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

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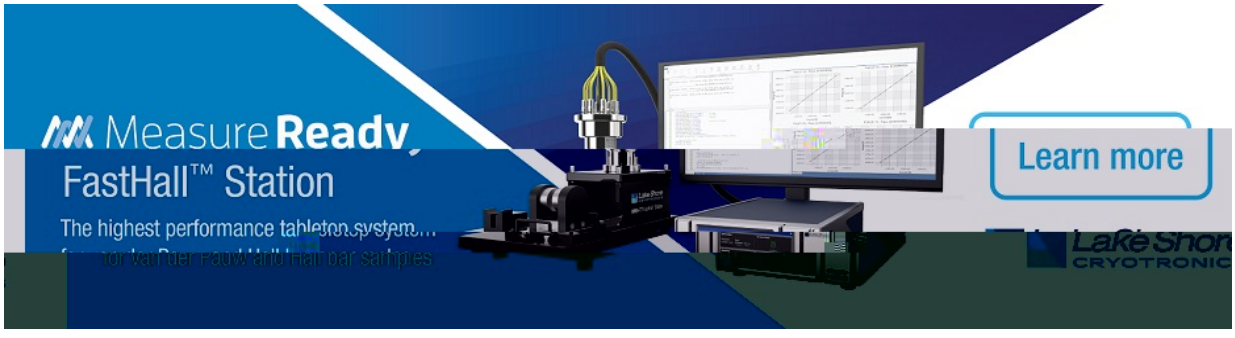

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AFFILIATIONS

[1]G I , C G , 430074, C
[2]I M , A , 47, K 04001,
[3] E M , M , L , L E1 4N , K E
[4]N K L D I F , C A E ,
M 621900, C
[5]N L , H , 11 0L , K
[6]E L , F , G 9 9 , K
[7] , L , L 730000, C

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ABSTRACT

M . H , A . H , A $Bi_{5.25}La_{0.75}Fe\ Co\ _3O_{18}$ A , *in situ* Fe^{3+} O Fe^{3+}, Co^{3+} O Co^{3+}, Fe^{3+} O Co^{3+} . A , C /F .

M (FM) (FE) , .[1–4] H , .[5] $(Bi_2O_2)^{2+}(A_{m-1}B_mO_{3m+1})^{2-}$ (A , B 12-)[6] B- $BiFeO_3$.[7–11] A $Bi_5Fe\ _3O_{15}$ (m = 4) $Bi_6Fe_2\ _3O_{18}$ (m = 5), $Bi_4\ _3O_{12}$ $BiFeO_3$, FE FM .[12,13] B C F B- , $Bi_5Fe_{0.5}Co_{0.5}\ _3O_{15}$ (m = 4) $Bi_6FeCo\ _3O_{18}$ (m = 5) .[14,15] H , D .[16] , A .

I , A B 5.25 L 0.75 F C 3 O 18 (BLFC) P (P). P L

C , [14,17] D F , A a b , P BLFC a b A

[18]

A in situ I H I I N , AL, D O K. F

( ). A BLFC P

BLFC P .

F 1 (D) BLFC . A B2cb A

A2$_1$ [19,20] A B2cb $a = 5.4530(2)$ A, $b = 5.4427(1)$ A, $c = 50.670(2)$ A A2$_1$am $a = 5.4651(6)$ A, $b = 5.3943(6)$ A, $c = 41.487(2)$ A F P (:// . .).

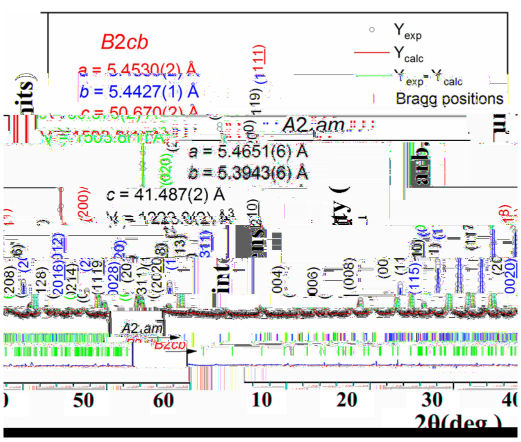

FIG. 1. -

BLFC A = 4 = 5 . N D'

. F 1 EM BLFC (a–b) . P . M , F . 1 1.4 . %, D. ED (F . 2 1) F , C , O, , C 2 F O 4

A B 5 F 0.5 C 0.5 3 O 15. [16] F 2( ) BLFC P (50, 70, 100, 300, 500 H). 1060 K FE T BLFC . H BLFC B 6 3 F 2 O 18 (973 K). [13] F 2( ) P–E I–E BLFC P I–E [21,22]

