>3</sub>) = 7.26 ppm,  $\delta_{\rm C}$  = 77.2 ppm. Multiplicities in the <sup>1</sup>H NMR spectra are described as: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad. Numbers in parentheses following carbon atom chemical shifts re-

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fer to the number of attached hydrogen atoms as revealed by the DEPT spectral editing technique. Low- (MS) and high-resolution mass spectra (HRMS) were obtained by using either the electron impact (EI) or electrospray (ES) ionization techniques. Ion mass/ charge (m/z) ratios are reported in atomic mass units.

Representative Procedure – (1R,2S)-1,2-Dimethyl-1,4-diphenylbutan-1,2-diol (33a): A stirred solution of tBuLi (0.072 mL, 1.52 M in pentane, 0.109 mmol) in anhydrous THF (1.0 mL) at -100 °C under Ar was treated with a mixture of sulfinyl epoxide 20c (30 mg, 0.105 mmol) and *B*-phenethyl pinacol boronate (1,  $R^0 = BnCH_2$ , 19 mg, 0.082 mmol)<sup>[1b]</sup> in anhydrous THF (1.0 mL). The resulting mixture was stirred for 20 min at -100 °C, then treated with TBSOTf (0.020 mL, d = 1.151, 23 mg, 0.087 mmol), warmed to room temp. over 2 h, and stirred for a further 2 h at room temp. The mixture was then cooled to 0 °C, treated with aq. NaOH (1.0 mL, 2.0 м) followed by 30 wt.-% aq. H<sub>2</sub>O<sub>2</sub> (0.50 mL), and stirred for 2 h at 0 °C. The mixture was partitioned between CH<sub>2</sub>Cl<sub>2</sub> (5 mL) and H<sub>2</sub>O (3 mL), and the layers were separated. The aqueous phase was extracted with  $CH_2Cl_2$  (3 × 5 mL), and the combined organic phases were washed with brine (5 mL), dried (Na<sub>2</sub>SO<sub>4</sub>), and concentrated in vacuo. The residue was purified by column chromatography (SiO<sub>2</sub>, eluting with 30% Et<sub>2</sub>O in hexanes) to afford the desired anti-like 3°/3° diol 33a (13 mg, 0.048, 59%) as a colorless oil. IR (neat):  $\tilde{v} = 3440, 3063, 3028, 2983, 2930, 1604,$ 1496, 1447, 1375, 1058, 1029, 760, 702 cm<sup>-1</sup>. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):  $\delta$  = 7.49 (dm, J = 7.3 Hz, 2 H), 7.33 (tm, J = 8.0 Hz, 2 H), 7.29–7.22 (m, 3 H), 7.15 (tm, J = 7.3 Hz, 1 H), 7.10 (dm, J =7.1 Hz, 2 H), 2.72 (td, J = 13.4, 4.7 Hz, 1 H), 2.54 (td, J = 12.5, 5.2 Hz, 1 H), 2.42 (s, 1 H), 1.97 (s, 1 H), 1.84 (td, J = 13.7, 4.9 Hz, 1 H), 1.68 (s, 3 H), 1.50 (ddd, J = 13.9, 12.3, 5.3 Hz, 1 H), 1.33 (s, 3 H) ppm. <sup>13</sup>C NMR (175 MHz, CDCl<sub>3</sub>):  $\delta$  = 144.4 (0), 142.8 (0), 128.4 (2 C, 1), 128.3 (2 C, 1), 127.8 (2 C, 1), 127.0 (1), 126.7 (2 C, 1), 125.7 (1), 79.2 (0), 38.2 (2), 30.1 (2), 24.8 (3), 21.1 (3) ppm (one RR'MeCOH signal obscured by CDCl<sub>3</sub>) ppm. MS (ES<sup>+</sup>): m/z =293 [M + Na]<sup>+</sup>. HRMS (ES<sup>+</sup>): calcd. for C<sub>18</sub>H<sub>22</sub>NaO<sub>2</sub> 293.1517; found 293.1531.

