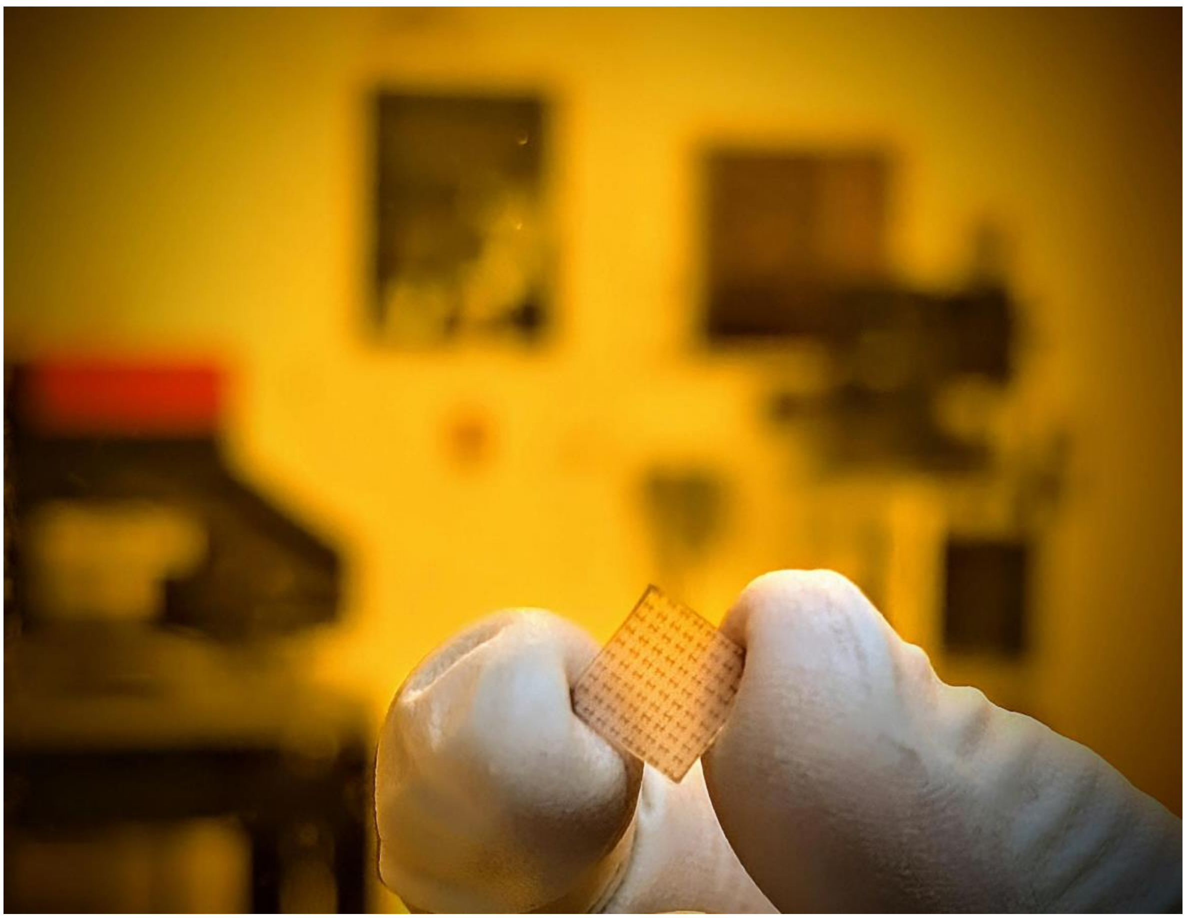
New metal material developed by Professor Il-Kwon Oh’s Team published on the January Issue of Science

- A new metal material to break through the technical limits of the semiconductor industry

- Non-crystalline semimetal nanofilm with properties opposite to metals, experimentally proven for the first time in the world



Professor Il-Kwon Oh's team at Ajou University has developed a new non-crystalline semimetal ultrathin nanomaterial with properties different from known metals. This marks the first experimental demonstration of an unknown material that had previously existed only in theoretical research and is expected to be utilized as a fundamental technology for next-generation semiconductors.

