Polaronic effects in thin films of metal-insulator nickelates

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Rare-earth nickelates is a rare family of oxides showing metallic conductivity. A first member of the family $LaNiO_3$ having practically ideal perovskite structure is metallic in the whole temperature range. Substituting the rare-earth element by smaller ions (Pr, Nd or Sm) distorts the lattice orthorhombically initiating a sharp metal-to-insulator transition (MIT) at cooling. Rich physics and promising application potential of the MIT maintain intensive research of the nickelates. Due to extreme synthesis conditions, there is still no a sizable single crystal of $NdNiO_3$ and $SmNiO_3$ having the MIT at 200 and 400 K, respectively. Therefore, thin epitaxial films present the best current approach to study its intriguing physical properties including strong electron-lattice coupling [1].

We have firstly analysed dc electrical resistivity of epitaxial thin films of the rare-earth nickelates in a wide temperature interval up to 800 K. A noticeable deviation of the metallic resistivity of $NdNiO_3$ films from the classical linear relation $\rho \propto T$ is observed. This deviation is ascribed to an additional conductivity channel with a thermally activated hopping mobility: small polaron is suggested as a plausible charge carrier. The high-temperature conductivity of our $SmNiO_3$ films is of hopping nature: $\sigma T \propto \exp(-E_a/k_B T)$ with similar activation energy $E_a \approx 80$ meV [2]. Emerging hopping conductivity is related to a Jahn–Teller distortion of the perovskite structure with decreasing radius of the rare-earth ion.

The hopping conductivity prevails in the low-temperature insulator phase of the nickelates. This emphasizes an importance of the electron-phonon coupling and suggests a formation of small polaron quasi-particles in the nickelates films. Their hopping activity observed in the high-temperature metallic phase should remain from a co-operative breathing distortion of the nickelate lattice, which drives the MIT. This finding should also shed light on other electro-magnetic anomalies in the nickelates: for instance, opposite signs of the Hall and the Seebeck coefficients. In particular, we also demonstrate that anomalous behaviour of the Hall resistance is defined by the hopping conductivity component, whereas the Seebeck thermal force mostly reflects the metallic conductivity.

References:

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This work was funded by the Czech Science Foundation (GA ČR) through a grant number 20-21864S.