

Class 4: Perovskite manganese oxides and magnetoresistance

Structure of perovskites, typical charges, notion of the tolerance factor:
Please see the handout, or read a book (Megaw, Galasso etc.)

The notion of aliovalent substitution:

In $\text{La}_{1-x}\text{Sr}_x\text{BO}_3$, the B atom (a transition metal) has the formal charge $3+x$. This makes a huge difference to property.

Most 1st transition metal series LaBO_3 perovskites are insulating antiferromagnets. LaNiO_3 and LaCuO_3 are paramagnetic metals.

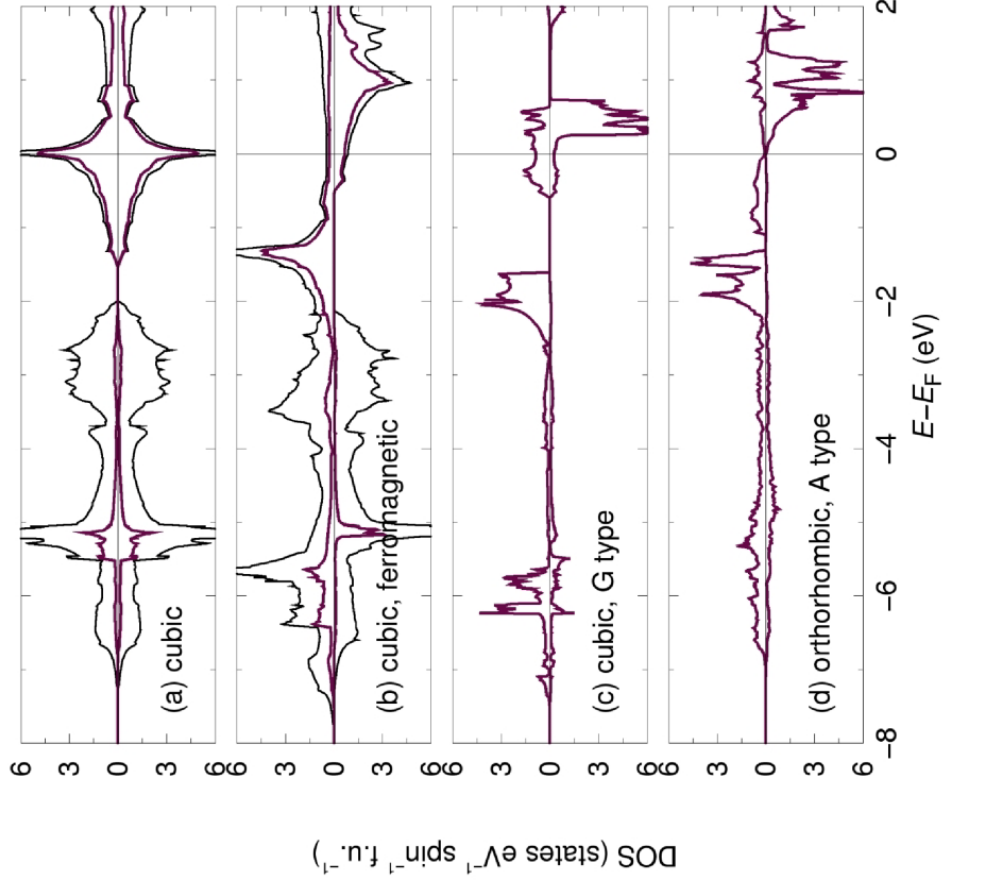
The nature of the insulating ground states has mostly to do with electron correlation. The precise nature of the gap in the insulators changes as a function of the B atom. See Arima et al. Phys. Rev. B. 48 (1993) 17006; Zaanen et al. Phys. Rev. Lett. 55 (1985) 418.

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In 1950, Jonker and van Santen studied the electrical and magnetic properties of the series of $\text{La}_{1-x}\text{A}_x\text{MnO}_3$ compounds, with A a divalent (alkaline earth) cation. They found that the mixed systems display a transition from insulating behavior to metallic behavior (seen as a change in the sign of slope of the resistivity as a function of temperature) as the same temperature that the systems became ferromagnetic. [Physica 16 (1950) 337 and 16 (1950) 599, obtainable through the ScienceDirect website]. The behavior was explained by C. Zener in 1951 [Phys. Rev. 82 (1951) 403] using the idea of **double exchange**.

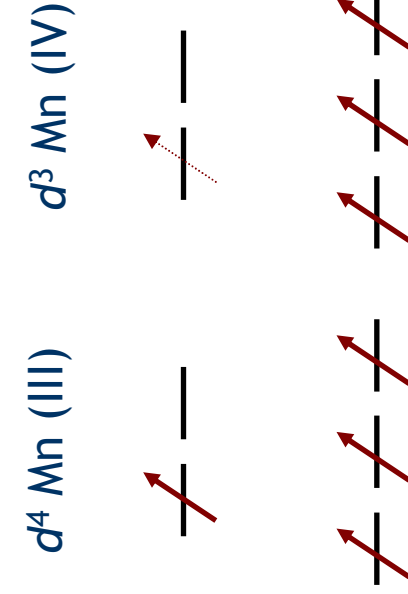
We first attempt to understand the electronic structure of LaMnO_3 :

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Zener double-exchange. When an electron hops from Mn(III) to Mn(IV), it tends to align spins on both atoms:



Such hopping requires there to be adequate *bandwidth*.

One of the consequences of Zener DEX is that the application of a high magnetic field tends to align spins on neighboring Mn and thereby results in a strong decrease in the electrical resistivity → Colossal Magnetoresistance or CMR, as opposed to Giant Magnetoresistance observed in metallic/ferromagnetic multilayers: Baibich et al. Phys. Rev. Lett. 61 (1988) 2472. The paper that made CMR well known is Jin et al. Science 264 (1994) 414.

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Soon after CMR was discovered, the unusual physics of these materials started becoming evident. For example, the tolerance factor strongly controls properties [Phys. Rev. Lett. 75 A(1995) 914], and does disorder [Phys. Rev. B. 58 (1998) 2426], and phase coexistence [Nature 399 (1999) 560]. Issues of CMR are reviewed by Millis, Nature 392 (1998) 147. Mazumdar and Littlewood have looked at the general phenomena across a number of different materials: Nature 395 (1998) 479.