Abstract for IAS Focused Program on Reticular Quantum Matter (Nov 30 - Dec 4, 2026)

Coordination Nanosheets: From Molecular Design to Emerging Functions

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Coordination nanosheets (CONASHs), two-dimensional π-conjugated metal–organic frameworks synthesized under mild solution conditions, have emerged as a versatile class of electro-functional materials complementary to conventional inorganic 2D materials [1, 2]. Owing to their molecular design flexibility, redox activity, and structural tunability, they offer a unique platform bridging coordination chemistry, condensed matter, and device science (Figure 1). This presentation highlights recent developments in coordination nanosheets, from their interfacial synthesis and electronic structures to emerging aspects of functional reticular quantum matter.

Particular emphasis will be placed on recent progress in metalladithiolene nanosheets based on benzenehexathiol (BHT). Following our original discovery of conductive Ni_3BHT_2 nanosheets [3] and subsequent development of highly crystalline heterometallic $NiCu_2BHT$ [4], new synthetic strategies now enable rational access to structure-defined heterometallic frameworks. Selective colloidal synthesis of porous NiDT and nonporous NiBHT, their use as coordination nanosheet inks, and sequential metal-ion insertion have recently led to the creation of $NiCu_2BHT$ and the new $NiZn_2BHT$ with controlled atomic arrangements and tunable conductivity [5]. These results demonstrate how precise heterometal design in 2D coordination frameworks provides a route to emergent electronic and catalytic properties.

A second focus concerns bis(diimino)metal nanosheets as electrocatalytic quantum materials. We recently developed bis(diimino)palladium (PdDI) nanosheets exhibiting hydrogen evolution activity approaching that of metallic platinum, despite a sparse Pd atom arrangement [6]. The remarkable performance originates from coupling the conductive conjugated nanosheet scaffold with in situ generation of catalytically active Pd(0) species, illustrating how coordination nanosheets can function as electronically integrated catalytic architectures.

A third topic addresses device concepts based on lateral heterostructures. Through spatially controlled sequential transmetallation of Zn_3BHT, seamless tmFe/tmCu lateral heterojunctions showing rectifying behavior were realized [7]. This provides a new synthetic route to in-plane electronic junctions entirely constructed from coordination nanosheets and points toward integrated circuitry and points toward integrated circuitry and new functional architectures in reticular materials.

Together, these advances highlight a transition of coordination nanosheets from chemically versatile 2D polymers to a broader materials platform, where precise structural design, redox-active frameworks, heterometallic integration, and heterostructure engineering can be exploited to generate emergent electronic, catalytic, and multifunctional properties. This presentation will also touch upon future opportunities for developing coordination nanosheets as versatile platforms for fundamental science and functional materials.

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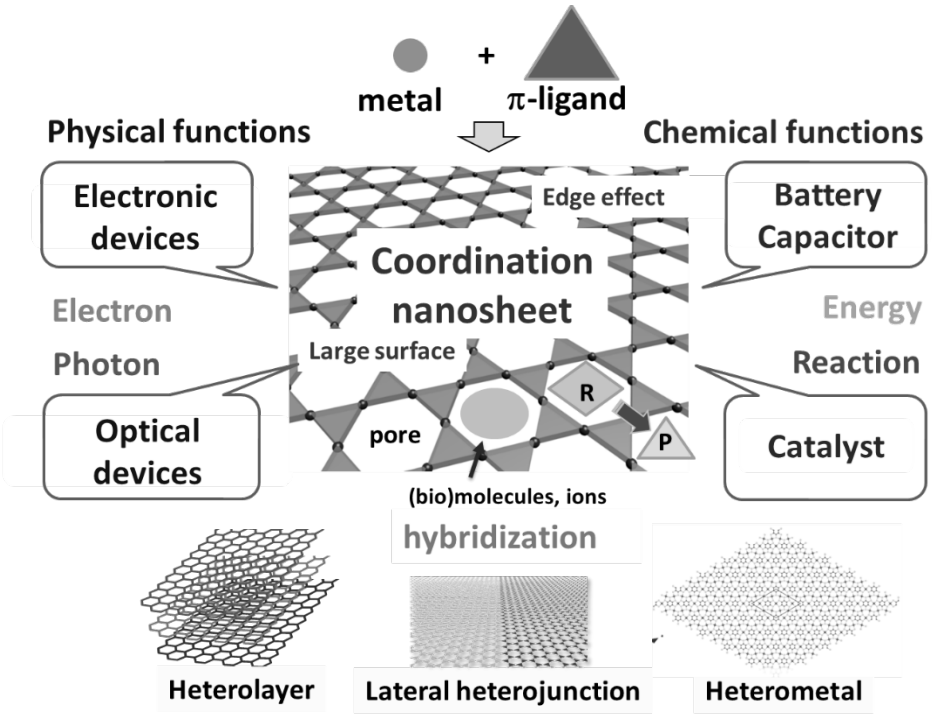


Figure 1. Conceptual overview of coordination nanosheets, from molecular design and interfacial synthesis to electronic, catalytic, and device functions.

References:

[1] H. Maeda, K. Takada, N. Fukui, S. Nagashima and H. Nishihara, Coord. Chem. Rev. 470 214693 (2022).
[2] K. Takada, H. Maeda, N. Fukui and H. Nishihara, Coord. Chem. Res. 1 100006 (2025).
[3] T. Kambe, R. Sakamoto, K. Hoshiko, K. Takada, M. Miyachi, J. Ryu, S. Sasaki, J. Kim, K. Nakazato, M. Takata and H. Nishihara, J. Am. Chem. Soc. 135 2462-2465 (2013).
[4] R. Toyoda, N. Fukui, D. H. L. Tjhe, E. Selezneva, H. Maeda, C. Bourgès, C. M. Tan, K. Takada, Y. Sun, I. Jacobs, K. Kamiya, H. Masunaga, T. Mori, S. Sasaki, H. Sirringhaus and H. Nishihara, Adv. Mater. 34 e2106204 (2022).
[5] M. Ito, N. Fukui, K. Takada, Z. Yu, H. Maeda, K. Mizuno and H. Nishihara, Small 21 2503227 (2025).
[6] H. Maeda, E. J. H. Phua, Y. Sudo, S. Nagashima, W. Chen, M. Fujino, K. Takada, N. Fukui, H. Masunaga, S. Sasaki, K. Tsukagoshi and H. Nishihara, Chem. Eur. J. 31 e202403082 (2025).
[7] C. M. Tan, N. Fukui, K. Takada, H. Maeda, E. Selezneva, C. Bourgès, H. Masunaga, S. Sasaki, K. Tsukagoshi, T. Mori, H. Sirringhaus, H. Nishihara, Angew. Chem. Int. Ed. 63, e202318181 (2024).