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e td y the t c t a feat e f c ea it a d the i-i ita g h f TFCD ca ed b y the e ec tic fie d i a h e t ic ce i h a S A a e ia hat u d ed i h a a ice .

Li a d La e t ich [2] i e iga ed the ce a i f the e ec tic fie d-i d ced ta i it i a ge e t y i-i a t the e e t td y b tf a d ed S A a e ia . The y de ta ed hat t the ta i it i a t - e ce . D i g the fi t e , a the age g ad a y i c ea e , TFCD f ic b ic the *a** c ea e a t diffe e t i e i the ce . The e i e ha e ei the b face i e fec it . U f the fie d i c ea e, the adi *a* f the TFCD i c ea e , b t y t e c i ica adi *a***, f the de f the ce hic e *h*. A t *a* > *a***, the TFCD cha ge i t a ipe d ai (SD); the b ec t e i-t ci c a y e t y Th a fie d-i d ced a b e TFCD i the e tic ed ge e t y f a h e t ic ce ha t cha ac e i ic e : the i i *a** the be hich a TFCD e b y i a b e i h e ec t t the e t bed c fig a i f a t ec ic a e , a d a a i the *a*** ab e hich the TFCD i a b e i h e ec t t a SD. The t i the TFCD g h a e c t ed b y diffe e tc tib it t the f ee e g y f the y e [2, 3]. The fi t , he *a** < *a* < *a***, i c t ed ai y b y (a) die ec tic c i g e e g y f the a i t ic S A ha e a d the e ec tic fie d, (b) e a ic e e g y f def a it i the TFCD , a d (c) e e g y f di t it a d i e fec it i the b f the a e ia a t the face f the ce . D i g the ec d , *a* > *a***, the face a ch i g f the ec ic a e a t the b di g a e f the ce begi t a y a i c ea i g y ig ifica t e i ce TFCD f a ge e i e i ab y e i e a ge de ia it f a e f hei i i ia e a it a t the b da ie (a e t the c fi i g a f the ce); e face a ch i g ead t the h gica TFCD SD cha ge [2].

Na a ic e i the i id c y a igh t e e a c ea it i e a g i h the i eg a i e , ch a ace a d the ai i id c y a i e face a t the edge f the ce . The g a f hi ec i t i e iga e the i-i ita g h f the TFCD it i t eache the c i ica dia e e *a*** bef e the ta i it t the ed ha e a e ace, a d a t i t the g h f SD a t ca e a ge ha *a*

