# The Sir Martin Wood Prize Lecture

## Correlation between Nanostructures and Transport Properties in Inhomogeneous Condensed Systems


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**Biography**

**September 2022 ~ Present:**
Professor, Nano-Technology Center for SANKEN, Osaka University

**April 2019 ~ September 2022:**
Associate Professor, Institute for Molecular Science

**September 2022 ~ March2023:**
Professor (Concurrently), Institute for Molecular Science

**October 2015 ~ March 2019:**
Lecturer, Department of Materials Engineering, Graduate School of Engineering, University of Tokyo

**December 2013 ~ September**
2015:Assistant Professor, Department of Materials Engineering, Graduate School of Engineering, University of Tokyo

**April 2011 ~ December 2013:**
Special Postdoctoral Researcher, RIKEN

**April 2010 ~ March 2011**:
JSPS (Japan Society for the Promotion of Science) Research Fellow, Graduate School of Engineering, Osaka University

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**Max Planck Institute for Solid State Science**

**Lecture Hall 2D5**


The advancements in nanotechnology during the late 20th century enabled the assembly and observation of materials at the atomic level. However, the way in which these nanostructures relate to the macroscopic properties arising from the interplay of numerous electrons and atoms remains largely mysterious, even in the 21st century. This is particularly true for inhomogeneous condensed systems such as surfaces, interfaces, and amorphous materials, where the nanostructures, characterized by broken symmetry, interact with quasi-particles, leading to unique transport properties. Therefore, understanding the correlation between nanostructures in inhomogeneous systems and their transport properties can pave the way for new methods of controlling material properties. From this perspective, we have developed novel theoretical methods incorporating quantum field theory, first-principles calculations, applied mathematics, and data science. In this lecture, I will present our findings on three targets: surface-adsorbed molecules, interface nanostructures, and amorphous materials.

In the first example, the key point is the interplay of the local symmetry of adsorbed molecules with conduction electron-localized spin interactions. The Kondo effect, a quantum many-body effect that universally arises from the interaction between localized spins and conduction electrons, strongly influences electron conduction. We discovered the SU(4) Kondo effect, which exhibits a unique magnetic field dependency on electrical conductivity, originating from the combination of spin and orbital degrees of freedom in adsorbed complex molecules containing magnetic atoms with fourfold symmetry on metallic surfaces.

The second example involves strong interactions of localized vibration and electron at a nanostructure interface and the correlation with electrical conductivity. As a promising method for creating next-generation electronic materials, the epitaxial growth of high-quality and large-area graphene via the thermal decomposition of SiC has garnered attention. The interface formed by this method exhibits a complex structure due to reconstruction and lattice mismatch. We found that the localized vibrations of Si atoms with dangling bonds at the interface significantly interact with electrons and impact electrical conduction through the interface.

Lastly, the correlation between nanostructures and thermal transport in amorphous materials. The amorphous structure is characterized by a hidden order called medium-range order consisting of dozens to hundreds of atoms. In amorphous materials, heat is diffusively transported by vibrational modes that spread spatially and exhibit collective behavior without periodicity, known as diffusons. We elucidated the correlation between diffuson-mediated thermal conductivity and medium-range order through a novel concept that integrates topology and geometry, known as persistent homology.


Professor Minamitani was awarded the Sir Martin Wood Prize at the Millennium Science Forum which took place in November 2024. The Millennium Science Forum was established in 1998 to promote scientific exchange between Britain and Japan and recognize the work of outstanding young Japanese researchers. The prize is named after Sir Martin Wood, founder of Oxford Instruments.