Poster

Pre-nucleation clusters in liquid benzoic acid

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Carboxylic acids play a pivotal role in crystal engineering, owing to their ability to form hydrogen-bonded cyclic dimers, which route the crystallization process. Benzoic acid (BZA) is the prototype of aromatic carboxylic acids. Recent results from our group [1] point out that several intermolecular recognition modes are present in the liquid phase, where the cyclic dimers that are found also in the $P2_1/c$ crystal – the only known to date – are overcome by trimeric structures with almost trigonal symmetry, and coexist with greater and more complex HB clusters. Thus, a question arises – when and why does the structure of the liquid change, so that nucleation of BZA dimers can occur?

To gain insights on the problem, we investigate liquid benzoic acid as a function of T by means of molecular dynamics with the free MiCMoS platform [2-5]. We propose novel structure-free energy-based criteria to highlight relevant supramolecular clusters that show a detectable cohesion and, for this reason, have lifetimes significantly longer than thermal fluctuations [6]. Our tool allows to single out nanoscale inhomogeneities that impact on the average structure of the liquid, in what is the nano-equivalent of bulk de-mixing within a binary system. We find clusters up to 17 molecules large that persist by more than 100 ps in undercooled BZA, and display an inner structure that is somewhat intermediate between the liquid and the crystal. Thus, they might lie on the path to the ripening of critical clusters or semi-liquid crystal embryos. Large aggregates still lack a definite inner symmetry and are highly dynamic and fluxional, as we expect. We hypothesise that, on longer time scales, persistent nanoscale inhomogeneities could set up a favourable environment that enhances the probability of nucleation, in agreement with non-classical theories [7].

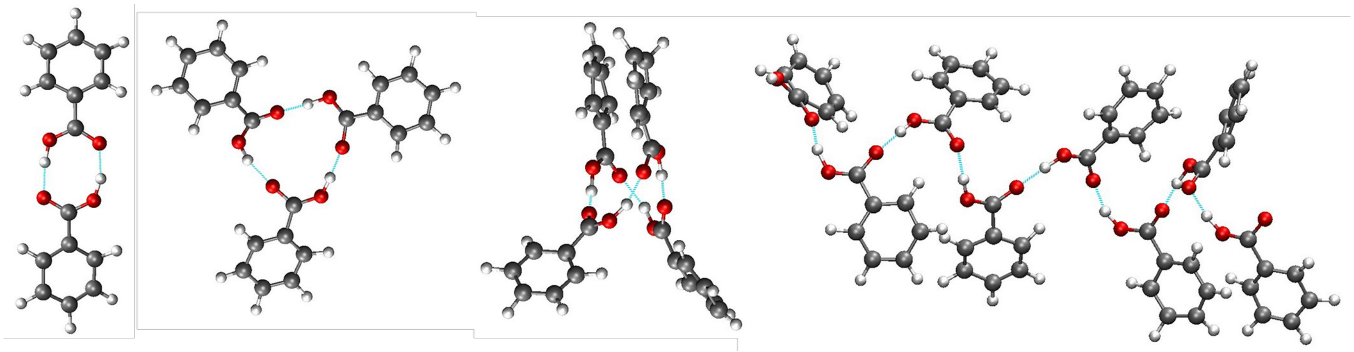

Figure 1. Benzoic acid cyclic dimer, trimer, tetramer and catemeric 8-mer.

[1] Sironi, L., Macetti, G., Lo Presti, L. (2023). *Phys. Chem. Chem. Phys.* **25**, 28006-28019

[2] Lo Presti, L., Gavezzotti, A. (2023) *MiCMoS (MIlano Chemistry MOlecular Simulation) 2.2*, Università degli Studi di Milano, Milano, https://sites.unimi.it/xtal_chem_group/index.php.

[3] Gavezzotti, A., Lo Presti, L., Rizzato, S. (2022). *CrystEngComm*, **24**, 922-930.

[4] Gavezzotti, A., Lo Presti, L., Rizzato, S. (2020). *CrystEngComm*, **22**, 7350-7360.

[5] Macetti, G., Sironi, L., Lo Presti, L. (2024). *Classical Molecular Dynamics Simulation of Molecular Crystals and Materials: Old Lessons and New Perspectives*. Comprehensive Computational Chemistry (First Edition), Elsevier, 777-803.

[6] Sironi, L., Macetti, G., Lo Presti, L. In preparation.

[7] Zhang, X. (2020) *Crystallization via Nonclassical Pathways*, Volume 1: Nucleation, Assembly, Observation & Application, ACS Symposium Series, American Chemical Society: Washington, DC.