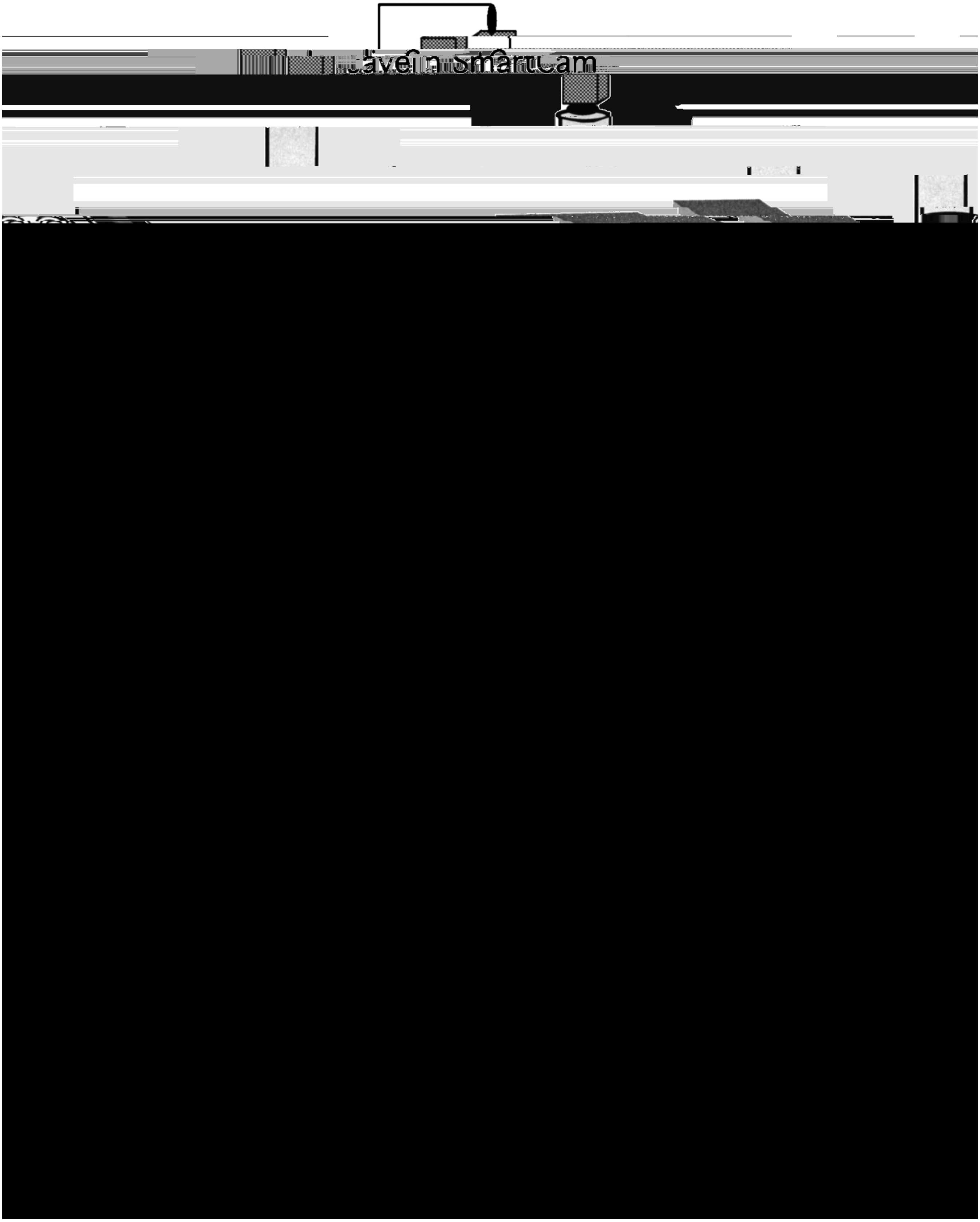


Fig e 1. E e i e a e -

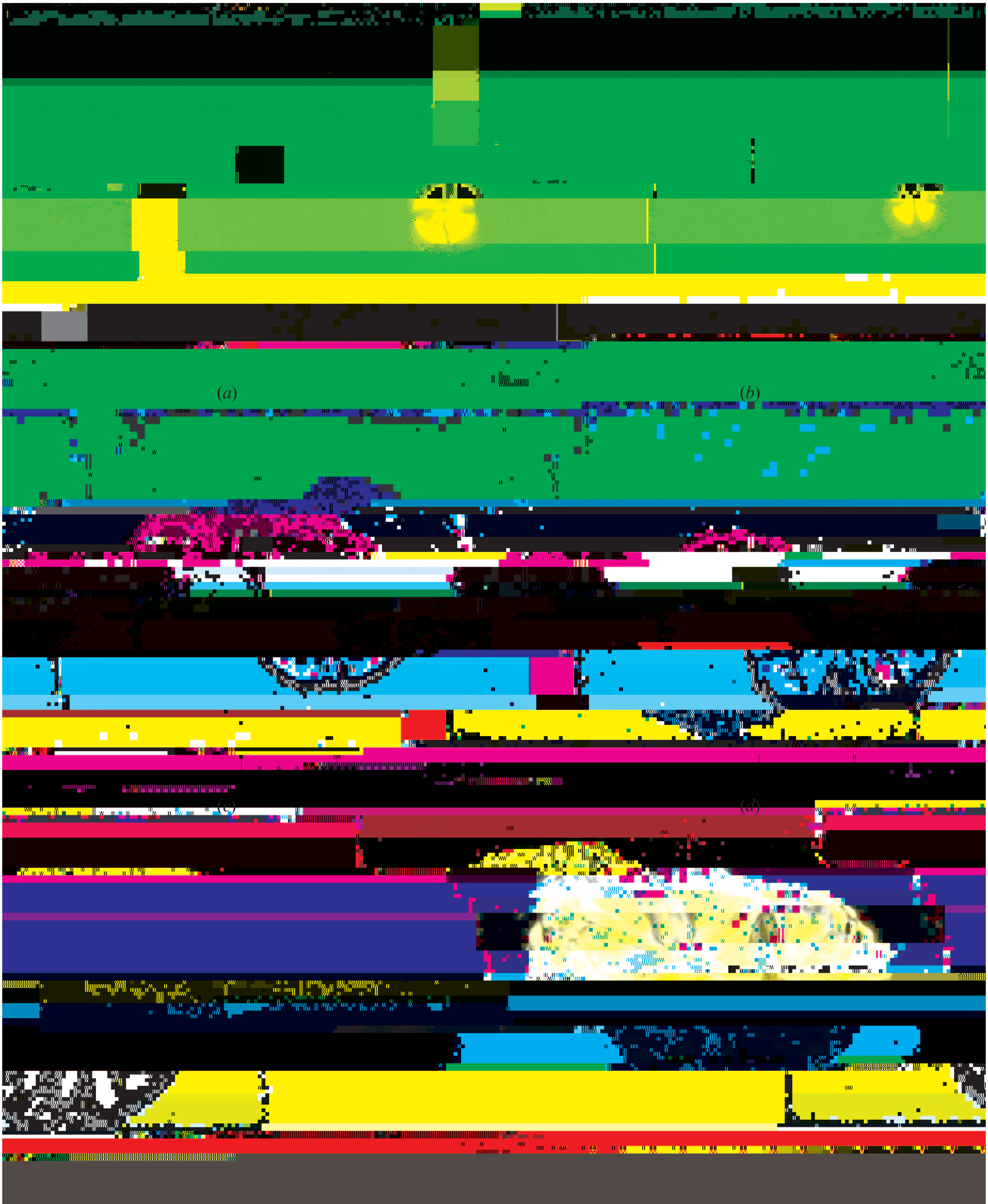


Fig e 2. N cea t- a d g h f a TFCD ı- a h e t Hic ce f CCN-47 a t 29°C. S a t-g ı h (*a*) he age a he d c a ta t 52.510 V f a f a e . (*a*) t = 0 ; (*b*) t = 25 ; (*c*) t = 50 ; (*d*) t = 95 ; (*e*) t = 100 .

egı . Lı a d La e t ıch [2] b e ed ha t he age a t hıch c ea ıt cc a t dıffe e t ı e a dıffe e t de e dı g he ı e fec ıt a t he ı e . Th , he a H a e f he age eed t be

