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Preface to Understanding and utilizing colossal magnetoresistance materials. A Discussion Meeting held at the Royal Society of London

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Preface

The main objective in setting up the meeting was to bring about possibly the first small meeting devoted entirely to the emergent area of colossal magnetoresistance (CMR) materials. Professor Brian Coles, who supported the meeting in the first instance, passed away in February 1997 and his presence was sadly missed. All invited speakers were enthusiastic and publicity for the meeting attracted a genuinely international audience of more than 140 participants from 12 countries.

Theory and physical properties

In her introduction as chairperson Professor Gehring stressed the need to go beyond the simplest double-exchange model of CMR materials in which the main effect of passing through the ferromagnetic Curie temperature T_C from below is a modest narrowing of the conduction band due to spin disorder. This alone cannot explain the rapid transition in electrical resistivity, from metallic to insulating character, which underlies the CMR phenomenon near T_C. This theme was taken up by succeeding speakers, who emphasized the importance of strong electron–lattice coupling, evidenced by Jahn–Teller distortion in the undoped parent compounds, and the possible role of orbital ordering in the conduction band. Professor Millis attributed the metal–insulator transition to a cross-over from itinerant electron behaviour to localized polaronic behaviour arising from a combination of the double exchange band-narrowing effect and strong electron–lattice coupling. His talk was one of the highlights of the meeting and he made many other valuable contributions to the discussion. Professor Inoue and Dr Long discussed effects arising from the symmetry, for example, of the two atomic d orbitals from which the conduction band is formed. Professor Inoue concentrated on the undoped insulating phase and emphasized the interplay between spin and orbital ordering. He finds that the A-type antiferromagnetism observed in $LaMnO_3$ is stabilized by the type of orbital ordering favoured by the Jahn–Teller effect. Dr Long pointed out the complexity of the doped ferromagnetic metal phase where mean field theory predicts orbital ordering; this would be accompanied by lattice distortion which is not observed in this phase. It appears that quantum fluctuations play an important role.

Professor P. Littlewood, as chair of the physical properties session, emphasized the universal relationship between the resistivity and magnetization as a function of applied magnetic field. Many magnetic materials fit into this description, but the manganites are anomalous and this is probably due to their strong electron–phonon coupling.

Professor Coey emphasized the important property of so-called half-metallic ferromagnetism, with electrons of only one spin at the Fermi surface, which the manganites have in common with other compounds such as CrO_2 and Fe_3O_4. He pointed out the advantages of low field extrinsic magnetoresistance, associated with grain boundaries, for example, over intrinsic CMR which demands rather high fields. He described new work along these lines on powders of half-metallic ferromagnetic materials. Dr McK. Paul illustrated the structure–electronic relationship by discussing the

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influence of pressure in tuning ferromagnetic and structural phase transition temperatures as determined by neutron scattering. Dr Perring discussed the implications of the spin-wave dispersion relationships.

Materials and chemistry

As chair of this session Dr P. Battle emphasized the importance of sample characterization and the influence of the random disorder on the A-site when the materials are doped. Dr Jose Alonso brought to our attention the importance of vacancies on the Ln and Mn site of the perovskite structure and the different influences these have on physical properties. Vacancies on the Mn site are more detrimental to carrier mobility. Preparation conditions influence the vacancy site occupancy. Dr Antoine Maignan discussed charge ordering in $Ln_{1-x}A_xMnO_3$. He emphasized the importance not only of average size of the interpolated actions (A,Ln), the mixed valency state of the manganese, but also the size mismatch between the A and Ln ions (ionic radius variance). The charge ordering can be suppressed by a magnetic field or substitution of Cr and Co on to the Mn site.

Devices

The device applications of CMR materials have considerable long-term potential, but there is a wide acceptance that considerable research into the fundamental properties of the materials will have to take place before serious development of applications can occur; this was concisely summarized by the session chairman Robert Hardiman (Seagate). The speakers in the devices section of the meeting all presented approaches which are clearly worth further study.

Dr Fontcuberta discussed how to enhance the MR effect in polycrystalline samples by varying the particle size. However, small particles are harder to magnetize because the surface anisotropy becomes important. He suggested a way to overcome this was to choose material with narrower bandwidth. The bandwidth can be tuned by varying the tolerance factor through doping. Similarly, magnetic frustration and coercivity can be tuned by the bandwidth. Dr Fontcuberta also discussed how materials with larger bandwidths are less sensitive to pressure effects.

Dr Jonathan Sun (IBM) presented an excellent review of spin-polarized tunnelling in general and its possible role in heterostructure CMR devices being developed at his laboratory. Michael Gibbs (Sheffield) outlined a proposed method of controlling the properties of CMR materials through exchange coupling to conventional magnetic materials; while the results to date were disappointing, there are promising research directions based on the concept which may be explored. Dr Jan Evetts discussed the potential for modelling the grain boundary effects by studying artificial grain boundaries grown on bicrystal substrates. He suggested that the model proposed could be extended to the pyroclores, spinal or other systems.

Finally, Professor T. Venkatesan demonstrated the applicability of CMR materials outside the area of simple magnetic sensors and showed, in particular, that the very high temperature coefficient of resistivity could be applied in room temperature thermal imaging devices.

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