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Material witness: A blast from the past

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Sometimes you never know when a material will come into its own. Fifty years ago there was a small flurry of work on a rather obscure class of metal oxides, manganites with a perovskite structure. These materials had interesting magnetic properties: they exhibited a phenomenon dubbed double exchange, wherein electron spins on adjacent mixed-valence metal ions are coupled by delocalization of an electron between them.

This process, explained by Clarence Zener (of Zener diode fame) in 1951, posed a nice theoretical challenge, and it drew the attention of two future Nobel laureates (Philip Anderson and Pierre-Gilles de Gennes) as well as John Goodenough, now arguably the world's leading expert on the behaviour of metal oxides. But despite the calibre of the researchers, no one would have guessed that papers with titles like 'Interaction between *d*-shells in transition metals. II. Ferromagnetic compounds of manganese with perovskite structure.' were destined for great things.

Yet this, Zener's original paper on double exchange in manganites (*Physical Review* **82**, 403–405; 1951), has just been ranked as the paper with the sixth highest impact among all the publications in the *Physical Review* (*PR*) journals since 1893. A publication on the subject by Anderson ranks at number 19, de Gennes' at 21, and Goodenough's at 37.

Even more remarkably, all four papers, along with one by E. O. Wollan and W. C. Koehler on neutron diffraction from manganites (published in 1955, ranked 37), made very little impact at the time of publication. They were cited just a few times a year, if at all, until the mid-1990s, when the citation statistics for all of them soared. In 2000, Zener's paper was cited over 100 times within the *PR* journals alone.

They were classic 'sleepers'. These papers suddenly became hot when it was discovered in 1993 that thin films of manganite materials exhibit so-called colossal magnetoresistance: their electrical resistance changes dramatically in the presence of a magnetic field. This is the crucial characteristic of readout heads for magnetic data storage, and the manganites were suddenly of vast technological interest.

This history of the early work on manganites emerges from a fascinating analysis by Sidney Redner of Boston University of the citation statistics of all the papers published in the *PR* journals since they began 111 years ago (xxx.arvix.org/abs/physics/0407137). The extraordinary burst of citations of the manganite studies, 40 years after their first appearance, is 'unique in the entire history of *PR* journals', Redner says.

Nonetheless, the significance of that work fits within the general consensus from Redner's list of highest-impact papers in *PR* journals, which is to say that twentieth-century physics was largely about condensed matter, and more specifically about the quantum-mechanical theory of electronic and magnetic properties in the solid state. The top two papers, both co-authored by future Nobel laureate Walter Kohn, established the density-functional theory by which means electronic band structures are typically calculated. The story Redner's study tells is one of physics' persistent engagement with materials and technology.