Professor Il-Kwon Oh (Department of Intelligent Semiconductor Engineering and Department of Electronics Engineering) and the international joint research team announced that they have developed a next-generation metal material with reduced resistivity in ultra-thin films used for semiconductor wiring. This topological semimetal exhibits the opposite characteristic of conventional metals, where the resistivity increases as the thickness of the thin film decreases. Specifically, the resistivity of this material rapidly decreases as the thickness of the thin film is reduced.

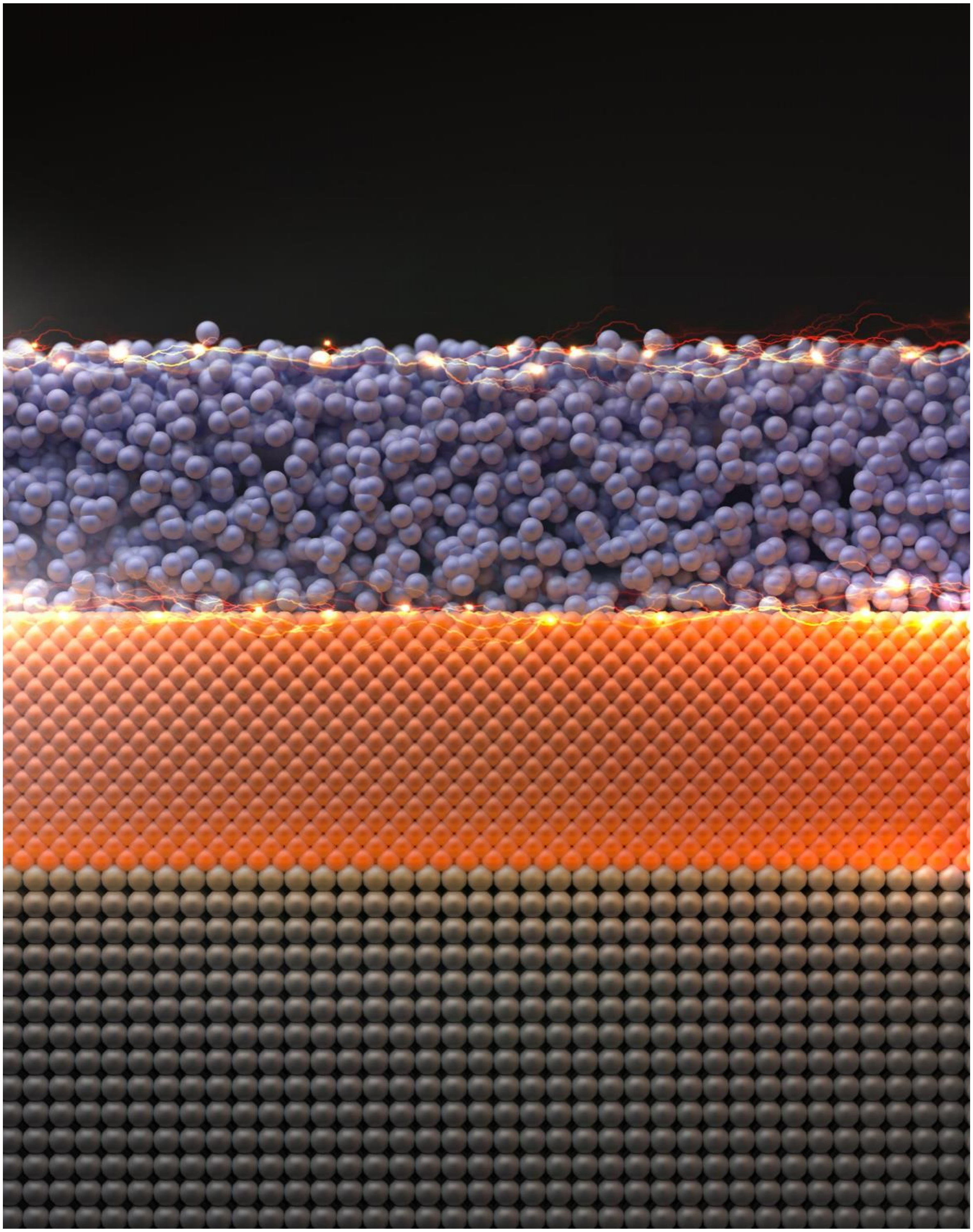
This was published in the January issue of the globally renowned journal, Science, under the title "Surface Conduction and Reduced Electrical Resistivity in Ultrathin Non-Crystalline NbP Semimetal." Professor Eric Pop and Dr. Asir Intisar Khan from the Department of Electrical Engineering at Stanford University in the United States also participated in this study. Our school's master's graduate, Byung-Jun Won (Department of Intelligent Semiconductor Engineering), also participated as a co-author.

