The quest for high temperature superconducting nickelates

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The discovery of superconductivity in the Ba-La-Cu-O system (the cuprate) at around 30 K marked a major breakthrough, spurring extensive exploration of oxide-based layered superconductors to achieve even higher critical temperatures (T_c) and to understand their electron pairing mechanisms. Until recently, evidence of Cooper pairing above 30 K in systems isostructural to the cuprates but without copper, under ambient pressure, and without lattice compression, had remained elusive despite observations of superconductivity in nickel oxide-based compounds (the nickelates). In this talk, I will present our efforts in designing and understanding higher-temperature superconducting nickelates. We demonstrate a new superconducting infinite-layer nickelate, with a T_c approaching 40 K under ambient pressure, realized in d^9 hole-doped, late rare-earth nickel oxide $SmEuCaNiO_2$ (SECNO) thin films with negligible lattice compression. This is supported by observations of a zero-resistance state above 31 K and the Meissner effect. The material can be synthesized with essentially no Ruddlesden–Popper-type structural defects, and it exhibits ultralow resistivity of approximately 0.01 mΩ·cm and a residual resistivity ratio of up to 10. Using resonant inelastic x-ray scattering, we observe dispersive paramagnonic excitations in both optimally and overdoped (Sm-Eu-Ca)NiO_2 samples, supporting a spin-fluctuation-mediated pairing scenario. Notably, despite a two-fold enhancement of T_c in (Sm-Eu-Ca)NiO_2 nickelates compared to their Pr- or Nd-based counterparts, the effective exchange coupling strength is reduced by approximately 20%. This behavior contrasts with hole-doped cuprates, where magnetic interactions are positively correlated with T_c, highlighting key differences in their superconducting mechanisms. Our findings demonstrate the potential for achieving high-temperature superconductivity in strongly correlated *d*-electron metal oxides beyond copper, offering a promising platform for further investigation into the nature of high-temperature Cooper pairing.