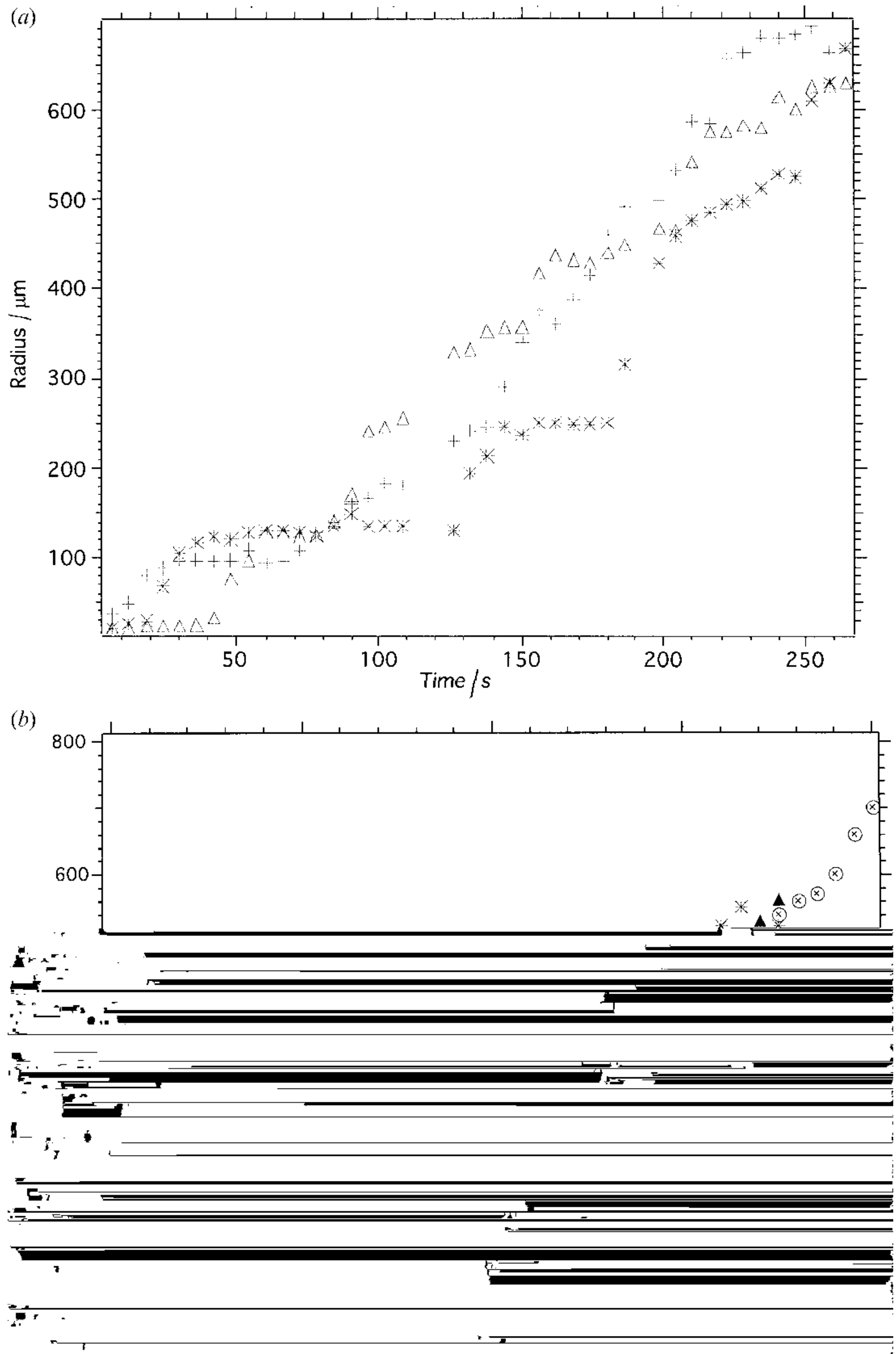


Fig e 3. (a) G h f d a CCN-47 a 22°C ($\Delta T = 7$°C). S b efe t ea e e t ee diffe e t di ec- t f a h a e: + 145°; 225°; △ 320°. (b) G h f TFCD a d b e e t e d a a 29°C ($\Delta T = 1$°C) e CCN-47. S b efe t ee diffe e t ea e e t e c t t e h a : ▲ 45°, 135°; ⊗ 325°. I a

e e t. The bi ef i ge ce f CCN-47 i e a te ($= 1.4723$, $_e = 1.5075$), hich he t ai ai ea ab e e t f he i agi g (ab t l µ).

The S A ce a e ed i a a e i a t he e e t i i a a ce ; a e ec tic fe d a ed t c ea e he TFCD . I he FCPM, he

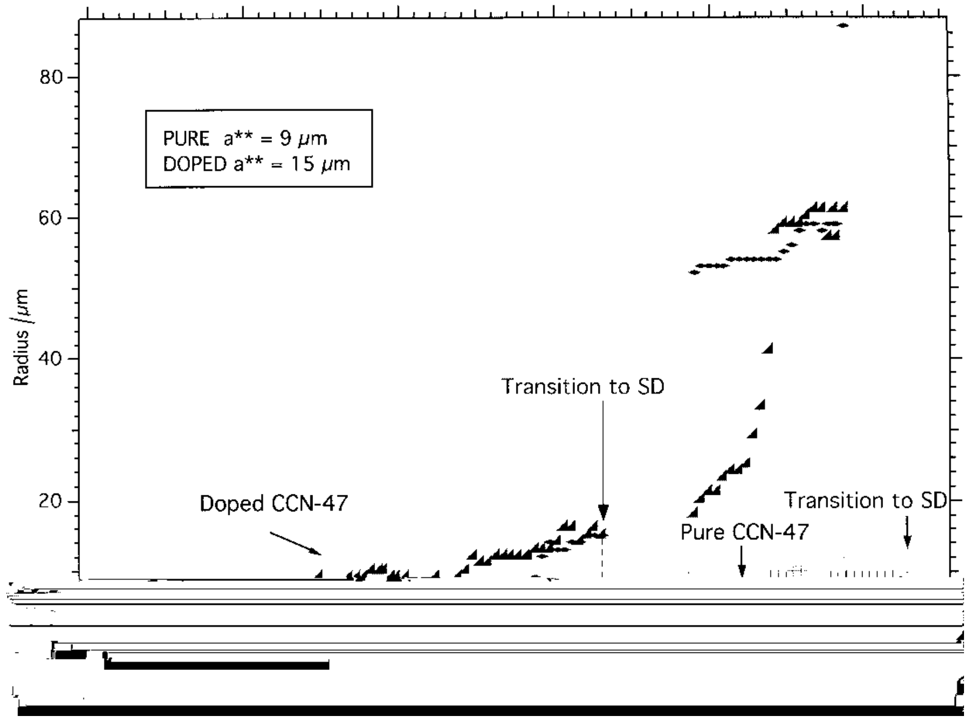


Fig e 4. De e i a i f c i ica adi a^{**} i e a d d ed CCN-47 a 22°C ($\Delta T = 7$°C f e a d 6°C f he d ed).

a e bea ca he e i e e f he ce ; he TFCD ha t e ai i he ce af e he e ec ic e d i ce a e a fe ec d , e f ec d if he i ched ff; he i e a a i i a d a e t be f i ca ec i i a ge. Beca e f hi i i i e f i ca ec i i g f he a e i h ffcie t a i , e e f ed b e a i f he e a a be e i .