The Ajou University research team worked on material synthesis, mechanisms, and material properties, while the Stanford University research team focused on material synthesis and electrical properties.

Metallization, one of the key processes in semiconductor manufacturing, is the process of connecting individual transistor materials within a semiconductor chip. A single semiconductor chip, only a few centimeters in size, uses metal wiring materials extending up to 100 Km, akin to roads connecting scattered villages and houses. Electrons flow through this metal, storing or processing information, and driving a single chip.

Every metal has a resistivity value, which is known to be an intrinsic property of the material. However, different phenomena occur in ultra-thin films on the order of several nanometers. As the size of semiconductor devices decreases, the width of the metal wiring also continuously shrinks, resulting in the current level of developed semiconductor devices having a width smaller than the electron mean free path (EMFP), which is the distance an electron travels before colliding. Consequently, in the miniaturized wiring, the probability of electrons colliding increases, and the resistivity value rises dramatically. Accordingly, finding metal materials with lower resistivity to match the miniaturization of semiconductor devices has become a key issue in both industry and academia.

Cu has been primarily used as a metal wiring material in semiconductors. However, other materials, such as Mo and Ru, recently proposed as alternatives, also show limitations. These materials also exhibit a characteristic where resistivity increases sharply below a certain thickness. Therefore, although they can serve as temporary substitutes for Cu, a new material will eventually be required.



The new ultrathin non-crystalline semimetal nanomaterial developed by the joint research team at Ajou University

The sapphire crystal layer (brown) and the Nb crystal layer (orange) are on top of the NbP non-crystalline layer (purple).

Image source: Science

In addition, introducing a specific material into semiconductor processes requires an investment ranging from tens of millions to tens of billions of dollars. Consequently, materials with superior performance are in high demand.

The topological semimetal material developed by the Ajou University research team, a groundbreaking innovation, exhibits characteristics opposite to existing metals, showing a decrease in resistivity in ultra-thin films. Additionally, it is exceptionally compatible with current semiconductor processes. This is because it grows at a low temperature below 400 °C and, despite being a non-crystalline thin film rather than the crystalline single or polycrystalline forms typical of conventional metals, it still demonstrates the resistivity reversal phenomenon.

In most metals, the crystalline form, rather than the non-crystalline form facilitates electron transport and has lower resistivity. Therefore, polycrystalline metal thin films are used in semiconductor wiring processes. To convert a non-crystalline form into a crystalline form, a subsequent high-temperature heat treatment process is required after depositing the metal thin film. However, the material newly developed by the Ajou University research team is a non-crystalline material that does not require a separate high-temperature process. In particular, the new semimetal material is non-crystalline, allowing for easy, low-cost implementation and processing at low temperatures. This implies it has overcome the two biggest hurdles for practical use as a semiconductor wiring material.

