





Room-temperature multiferroic behavior in layer-structured Aurivillius phase ceramics

Cite as: Appl. Phys. Lett. **117**, 052903 (2020); <https://doi.org/10.1063/5.0017781>

Submitted: 09 June 2020 . Accepted: 25 July 2020 . Published Online: 07 August 2020

Zheng Li, Vladimir Koval , Amit Mahajan, Zhipeng Gao, Carlo Vecchini, Mark Stewart, Markys G. Cain , Kun Tao, Chenglong Jia , Giuseppe Viola, and Haixue Yan 



View Online



Export Citation



CrossMark

ARTICLES YOU MAY BE INTERESTED IN

[Intrinsic piezoelectricity in \(K,Na\)NbO₃-based lead-free single crystal: Piezoelectric anisotropy and its evolution with temperature](#)

Applied Physics Letters **117**, 052904 (2020); <https://doi.org/10.1063/5.0012124>

[Current-induced bulk magnetization of a chiral crystal CrNb₃S₆](#)

Applied Physics Letters **117**, 052408 (2020); <https://doi.org/10.1063/5.0017882>

[Magnetic transition behavior and large topological Hall effect in hexagonal Mn_{2-x}Fe_{1+x}Sn \(x = 0.1\) magnet](#)

Applied Physics Letters **117**, 052407 (2020); <https://doi.org/10.1063/5.0011570>



Measure Ready
FastHall™ Station

The highest performance tabletop system
for van der Waals and Hall effect samples

[Learn more](#)

Room-temperature multiferroic behavior in layer-structured Aurivillius phase ceramics

Cite as: Appl. Phys. Lett. **117**, 052903 (2020); doi: 10.1063/5.0017781
 Submitted: 9 June 2020 · Accepted: 25 July 2020 ·
 Published Online: 7 August 2020 · Corrected: 11 August 2020



Zheng Li,¹ Vladimir Koval,² Amit Mahajan,³ Zhipeng Gao,⁴ Carlo Vecchini,⁵ Mark Stewart,⁵ Markys G. Cain,⁶ Kun Tao,⁷ Chenglong Jia,^{7,a)} Giuseppe Viola,³ and Haixue Yan^{3,b)}

AFFILIATIONS

- ¹Gemological Institute, China University of Geosciences, Wuhan 430074, China
- ²Institute of Materials Research, Slovak Academy of Sciences, Watsonova 47, Kosice O4001, Slovakia
- ³School of Engineering and Materials Science, Queen Mary, University of London, London E1 4NS, United Kingdom
- ⁴National Key Laboratory of Shock Wave and Detonation Physics Institute of Fluid Physics, China Academy of Engineering Physics, Mianyang 621900, China
- ⁵National Physical Laboratory, Hampton Road, Teddington TW11 0LW, United Kingdom
- ⁶Electrosiences Ltd, Farnham, Surrey GU9 9QT, United Kingdom
- ⁷School of Physical Science and Technology, Lanzhou University, Lanzhou 730000, China

^{a)}Email: cjlja@lzu.edu.cn
^{b)}Author to whom correspondence should be addressed: h.x.yan@qmul.ac.uk

ABSTRACT

Multiferroic Aurivillius phase ceramics, such as Bi₂Fe_{2.5}La_{0.75}F₃C₃O₁₈, exhibit room-temperature multiferroic behavior. In this study, the room-temperature multiferroic behavior of Bi₂Fe_{2.5}La_{0.75}F₃C₃O₁₈ is investigated. The results show that the material exhibits a room-temperature magnetic phase transition from a paramagnetic state to a ferromagnetic state, accompanied by a structural phase transition from a high-symmetry phase to a low-symmetry phase. The room-temperature multiferroic behavior is attributed to the coexistence of magnetic and ferroelectric orders. The results provide a new insight into the room-temperature multiferroic behavior of Aurivillius phase ceramics.

Published under license by AIP Publishing. <https://doi.org/10.1063/5.0017781>

The Aurivillius phase structure is a layered structure consisting of perovskite layers (A₂B₂O₆) and BiO layers (B₂O₂). The Aurivillius phase structure can be represented as (A₂B₂O₆)_n(BiO)_{2n-1}. The Aurivillius phase structure is a layered structure consisting of perovskite layers (A₂B₂O₆) and BiO layers (B₂O₂). The Aurivillius phase structure can be represented as (A₂B₂O₆)_n(BiO)_{2n-1}. The Aurivillius phase structure is a layered structure consisting of perovskite layers (A₂B₂O₆) and BiO layers (B₂O₂). The Aurivillius phase structure can be represented as (A₂B₂O₆)_n(BiO)_{2n-1}.

