Possible Superconductivity in Weyl Semimetal NbP

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Abstract. In the present paper, we have observed the possible superconductivity in polycrystalline NbP compound. This belongs to the so-called Weyl Semimetal family where there is band crossing and linear dispersion point near the Fermi level. Critical temperature calculated from the resistivity measurement is found near 7.5 K. Superconductivity is also confirmed from the magnetization measurement. In the normal state, this sample shows significant magnetoresistance.

Keywords: Weyl semimetal, Transport properties, Magneto-resistance

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INTRODUCTION

Topological semimetals such as WTe$_2$, Cd$_3$As$_2$ and NbP [1, 2, 3] are under intense investigation because these materials are three-dimensional analogue of Graphene [4]. In the momentum space, all these examples show linear dispersion near Fermi energy. In case of NbP, the valence band and conduction band cross below the Fermi energy at the so-called “Weyl point”. As a consequence, extremely large magnetoresistance of 250% at room temperature has been reported [3]. In this paper we report evidence of possible superconducting transition in phase pure NbP with a transition temperature ($T_c$) of 7.5 K.

EXPERIMENTAL DETAILS

Polycrystalline NbP samples were synthesized using two-step solid state reaction technique. Niobium powder (99.8%) and Phosphorous powder (>97%) were weighed in stoichiometric composition, ground and compacted into pellets. The pellets were then vacuum sealed in quartz tube and sintered at 800 °C for 24 hr. After regrinding the obtained sample was compacted again, vacuum sealed and sintered at 800 °C for 12 hr. The X-ray diffraction (XRD) measurements have been performed with RIGAKU powder X-ray Diffractometer (Miniflex 600) using Cu-$K_{α}$ radiation. The magneto-resistivity measurements are done using a Cryogenic 8 Tesla Cryogen-free magnet in conjunction with VTI in the temperature range 2 – 300 K. Magnetization (zero-field cooled (ZFC) and field cooled (FC)) measurement are done in the temperature range 2 – 300 K in 20 Oe applied field using Cryogenic Physical Properties Measurement System (PPMS).

RESULTS AND DISCUSSION

Figure 1 shows the XRD pattern for NbP in 2θ range of 20° and 100°. All the peaks matched well with the body-centered tetragonal structure of NbP with the space group I4/mmd. The lattice parameters as calculated from Rietveld refinement of the XRD pattern using Fullprof are $a = 3.3243$ Å and $c = 11.3563$ Å. No trace of metallic Nb as an impurity is seen. Subsequent EDAX measurements indicated that Nb to P ratio was 0.934.

![FIGURE 1. XRD pattern of polycrystalline NbP.](image)

Figure 2 (a) shows the resistivity measurement performed in zero field in the temperature range 2 – 300 K. The low temperature normal state resistivity shows metallic behavior before the onset of superconductivity at around 7.5 K (inset Figure 2 (a)). Note that zero resistive state is not reached in this polycrystalline sample. This behavior in polycrystalline NbP sample is different from that of single-crystalline sample reported recently which shows metallic nature down to 1.85 K [3].

In order to confirm the observed trace of superconductivity in the sample, we have performed
zero field cooled (ZFC) and Field cooled (FC) magnetization measurements at 20 Oe external field. The data are plotted in Figure 2 (b). The magnetic measurements clearly reconfirm onset of superconductivity at 7.5 K.

The single crystalline NbP is reported to possess extremely large magnetoresistance (MR). The present polycrystalline NbP also shows MR in the normal state and the critical temperature (Tc) decreases with applied field. Tc decreases to ~ 4.5 K on application of 1 Tesla external field. Figure 3 (a) shows the magnetoresistivity in polycrystalline NbP sample in the applied fields 0 T, 0.5 T, 1 T, 2 T and 3 T. The MR measured in the field ranging from 0 to 5 T at 3 K, 10 K and 280 K is shown in Figure 3 (b). It clearly shows significant increase in MR with increasing field. At 3 K, the sample shows around 12 % MR at 5 T. However, in the present case, MR observed is much less than the reported values for the case of single crystalline sample.

CONCLUSIONS

In conclusion, we find superconductivity in polycrystalline NbP at Tc ~ 7.5 K. This compound is a Weyl semimetal and large magneto-resistance is also observed even at room temperature. The microscopic origin of such phenomena needs to be ascertained.

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