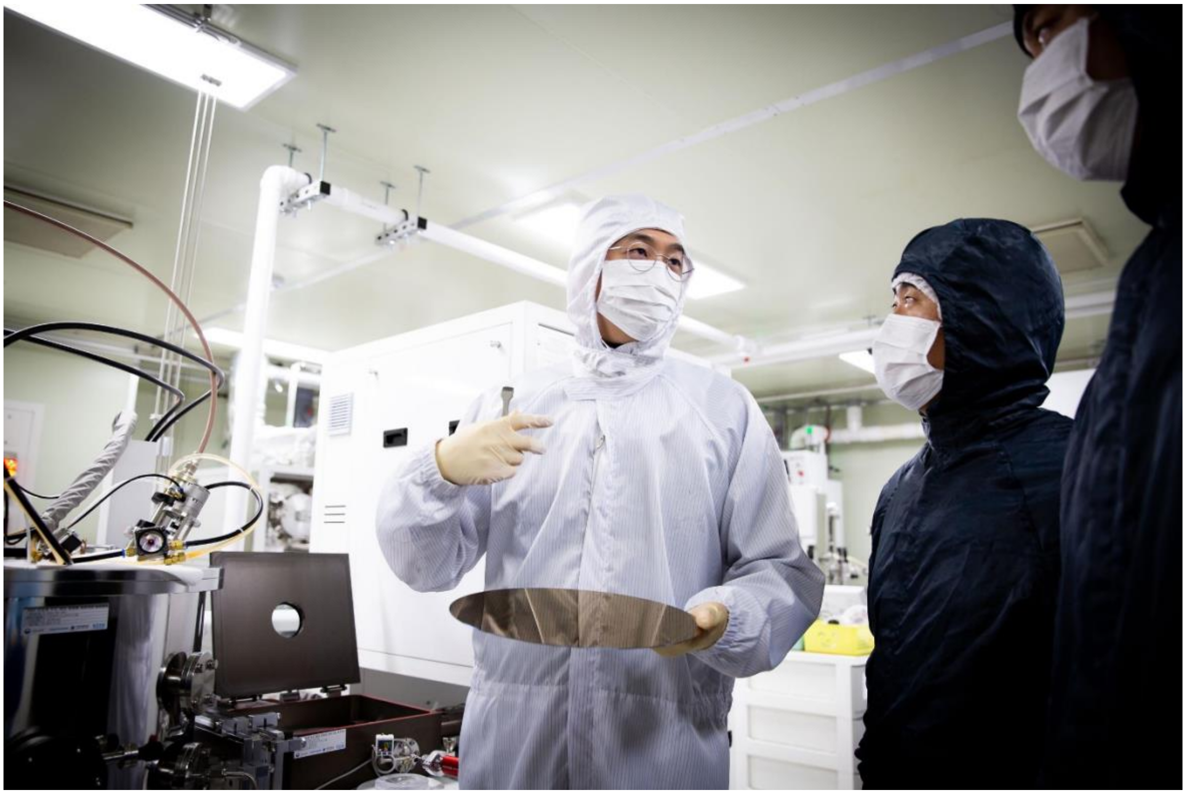
The Ajou University research team is developing a topological semimetal process based on atomic layer deposition as a follow-up study. Compared to physical vapor deposition, atomic layer deposition can control the thickness of thin films at the atomic level, making it more suitable for miniaturization. Therefore, it is being evaluated as a technology closer to commercialization.

Professor Il-Kwon Oh from Ajou University stated, "As a scientist, I have consistently pursued research in new fields without losing the curiosity of 'why?' Through research that has never been attempted before, I have experimentally proven a new substance for the first time, which is a significant achievement."

"The new concept metal material developed through this research could be a breakthrough for future semiconductor technology facing limitations." Professor Oh continued. "It can not only be utilized as a fundamental technology to seize the initiative in the future semiconductor industry but also has limitless application potential."

This study was conducted with the support of the Korea Research Foundation's Excellent Young Researchers Program and Ajou University's New Faculty Settlement Research Fund.

Professor Il-Kwon Oh explaining his research



Professor Il-Kwon Oh explaining the semimetal wafer manufacturing process in the Ajou University's clean room (left on the photo)