I (BLFC), a , P , L , A , B_a , $5.25L_a$, $0.75F$, C , $3O_{18}$ (P).
 F , A , C , $14,17$ D.
 $BLFC$, a , b , A , a , b , a , P .
 A , 18 .
in situ AL, D, O, K.
 (a) , P , A , $BLFC$.
 $BLFC$, P .
 F , 1 , (D) , $BLFC$.
 $B2cb$, A , $A2$, $A2$.
 $B2cb$, $a = 5.4530(2) \text{ \AA}$, $b = 5.4427(1) \text{ \AA}$, $c = 50.670(2) \text{ \AA}$, $a = 5.4651(6) \text{ \AA}$, $b = 5.3943(6) \text{ \AA}$, $c = 41.487(2) \text{ \AA}$.
 F , P .

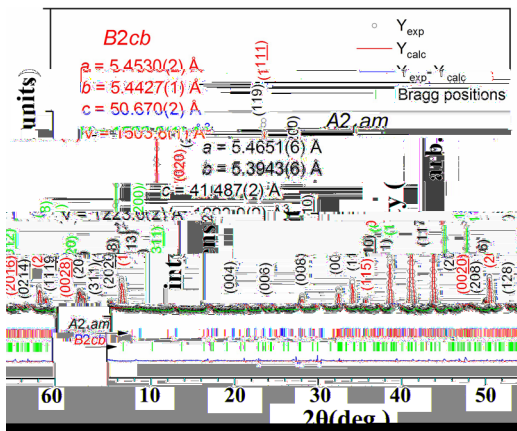


FIG. 1. ...

$BLFC$, a , a , $BLFC$, a , A , N , D , F , 1 , $(a-b)$, M , F , 1 , a , a , 1.4 %, D , ED , $(F \cdot 2$, $1)$, F , C , O , $C_2F O_4$, A , $B_5F_{0.5}C_{0.5}O_{15}$.
 F , $2(a)$, $BLFC$, $(50, 70, 100,$, $300,$ $500 \text{ H})$, $FE T$, $BLFC$, H , $BLFC$, $P-E$, $I-E$, B_6 , $3F_2O_{18}$, $I-E$, $21,22$, $BLFC$, $10 \mu C/$, F , $2(a)$, (FC) , $200 O$, $BLFC$, $BLFC$.

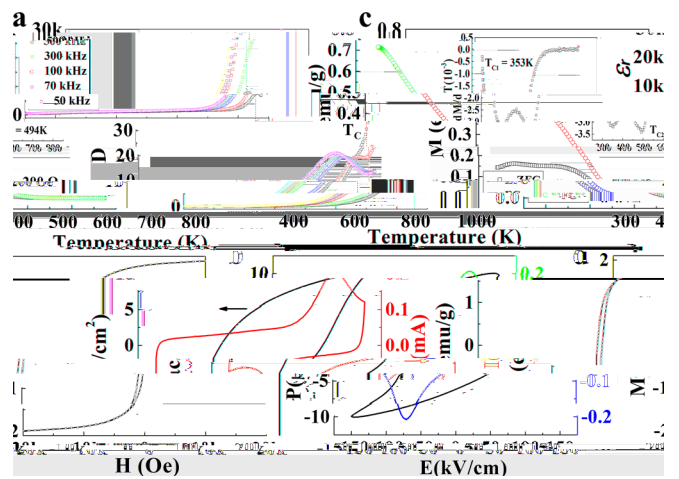


FIG. 2. ...

~ 494 K
 $B_6FC_{3O_{18}}$ (526 K).²³
 BLFC
 $F^{3+} O F^{3+}, C_a^{3+} O C_a^{3+}, F^{3+} O C^{3+}$ (\dots).²⁴
 ED
 FC
 ~ 353 K
 $C_2F_2O_4$
 $C_2F_2O_4$ (460 K)
 (M) $C_2F_2O_4$
 16.235 / 25
 $C_2F_2O_4$ 0.22 0.32 / 1.4 %
 $M = 1.85$ / $F_a \cdot 2(\dots)$ I M_H
 $2(F_a \cdot 3)$
 425 K 1.58 / 0.27 / ED
 $BLFC$
 $F_a \cdot 3$
 (DF) $F^{3+} O C^{3+}$ *ab initio*
 $(A P)$
 $F = 2$ $C = 3$ F_a C_a
 $(GGA) + I$
 $F \cdot 3(a)$ F^{3+} C^{3+} (3.1 $2.1 \mu_B/a$)
 $0.1 \mu_B/a$
 $F O_6$ $C O_6$
 F/C $F \cdot 3(\dots)$
 F O F^{3+} C^{3+}
 (\dots)
 $E_{FM} - E_{AFM}$
 $= -144.1$
 H_a 43.5 ($\dots, 504.6$ K), (FM) FM
 FC/FC $F \cdot 2(\dots)$ $a b$
 010
 $BLFC$ $F_a \cdot 4$
 I

