Atomic-Scale Imaging of Phenylalanine Self-Assembly on a Copper Surface

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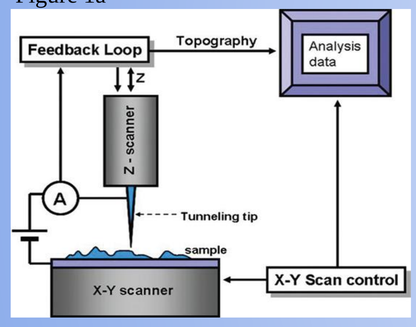
Abstract

The purpose of this project was to investigate the self-assembly of phenylalanine, a chiral amino acid, using scanning tunneling microscopy. Chiral amino acids have L- and D- forms, and current research is working to determine why one of these two forms is used more predominantly than the other in nature. The goal of studying chiral forms separately, as well as in a racemic mixture, is to determine if the different forms selectively self-assemble. Our hypothesis is that the selective self-assembly of chiral amino acids is the explanation as to why L-forms of chiral amino acids are the primary form in life. In our experiment, we have found evidence of self-assembly in phenylalanine.

Introduction

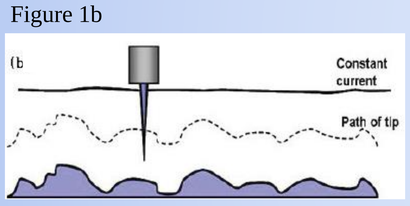
- This research utilized scanning tunneling microscopy (STM- Figure 1) to study the molecular self-assembly of a chiral amino acid on copper surfaces.
- The exploration of molecular self-assembly can further the understanding of a critical phenomena found throughout nature. There may be chiral selectivity occurring within these assemblies while studying them at the atomic level.
- Ultimately, this experiment will provide insight into why amino acids in living things utilize the “L” form of molecules, when the “D” form occurs in equal amounts.

Figure 1a



http://www.parksystems.com/index.php/park-spm-modes/electrical-properties/241-scanning-tunneling-microscopy-stm

Figure 1b



Methods

- Using the STM, shown in Figure 2(a), samples were prepared in an ultrahigh vacuum chamber. Samples were characterized with atomic-resolution utilizing the STM. Images and data samples were collected with a computer software.
- The Cu (111) surface was cleaned by sputter annealing.
- The molecules were dosed onto the copper surface using a molecular doser, shown in Figure 2(b). Upon dosing, the carboxylic acid and amine group bound with the copper surface.
- Following the dose, the samples were annealed at 450 K.
- While remaining in the Ultra High Vacuum, the sample was transferred to the STM to be imaged.
- Images were taken at 55 K.

Figure 2a

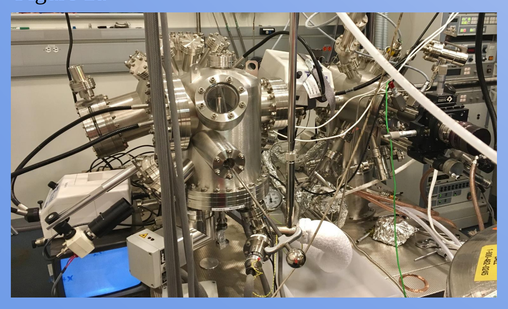


Figure 2b

Results

- Phenylalanine self-assembled on the Cu 1:1:1: surface
- At high coverage, there was a high level of order in phenylalanine.
  - The phenylalanine self-assembled in three different planes (Figure 3), corresponding with the planes of the hexagonal Cu 1:1:1 surface (Figure 3b).
  - Aromatic ring structures were observed, consistent with the structure of phenylalanine (Figure 3c, 3d)

