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ROUTE TO CONTROLLING THERMAL MANAGEMENT IN MAGNETOCALORIC MANGANITES

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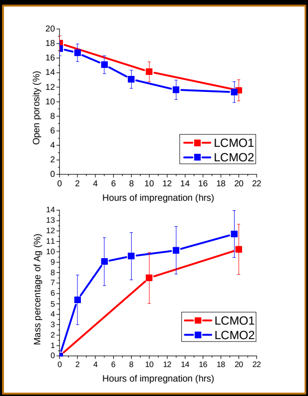
ABSTRACT

The magnetocaloric effect (MCE) is the change in temperature of a material caused by an applied magnetic field, and is largest when a phase transition is induced. It has been highlighted as a potential ingredient for efficient solid state cooling and there have been significant advances over the last 10 years that together bring such a technology closer to realisation. A suitable magnetic refrigerant exhibits large changes in temperature in response to a magnetic field, a property that is often associated with first order phase transitions. The disadvantage of a first order phase transition, however, is that it is generally accompanied by hysteresis; a feature that reduces the efficiency of the refrigeration cycle. It was shown recently that the hysteresis observed during some "isothermal" magnetisation measurements is due to an extrinsic contribution when the material is driven out of equilibrium by the temperature change arising from the magnetocaloric effect [1], and due to poor thermal conductivity of the ceramic. Here we discuss routes to control thermal management by silver impregnation of $La_{0.67}Ca_{0.33}MnO_3$ (LCMO) porous pellets, a material that undergoes a transition ferromagnetic to paramagnetic at about 265 K.

SILVER IMPREGNATION TECHNIQUE

LCMO porous pellet with average grain size of 2 µm → Immersion in a melt of $AgNO_3$ for a certain amount of time → Annealing at 500° C for 10 hours to decompose the nitrate into metallic silver

SILVER MASS PERCENTAGE AND OPEN POROSITY



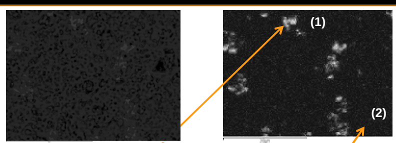
Methods

The open porosities of the resulting pellets were measured by the Archimedes method. The mass percentages of silver were calculated from mass and volume measurements.

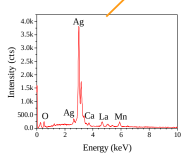
Results

The open porosity decreases with silver impregnation. The mass percentage of silver inside the pellets increases with impregnation.

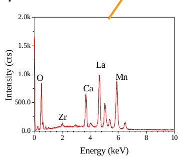
SPECTROSCOPY ANALYSIS OF IMPREGNATED LCMO



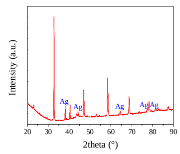
a . Back scattered image (left) and Ag La1 map (right) of the interior of the Ag impregnated sample



b.EDX spectra taken from the area (1).



c.EDX spectra taken from the area (2).



d.XRD pattern of the LCMO pellet after Ag impregnation.

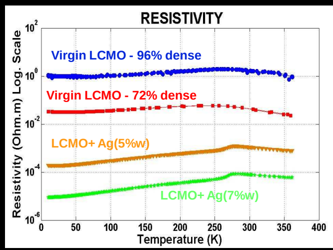
The backscattered electron microscopy image ((a), left) of the LCMO specimen after Ag impregnation. We see distinct light grey, dark grey and black regions (the latter corresponding to pores) thus confirming its heterogeneous nature.

Ag La1 map ((a), right) shows Ag rich regions which correspond to the lighter regions observed on the backscattered image. The EDX spectra from lighter (b) and darker (c) regions confirm that they correspond to LCMO and Ag phases, respectively. Finally, the XRD analysis (d) confirms the presence of Ag metal.

THERMAL TRANSPORT

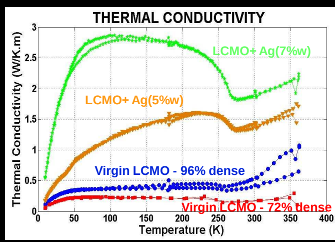
Method

Thermal transport measurements were made using a PPMS (thermal transport option) in a 2-probe configuration.



Results

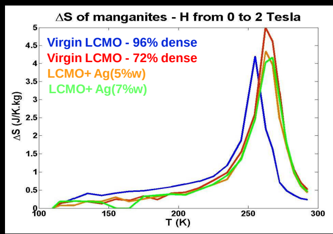
➢**Huge drop in resistivity with silver impregnation.**
Silver is thought to have gone to grain boundaries and improved electrical connectivity.
➢**Thermal conductivity improved by a factor of 5 to 10 with silver impregnation.**



MAGNETOCALORIC AND HYSTERESIS

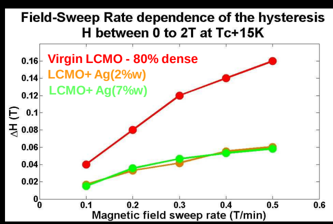
Method

Entropy changes were calculated using Maxwell equations.
Hysteresis were determined as the *H*-field difference between the increasing field side and decreasing field side in *M-H* loops.



Results

➢**No significant change for the MCEs of impregnated samples.**
➢**Hysteresis is decreased by a factor of 2 to 4 by silver impregnation.**



CONCLUSION

By using a silver impregnation method on LMCO materials, we have greatly increased their poor thermal conductivity, and by this way reduced the extrinsic hysteresis without significantly affecting the amplitude of the MCE. This methods looks promising and its optimization in term of optimal porosity and grain size of the starting material is currently under investigation. However, it is believed that silver impregnation could be used in other porous materials that suffer from a low thermal conductivity.

ACKNOWLEDGEMENTS

This work was supported by the UK EPSRC grant no **EP/G060940/1**.

REFERENCES

J.D. Moore et al., *Appl. Phys. Lett.* **95** 252504 (2009)