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Van der Waals Heterostructures beyond 2D Materials

The heterogeneous integration of dissimilar materials is a long pursuit of material science community and has defined the material foundation for modern electronics and optoelectronics. The typical material integration approaches usually involve strong chemical bonds and aggressive synthetic conditions and are typically limited to materials with strict structure match and processing compatibility. Alternatively, van der Waals integration, in which freestanding building blocks are physically assembled together through weak van der Waals interactions, offers a bond-free material integration strategy without lattice and processing limitations, as exemplified by the recent blossom of 2D van der Waals heterostructures. Here I will discuss the fundamental forces involved in van der Waals integration and generalize this approach for flexible integration of radically different materials to produce artificial heterostructures with minimum interfacial disorder and enable high-performing devices. Recent highlights include the formation of van der Waals metal/semiconductor junctions free of Fermi level pinning to reach the Schottky-Mott limit; the creation of a new class of high-order van der Waals superlattices with highly distinct constituent atomic or molecular layers; and the development of van der Waals thin film electronics with unprecedented flexibility and stretchability. I will conclude with a brief prospect on exploring such artificial heterostructures as a versatile material platform with electronic structure by design to unlock new physical limits and enable device concepts beyond the reach of the existing materials.