Figure 3a

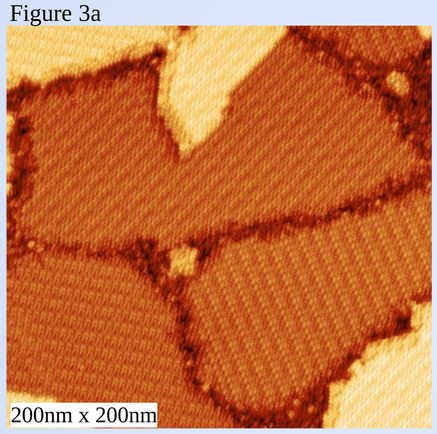


Figure 3b

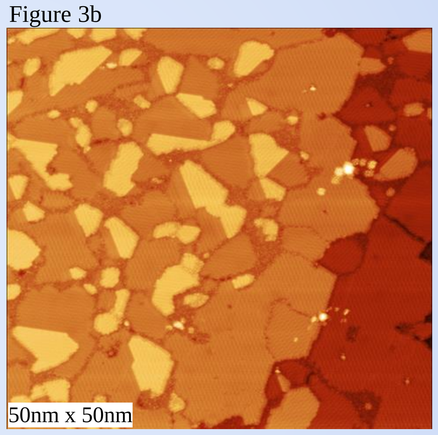


Figure 3c

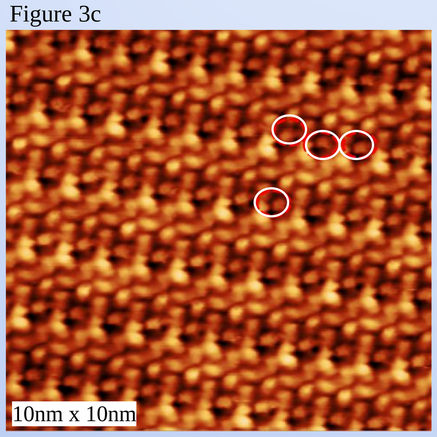
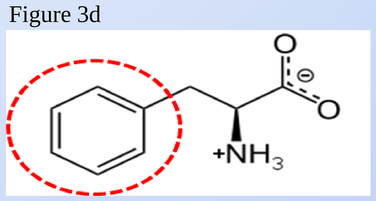


Figure 3d



- At low coverage, there was a low level of order in the phenylalanine (Figure 4)

Figure 4a

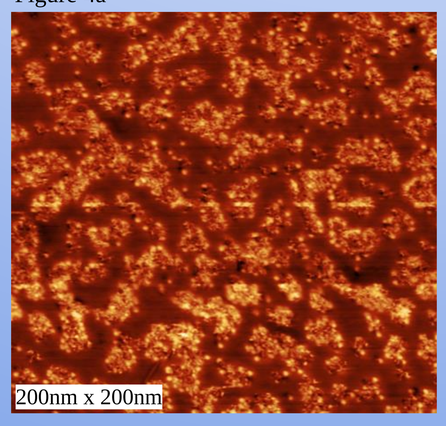
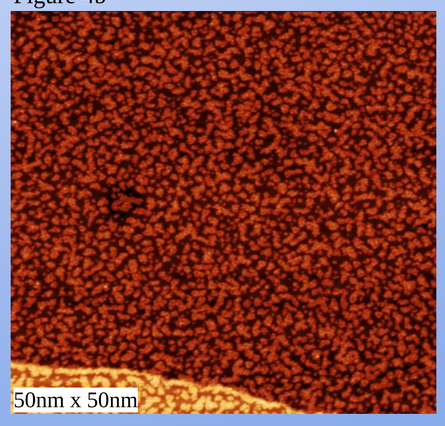
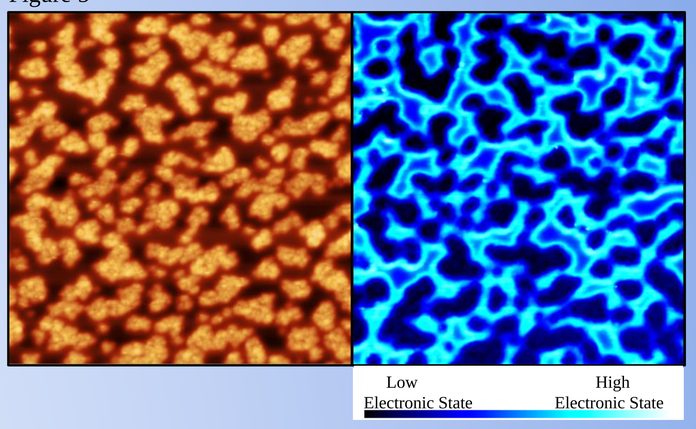


Figure 4b



Results (*cont.*)

Figure 5



- Figure 5 shows the STM image of the phenylalanine assembly as well as the electronic states such that phenylalanine is shown in darker colors and the Cu is represented with the lighter blue.
- The results provide evidence that the low-coverage phenylalanine did not form a continuous monolayer.

Conclusion

- The L-form of Phenylalanine self-assembles when at high coverage.
- Differences in order across levels of coverage are similar to assembly patterns observed on Cu 1:1:1 with threonine, but differ from observations of isoleucine and tryptophan.
- Research on other amino acid self-assemblies has shown that when L- forms self-assemble, D-forms also often self assemble. Further research will test this as well as the propensity for selective self-assembly

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Acknowledgements

This research was made possible through the Exemplary Student Research Program, supported by Argonne National Laboratory’s Educational Programs (HRS), the CNM User Office, and supported by Center for Nanoscale Materials at Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC .”