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Superconductivity in exfoliated transition-metal dinitrides ReN_2

Rhenium nitride (ReN_2) is a newly synthesized transition-metal dinitrides crystal from a metathesis reaction between $ReCl_5$ and LiN_3 under high pressure. The structure of ReN_2 crystal is isostructural with MoS_2 ($P6_3/mmc$), confirmed by XRD profiles [Fig. 1(a)]. Under optical microscope, the crystal shows a metallic luster like graphite with reflected light [Fig. 1(b)]. However, with transmitted light, it shows a unique red translucent color [Fig. 1(c)]. Although the structure and mechanical strength of ReN_2 have been analyzed, its electrical properties remain completely unknown.

In this work, we reveal the carrier transport properties of ReN_2. First, we exfoliated ReN_2 crystal using Scotch tape onto SiO_2/Si wafer with 290 nm oxide layer. The thickness of flakes obtained by AFM was about 60-80 nm. We put electrode with Au 40 nm/Cr 40 nm by metal deposition. The four-terminal resistance of the sample was 4.2 Ω at room temperature, and it decreased as the temperature decreased. The observed metallic temperature dependence of longitudinal resistance and the linear current-voltage characteristic suggest that ReN_2 is a meta, which is in agreement with the band structure calculation using the density-functional theory (DFT) framework [Fig. 3].

Furthermore, the temperature dependence of R_{xx} at low temperature showed another feature of ReN_2: superconductivity [Fig. 4(b)]. R_{xx} dropped rapidly at around $T = 10$ K. With further decreasing temperature using dilution refrigerator, R_{xx} dropped down to 0.18 Ω at 60 mK, which is almost zero. *I-V* curve was non-linear at $T = 100$ mK, and it restored linear shape as the magnetic field was applied perpendicular to the plane [Fig. 4(c)]. ReN_2 can be utilized as a novel layered superconductor, extending the possibility of van der Waals heterostructures.

References

[1] F. Kawamura, H. Yusa, and T. Taniguchi, *Appl. Phys. Lett.* **100**, 251910 (2012).

Figures

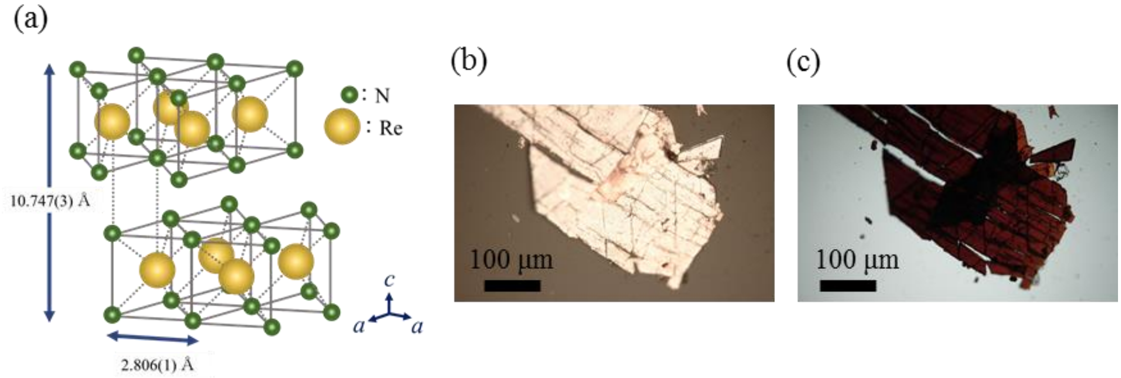

Figure 1: (a) Schematic image of ReN_2 crystal structure, which is isostructural with MoS_2 (*P63/mmc*). (b)(c) Optical micrograph of ReN_2 crystal with reflected light (b) and transmitted light (c).

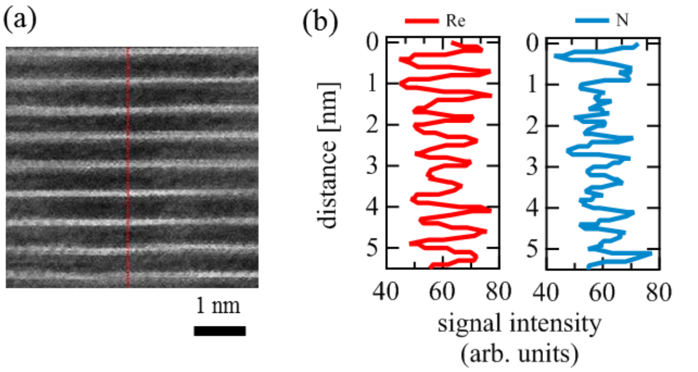

Figure 2: (a) Cross-sectional scanning transmission electron microscopy (STEM) image of a ReN_2 flake. (b) The depth profile of the EDX signal along the red line in (a) for Re and N.

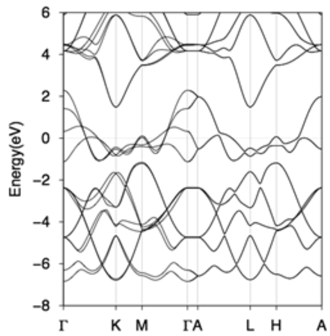

Figure 3: Band structure of ReN_2 calculated in the DFT framework with spin-orbit coupling.

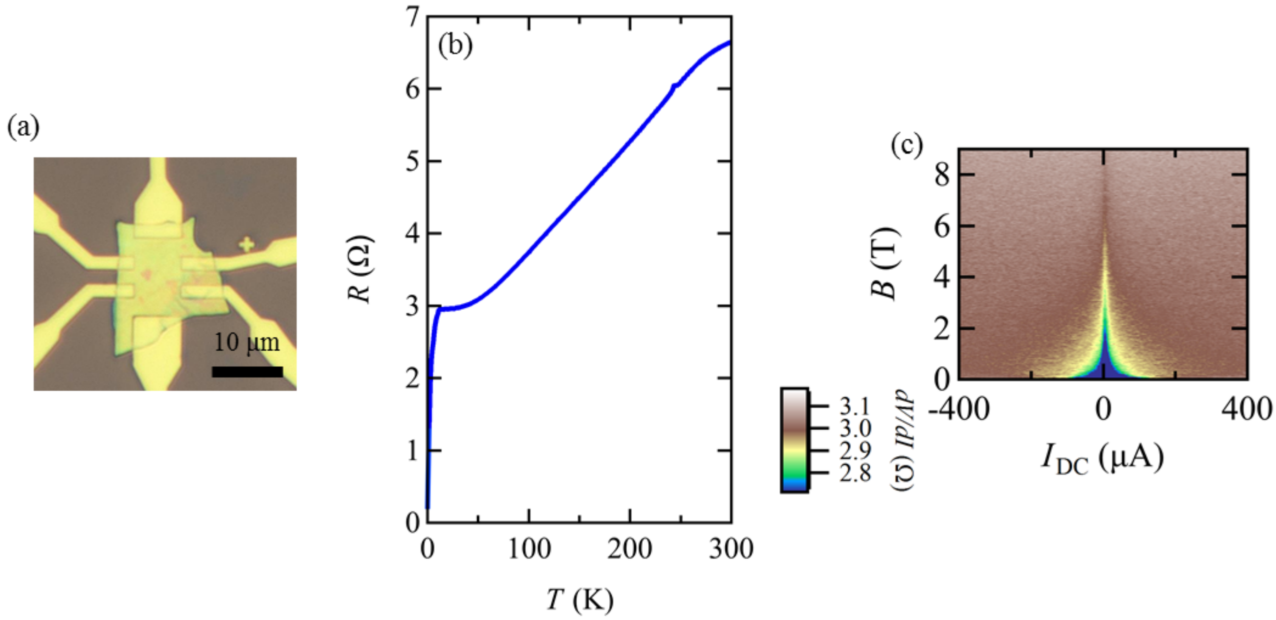

Figure 4: (a) Optical micrograph of ReN_2 sample on SiO_2/Si substrate. (b) Temperature dependence of longitudinal resistance. (c) Color map of *dV/dI* as a function of I_{DC} and perpendicular magnetic field B at T = 100 mK.