# Open position for LMU-CSC scholarship candidates 2027

**Department/Institute: Department of Chemistry**

**Subject area:** Organic Chemistry

**Name of supervisor:** Prof. Dr. Oliver Trapp

**Number of open position: 1**

**Project title: Immobilized Chiral Diamide Stationary Phases for the**

**Enantioseparation of Sugars from the Formose Reaction**

**Project description:**

Carbohydrates are essential building blocks of life, and the question of how D-sugars became dominant is central to understanding the origin of biological homochirality. The formose reaction, the base- or mineral-catalyzed oligomerization of formaldehyde and glycolaldehyde, is the most plausible prebiotic route to monosaccharides, but it produces complex mixtures of tetroses, pentoses and hexoses (*1-3*). Determining the enantiomeric ratio of each sugar in such mixtures requires highly selective and robust chiral stationary phases (CSPs). In 1981, König et al. introduced XE-60-L-valine-(S)-1-phenylethylamide (Figure 1), the first CSP able to separate carbohydrate enantiomers by gas chromatography (*4, 5*). However, this phase is only coated onto the capillary wall. As a result, its thermal stability is limited, it bleeds from the column (which hampers GC-MS), and several sugars such as ribose, lyxose and fucose are separated incompletely or not at all.

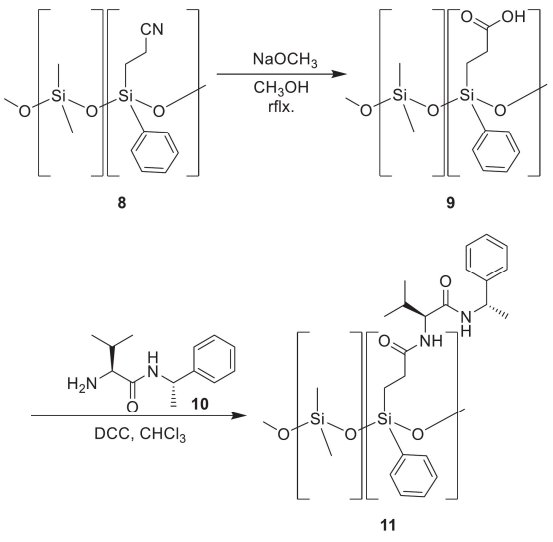


**Figure 1.** Synthesis of the chiral stationary phase XE-60-L-valine-(S)-1-phenylethylamide **11** from the cyanoethyl polysiloxane XE-60 **8** via the carboxylic acid **9** and DCC coupling with L-valine-(S)-1-phenylethylamide **10** (reproduced from ref. *5*, CC BY-NC 4.0).

This PhD project aims to develop an **improved, immobilized version of this selector** that is covalently bonded to the inner wall of **fused-silica capillaries**. L-Valine-(S)-1-phenylethylamide selectors carrying alkenyl spacers of different lengths will be synthesized and grafted onto hydridomethyl-dimethylpolysiloxanes by Pt-catalyzed hydrosilylation (*5, 6*). The remaining Si–H groups allow thermal immobilization and cross-linking on the silanol-activated fused-silica surface, analogous to Chirasil-Dex (*7*). Selector density, spacer length and the structure of the amino acid (e.g., valine, tert-leucine) and of the aryl amide (phenyl, naphthyl) will be varied systematically. The goals are higher enantioselectivity, a wider operating temperature range and full compatibility with GC-MS.

To understand chiral recognition at the molecular level, the interactions of soluble model selectors with derivatized sugar enantiomers (O-trifluoroacetylated aldoses and methylglycosides) (*8*) will be studied by **NMR spectroscopy**: $^{1}H$ and $^{19}F$ NMR titrations, 2D NOESY/ROESY and DOSY. These experiments will give binding constants and complex geometries, which will be correlated with thermodynamic data from temperature-dependent GC and with quantum-chemical calculations. Finally, the optimized columns will be used to **separate the sugar enantiomers formed in formose reactions**. The reactions will be run under prebiotically relevant conditions, including mineral-catalyzed and mechanochemical variants and reactions with chiral additives (*2, 3*), to find out whether and how enantiomeric imbalances can arise.

The PhD candidate will work at the interface of **organic synthesis, polymer and surface chemistry, NMR spectroscopy, enantioselective gas chromatography and prebiotic chemistry**. The work spans selector design and synthesis, column fabrication, mechanistic studies of chiral recognition and the analysis of complex sugar mixtures, with applications in **chiral analysis, origin-of-life research and carbohydrate chemistry**.

1. A. Butlerow, *Justus Liebigs Ann. Chem.* **120**, 295-298 (1861); 2. S. Lamour, et al. *Life* **9**, 52 (2019); 3. M. Haas, et al. *Commun. Chem.* **3**, 140 (2020); 4. W. A. König, et al. *J. Chromatogr.* **217**, 71-79 (1981); 5. G. Betzenbichler, et al. *Chirality* **34**, 732-759 (2022); 6. M. J. Spallek, et al. *Eur. J. Org. Chem.* **2012**, 3929-3945 (2012); 7. V. Schurig, et al. *Angew. Chem. Int. Ed. Engl.* **30**, 987-989 (1991); 8. M. Haas, et al. *J. Chromatogr. A* **1568**, 160 (2018).

## Project time plan:

➢ Full Doctoral Study-Model: 36 months

**Year 1:** synthesis of alkenyl-functionalized selectors, grafting onto polysiloxanes, pretreatment of fused-silica capillaries and immobilization

**Year 2:** column characterization (efficiency, thermal stability, bleeding), optimization of the selector structure, GC separation of sugar enantiomers, NMR interaction studies and computational modelling of selector–sugar complexes

**Year 3:** formose reactions, enantioselective analysis of the sugar products, and writing up the thesis

## Language requirements: English (B2 level)

## Academic requirements:

Master's degree in chemistry (organic or analytical chemistry) with excellent performance; experience in organic synthesis is required, and experience in NMR spectroscopy and/or chromatography is an advantage.

## Contact information of supervisor:

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## To applicants:

➢ **please attach resume and research motivation letter**