The magic angle effect of the Bechgaard salts (TMTSF)$_2$X (X=PF$_6$, ClO$_4$, AsF$_6$, ReO$_4$ ...) has been extensively investigated both experimentally and theoretically. Recently the resonant-like enhanced Nernst effect of (TMTSF)$_2$PF$_6$ around the magic angles has been reported [1]. Here the metallic state is stabilized at high pressure, and for field directions coincident with specific crystallographic planes, an enhanced Nernst effect is observed which may be related to phase coherence in a vortex state [2]. In this work we have extended this investigation to (TMTSF)$_2$ClO$_4$ which is metallic at ambient pressure; here we note that the metallic state is followed by a field induced spin density wave (FISDW) transition above ~ 4 T, hence the magic angle effects are only apparent over a narrow range of field, or in a tilted field $H$, when $H_{\perp} = H \cos(\theta) < ~ 4$ T. For higher interplane fields, the FISDW is stabilized.

Fig 1 (a) shows the angle dependence of the Nernst signal ($N$) at different fields at 0.4 K. The down arrows indicate the threshold angle ($\theta_{th}$) for the FISDW transition. The Nernst signal changes its behavior at the threshold angle as the sample undergoes a phase transition between the metallic and FISDW states. Rich features of the Nernst effect are observed in both the FISDW ($\theta < \theta_{th}$) and the metallic ($\theta > \theta_{th}$) state. In the FISDW state, they are related to the series of transitions between FISDW sub-phases as $H_{\perp}$ (the field component perpendicular to the conducting planes) is swept by rotating the sample at a fixed field. The positions showing peaks and dips change according to the cosine law. In contrast, the positions of dips at -52 deg ($\theta_{m-}$) and peaks at -43 deg ($\theta_{m+}$), where the sample is in the metallic state, are independent of the field. Furthermore, the mid-angle between two extremes, which is -48 deg ($\theta_{m}$), is the magic angle where the field is along the $b+\text{c}$ direction. The magnitude of the peak or dip strongly depends on temperature and field; it decreases rapidly at higher temperatures above 1K and lower fields below 4.5 T. In the FISDW state, the Nernst signal is enhanced at $\theta_{m+}$ and $\theta_{m-}$ and the sign flips within small angle changes as shown in Fig. 1 (b). In conclusion, we have observed enhanced Nernst signal around the magic angles in (TMTSF)$_2$ClO$_4$ in the metallic state, and this effect seems to be more enhanced in the FISDW state.

Fig. 1. (a) The angle dependence of the Nernst signal ($N$) at different fields at 0.4 K. The up arrows are angles where the Nernst signal shows positive peaks ($\theta_{m+}$) or negative dips ($\theta_{m-}$) and a magic angle ($\theta_{m}$) respectively. The inset shows the contact configuration for the TEP and Nernst effect measurement. (b) The $H_{\perp}$ dependence of Nernst signal at 0.4 K at different angles.

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References