BLFC 10 μC/ 2. F 2( ) (FC) (FC) 200 O BLFC . BLFC

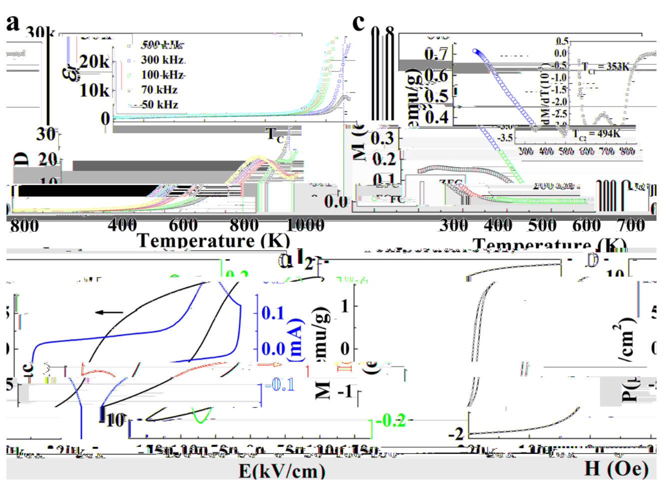

FIG. 2. ( ) ( ) , (,) ( ) ( ) = 200 ( ) 300

a a a a a a a $_1 \sim 494$ K
(a a a M/),
a B $_6$F C $_3$O$_{18}$ (526 K).[23] a
BLFC
F $^{3+}$ O F $^{3+}$, C $^{3+}$ O C $^{3+}$, a F $^{3+}$ O C $^{3+}$ (.).[24]
ED
A a a a a FC a $_2 \sim 353$ K a.
C $_2$F O$_4$.
C $_2$F O$_4$ (460 K) a ^{2} a [16,25]
a(M) a C $_2$F O$_4$
16 23.5 / .[25] , a 1.4 . %
C $_{2-}$ F $_a$O$_4$ a a 0.22 0.32 a / ,
BLFC
M = 1.85 / , F . 2( ). I a a , M H
a a a a ^{1} a
$_2$ (F . 3). a a a a
425 K a 1.58 / a a a a 0.27 / ,
a a a a a ED
a a BLFC
a A a a a .
F 3 a a
a F $^{3+}$ O C $^{3+}$
a (DF) a a a *ab initio* a
a a (A P) . H
$_F$ = 2 a $_C$ = 3 F a C , a
a a a a(GGA)+ a . I a a
BLFC
F . 3( ), F $^{3+}$ a C $^{3+}$ (3.1 a 2.1 μ_B/ a ,),
(a O 0.1 μ_B/ a). a a a a a
F O$_6$ a C O$_6$ a a
(a) F /C
F a a O a / . F . 3( ).
F a F $^{3+}$ a C $^{3+}$
a a (. ., a a) a a (. ., a
a) , a a . a a
a a a a a a $E_{FM} - E_{AFM}$
= −144.1 . a a a a a
H a . (FM) a a
43.5 a (. ., 504.6 K), FM a
a a a $_1$ a FC/FC a . F . 2( ). *a b*
a a a a a ,
010 .
F 4 a a a
BLFC a a a a a I a a
a a a a a a a

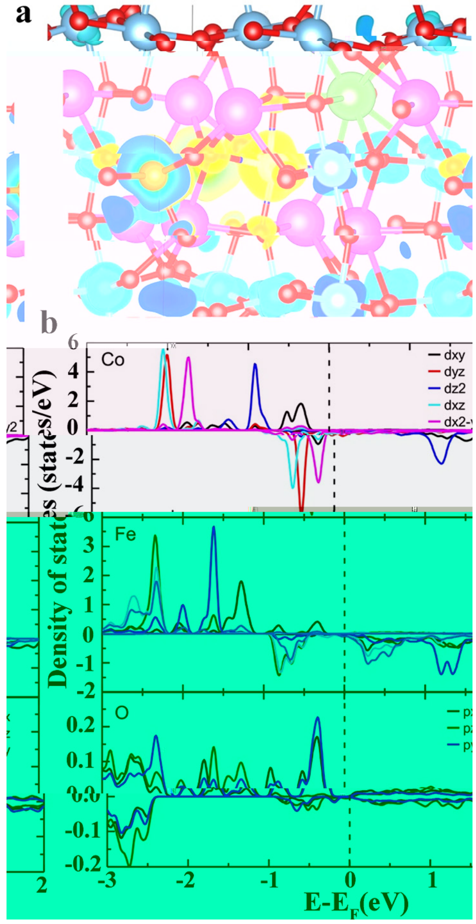

FIG. 3. ( ) (= 0.005) ( ) ( ) ( ) 3+ 3+ . ( )

a a a
a a a . N a a a
a a a a
a a a
a a a a . I F . 4, a
A a (0 1 20)
a
a a a a a 2 . F a
a(2 < H < 5 a), a a a a a a a
2 a a M H F . 2( ) a 3. F a a
a
a a
F 5
a BLFC a P a F M a a
a a a a a
a PFM a BLFC a a 399 O .
5( ). A a a a F .
F -

