

NU-1000 AS A HIGH-EFFICIENCY HPLC STATIONARY PHASE

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Metal–organic frameworks (MOFs) provide chemically programmable pore environments and coordinatively active metal nodes, making them promising candidates for liquid-phase separations. However, their practical application in high-performance liquid chromatography (HPLC) is often limited by non-ideal particle morphologies and restricted accessibility of the narrow pores, both of which increase mass-transfer resistance and reduce column efficiency.

Beyond conventional small-molecule separations, MOF-based HPLC holds particular promise for polymer analysis, which remains challenging for conventional chromatographic techniques. Recent reports have shown that MOF-packed columns can differentiate polymers according to end-group functionality[1] and subtle backbone isomerism,[2] reflecting the ability of nanopores to recognize local structural features along polymer chains. However, achieving high-resolution polymer separations remains difficult because limited separation efficiency and band broadening often compromise performance.[3]

Here, we establish the mesoporous Zr-MOF, NU-1000,[4] as a high-efficiency stationary phase by independently controlling particle size and pore accessibility. NU-1000 contains one-dimensional mesoporous channels (~3 nm diameter) that are expected to mitigate diffusion limitations. Using modulator-controlled synthesis with trifluoroacetic acid,[4] we prepare NU-1000 particles with controlled micrometer-scale dimensions suitable for column packing. In addition, the effective pore environment is tuned by incorporating benzoic acid as a co-ligand within the framework, enabling systematic investigation of intracrystalline mass-transfer effects.

The resulting NU-1000-packed columns are evaluated using reduced van Deemter and Péclet-number analyses, allowing independent assessment of eddy dispersion and mass-transfer resistance. Under optimized conditions, the NU-1000 columns achieve separation efficiencies comparable to those of state-of-the-art commercial C18 columns.

The practical capability of NU-1000 was demonstrated through chain-length-resolved separations of single-molecular-weight polyethylene glycol (PEG 400) homologs from a polydisperse mixture, surpassing the resolution obtained with the commercial C18 reference column. These results demonstrate that precise control over the particle morphologies and mass transport properties provides a powerful strategy to engineer MOF crystals into efficient and cost-effective alternatives for advanced HPLC applications.

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[2] N. Hosono, Y. Kono, N. Mizutani, D. Koga, T. Uemura, *Chem. Commun.* **2024**, *60*, 13690–13693.

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