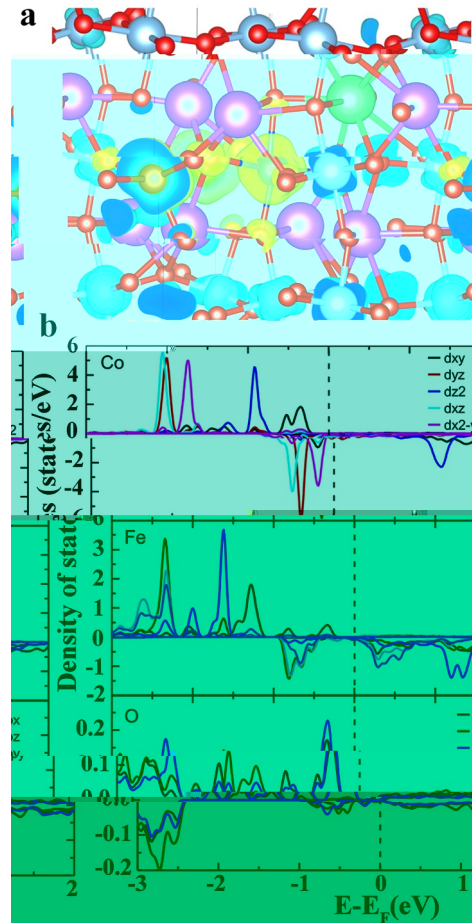


FIG. 3. (a) Crystal structure of BLFC. (b) Density of states (DOS) for Co, Fe, and O atoms. The x-axis is $E - E_f$ (eV) and the y-axis is Density of states (states/eV). The legend indicates contributions from d_{xy} , d_{yz} , d_{z^2} , d_{xz} , and $d_{x^2-y^2}$ orbitals.

N
 I
 $F_a \cdot 4$
 $(0_1 20)$
 2 $(2 \leq H < 5)$
 M_H $F_a \cdot 2(\dots)$ $3_a F$
 F 5
 $BLFC$ P F M
 PFM $BLFC$ $399 O$
 $5(\dots)$ A P

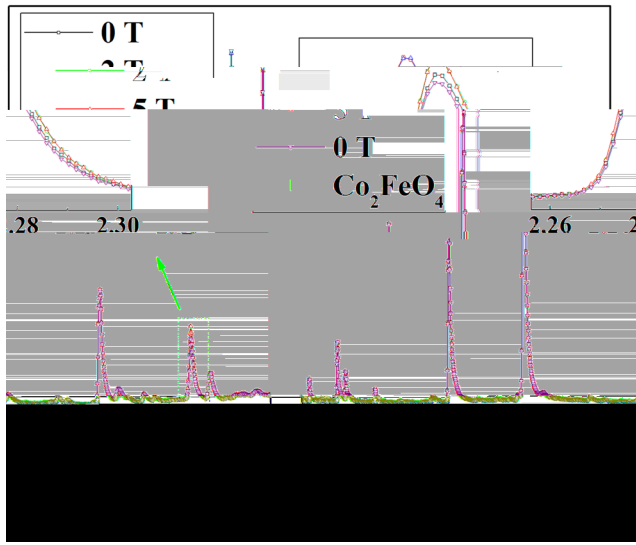


FIG. 4. XRD patterns of Co_2FeO_4 at 0 T, 2 T, and 5 T. The inset shows the sample and measurement setup.