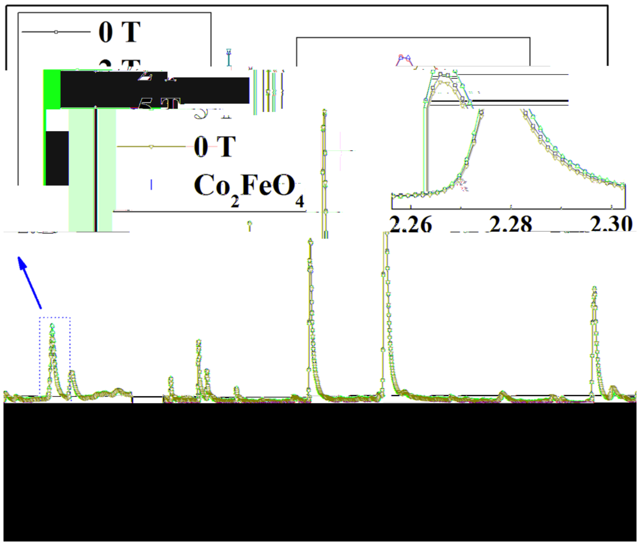

FIG. 4. [illegible] (0, 2, 5 [illegible] 0).

[illegible] C [illegible] +2000 O [illegible] Fig. 5( ) [illegible] −2000 O [illegible] Fig. 5( ) [illegible] Co_2FeO_4 [illegible] P [illegible] A [illegible] BLFC [illegible] G [illegible] (*P*) [illegible] 100 [illegible] (*M*) [illegible] 010 [illegible]

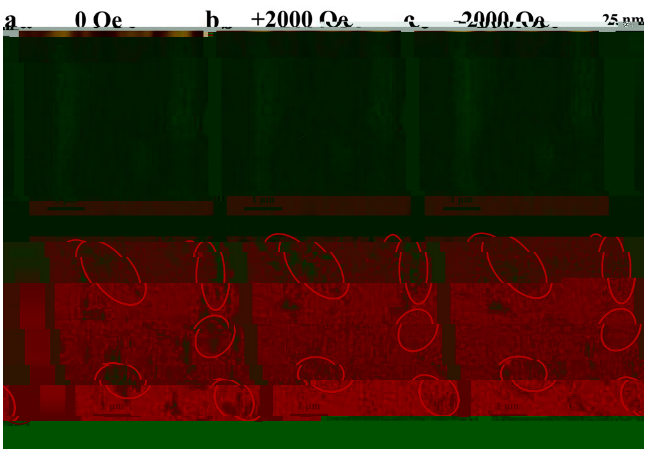

FIG. 5. [illegible] t 0 [illegible] +2000 [illegible] −2000.

) [illegible] $T = P \times M$ [illegible] BLFC [illegible] A [illegible] BLFC [illegible] Fe^{3+}–O–Fe^{3+}, Co^{3+}–O–Co^{3+}, Fe^{3+}–O–Co^{3+} [illegible] Co/Fe [illegible] EM [illegible] (EDS) [illegible] BLFC.

[illegible] D. M [illegible] D. K [illegible] D. [illegible] (Grant No. 2/0038/20), [illegible] (Grant No. K2015-0602006), [illegible] (Grant No. 11474138 [illegible] 11834005). [illegible] IND54 [illegible]

DATA AVAILABILITY

[illegible]

REFERENCES

1 [illegible] N. D. M [illegible] J. F. [illegible] Nature 442, 759 (2006).
2 [illegible] N. A. [illegible] Nat. Mater. 6, 21 (2007).
3 J. M [illegible] J. H [illegible] C. [illegible] Adv. Mater. 23, 1062 (2011).
4 L. F. H [illegible] O. C [illegible] J. B [illegible] J. L [illegible] C. H [illegible] H [illegible] O. G [illegible] D. C. L [illegible] A. J. B [illegible] Adv. Funct. Mater. 26, 2111 (2016).
5 N. A. H [illegible] J. Phys. Chem. B 104, 6694 (2000).
6 B. A [illegible] M [illegible] II. [illegible] 1(58), 499 512 (1949).
7 A. [illegible] G. K [illegible] M. M. K [illegible] J. Phys.: Condens. Matter 11, 3335 (1999).
8 N. [illegible] G. K [illegible] Mater. Sci. Eng., B 108, 194 (2004).
9 L. K [illegible] M [illegible] A. A [illegible] N. D [illegible] N. P [illegible] M. E. P [illegible] D. J [illegible] J. Am. Ceram. Soc. 96, 2339 (2013).
10 [illegible] J. M [illegible] G [illegible] A. M [illegible] C. J [illegible] C. N [illegible] H. [illegible] Dalton Trans. 45, 14049 (2016).
11 J. F. [illegible] NPG Asia Mater. 5, 72 (2013).
12 A. [illegible] C. E [illegible] Phys. Rev. B 90, 214109 (2014).
13 J. B. L [illegible] P. H [illegible] G. H. [illegible] G. [illegible] J. L [illegible] J. K. L [illegible] Appl. Phys. Lett. 96, 222903 (2010).
14 [illegible] Appl. Phys. Lett. 95, 082901 (2009).
15 [illegible] J. D [illegible] Appl. Phys. Lett. 101, 122402 (2012).

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