**Supporting Information** (see footnote on the first page of this article): Experimental procedures, characterization data, and <sup>1</sup>H and <sup>13</sup>C NMR spectra for all compounds.

### Acknowledgments

Financial support for this work by the National Science Foundation (US) (grant CHE-0906409) is gratefully acknowledged. E. A. thanks the Libyan–North American Scholarship Program administered by the Canadian Bureau for International Education for a scholarship.

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- [16] For example, synthesis of the *cis*-epoxide epimer of 16c (epimeric at sulfur and therefore of the *threo* type) by the nucleophilic epoxidation method of Fernández de la Pradilla was found to result in material with >98% *ee* from the corresponding enantiopure *cis*-vinyl sulfoxide precursor, see: R. Fernández de al Pradilla, S. Castro, P. Manzano, M. Martin-Ortega, J. Priego, A. Viso, A. Rodríguez, I. Fonseca, *J. Org. Chem.* 1998, *63*, 4954–4966.
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# SHORT COMMUNICATION

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- [18] Chain extension of  $1 (R^0 = c$ -Hex) with the *erythro* type *trans*like sulfinyl epoxide isomer of **18t** (obtained as a trace product from **15** and benzaldehyde by the Darzens protocol shown in Figure 1) also led to the unexpected *anti*-like product **31a**.
- [19] P. R. Blakemore in *Comprehensive Organic Synthesis 2nd Edition* (Eds.: P. Knochel, G. A. Molander, G. A.), Elsevier, Oxford, **2014**, vol. 1, pp. 516–608.
- [20] The reaction of organoborons with lithiated epoxides (generated by treatment of 2-substituted 3,3-dichloro-1,1,1-trifluoro-2-propanols with excess amounts of organolithium compounds) has been previously exploited for the stereocontrolled synthesis of tri- and tetrasubstituted trifluoromethyl-groupbearing alkenes by bora-Wittig elimination, see: a) M. Shimizu, T. Fujimoto, H. Minezaki, T. Hata, T. Hiyama, J. Am. Chem. Soc. 2001, 123, 6947–6948; b) M. Shimizu, T. Fujimoto, X. Liu, H. Minezaki, T. Hata, T. Hiyama, Tetrahedron 2003, 59, 9811–9823.
- [21] Reaction of 20t in an otherwise identical fashion to that indicated for 20c in Scheme 3 similarly generated 34s (68%) and (*E*)-36 ( $\leq 15\%$ ). See Supporting Information for details.

- [22] The epimerization of α-substituted lithiated epoxides prior to their interception by electrophiles has been previously noted. Thus, *cis-3-tert*-butyl-2-lithio-2-(trimethylsilyl)oxirane, generated in situ by direct lithiation of the corresponding *cis*-epoxide, epimerized to the more stable *trans*-lithiooxirane isomer prior to 1,2-addition to 2-cyclohexen-1-one, see: G. A. Molander, K. Mautner, *J. Org. Chem.* **1989**, *54*, 4042–4050.
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Received: August 18, 2014 Published Online: ■



**Chain Extension** 

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Chain extension of boronic esters with lithiated epoxides generated from sulfinyl epoxides by sulfoxide–lithium exchange enables stereocontrolled synthesis of  $\beta$ -alkoxyboronates, which can be converted to 2°/ 2°, 2°/3°, or 3°/3° vicinal diols. The method performs best when more highly substituted sulfinyl epoxides are employed as homologation reagents.



• yields 2°/2°: 4–32 % 2°/3°: 21–66 % 3°/3°: 59–68 % (dr > 98:2) (dr ≥ 65:35) (dr ≥ 95:5) E. Alwedi, L. N. Zakharov, P. R. Blakemore<sup>\*</sup> ..... 1–7

Chain Extension of Boronic Esters with Lithiooxiranes Generated by Sulfoxide– Metal Exchange – Stereocontrolled Access to 2°/2°, 2°/3°, and 3°/3° Vicinal Diols and Related Compounds

Keywords: Carbenoids / Epoxides / Diastereoselectivity / Metalation / Sulfoxidemetal exchange