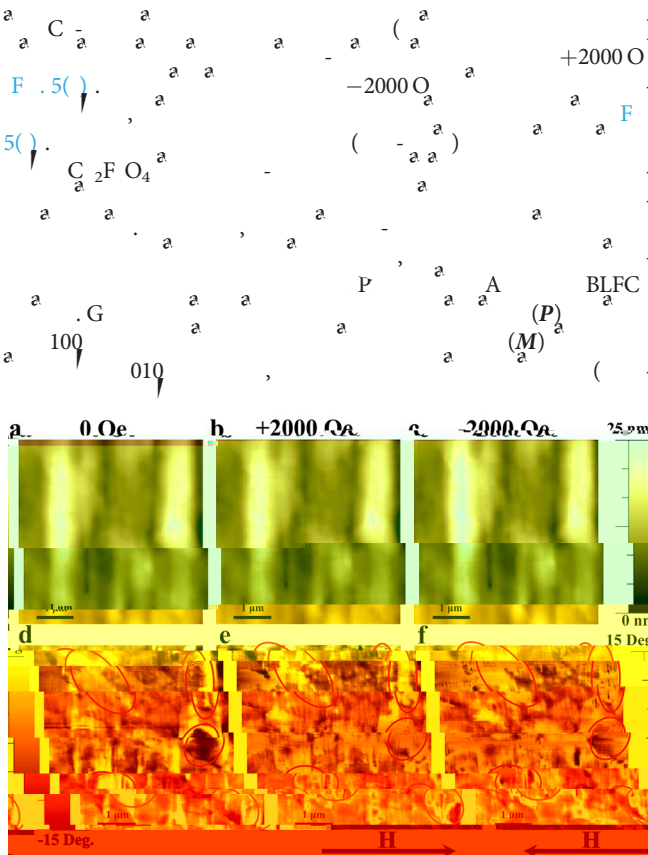


FIG. 5. MFM images of Co_2FeO_4 at 0 Oe, +2000 Oe, and -2000 Oe. The inset shows the phase images.

$T = P \times M$
 BLFC
 $\text{C}^{3+} \text{O}_2 \text{C}^{3+}$, $\text{F}^{3+} \text{O}_2 \text{C}^{3+}$, $\text{F}^{3+} \text{O} \text{F}^{3+}$,
 C_2F_4 , C_2F_2 , C_2F_6 , C_2F_8 , C_2F_{10} , C_2F_{12} ,
 EM (ED) BLFC
 D. M., P., D., K., D.,
 I H, I I N, AL,
 D, O, K,
 A, E, D, F,
 G, A, A, A, A, (G, N, 2/
 0038/20), C (G, N, K2015-0602006), N FC (G,
 N, 11474138, 11834005). A, P, (EM P)
 P, IND54, N, EM P
 EM P, E, AME, E

DATA AVAILABILITY

REFERENCES

1. E. A., N. D. M., J. F., N, 442, 759 (2006).
2. N. A., N, 6, 21 (2007).
3. J. M., J. H., L., C., N, A, M, 23, 1062 (2011).
4. L. F. H., O. C., J. B., J. L., C. H., H., O. G., D. C. L., H., K., A. J. B., A, F, M, 26, 2111 (2016).
5. N. A. H., J, P, C, B, 104, 6694 (2000).
6. B. A., M, : IL, B, 3O₁₂, A, K, I(58), 499-512 (1949).
7. A., G. K., M. M. K., J, P, C, M, 11, 3335 (1999).
8. N., P., G., K., M., E, B, 108, 194 (2004).
9. L. K., M., M., A. A., N. D., N. P., M., E. P., D. J., J, A, C, 96, 2339 (2013).
10. L., J. M., G., K., A. M., L., C. J., C. N., H., D, 45, 14049 (2016).
11. J. F., NPGA, M, 5, 72 (2013).
12. A., B, C. E., P, B, 90, 214109 (2014).
13. J. B. L., P. H., G. H., G., L., J. L., J., C., J. K. L., A, P, L, 96, 222903 (2010).
14. M., C., L., A, P, L, 95, 082901 (2009).
15. L., J., L., J. D., A, P, L, 101, 122402 (2012).

- ¹⁶M. P. A., P. C., M. B. A., A. P. B. A., J. P. H. A., K. A., L. K. A., M. P. A., C. A., H. A., K. A., A. J. B. A., *J. A. P.* **112**, 073919 (2012).
- ¹⁷J. L. A., H. A., M. J. A., K. A., P. A., *J. A. P.* **102**, 104107 (2007).
- ¹⁸M. G. C. A., *Characterisation of Ferroelectric Bulk Materials and Thin Films* (2014), 2.
- ¹⁹L. A., K. A., J. M. A., G. A., K. A., C. J. A., G. A., H. A., A. M. A. A., J. C. A., M. C. A., I. A. A., C. N. A., C. J. A., H. A., *J. M. A. C. C* **6**, 2733 (2018).
- ²⁰K. A., I. A., G. A., M. A., C. J. A., H. A., *J. P. C.* **122**, 15733 (2018).
- ²¹L. J. A., F. L. A., *J. A. C.* **97**, 1 (2014).
- ²²H. A., F. I. A., G. A., H. N. A., H. A., J. A., G. A., M. J. A., *J. A. D.* **1**, 107 (2011).
- ²³J. A., L. A., L. A., J. D. A., A. A., *J. P. L.* **101**, 012402 (2012).
- ²⁴B. A., J. A., J. C. A., L. A., J. D. A., A. A., *A. P. L.* **104**, 062413 (2014).
- ²⁵I. P. M. A., N. B. A., *J. P. L.* **11**, 719 (2009).