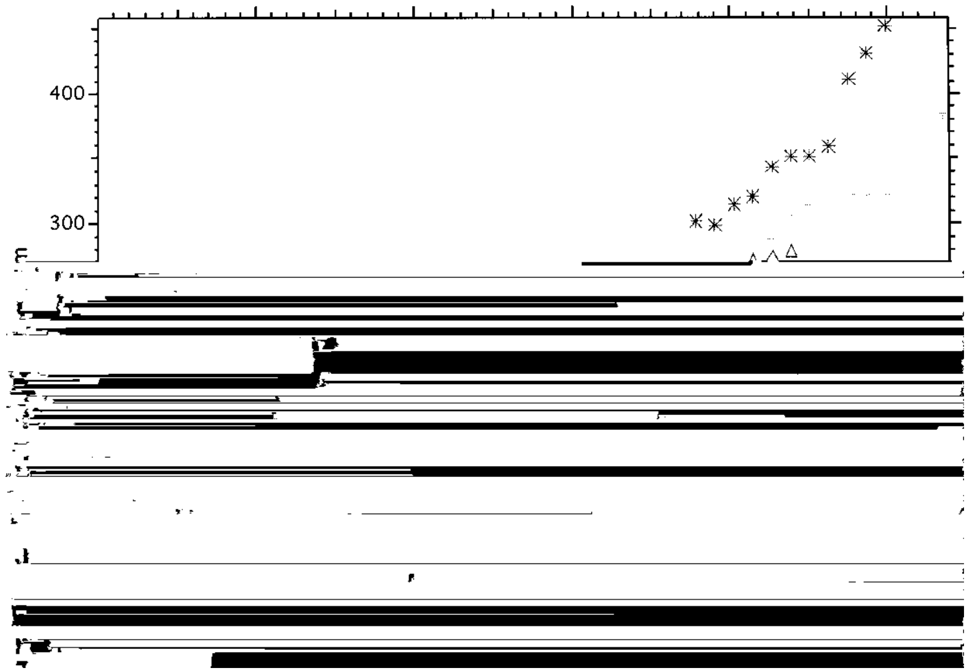
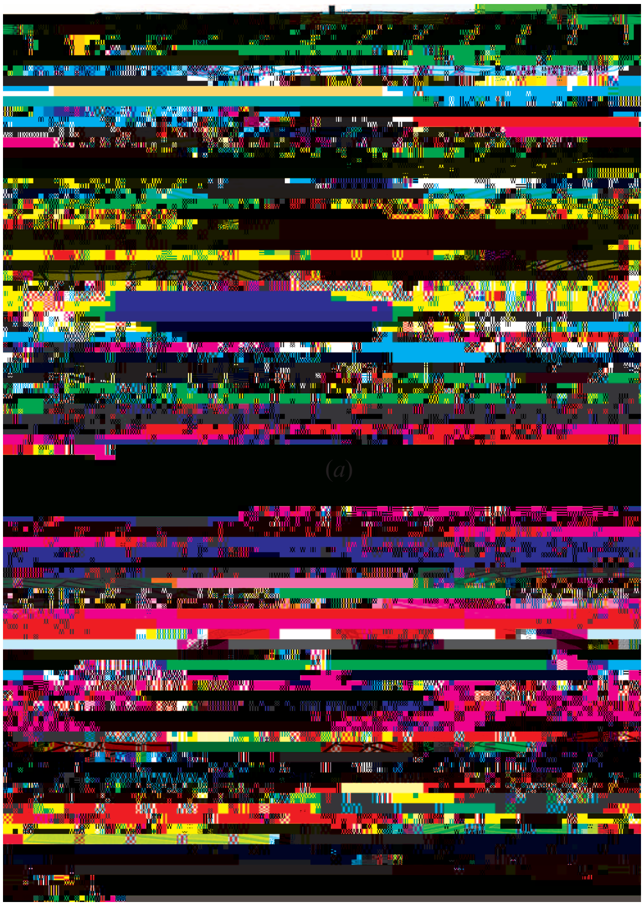


Fig e 5. G h f SD i d ed CCN-47 a t e e a t e 27°C ($\Delta T = 1$°C). V age he d c a t S b efe t ea e e t i h ee diffe e t di ec i f a h a i e: ✳ 38°, + 145°; △ 315°.



(*a*)

(*b*)

Fig e 6. A TFCD i a ec ic A i id c a c ea ed (*a*) a t he ce a , (*b*) i he b f he ce .

Fig e 7 h he i a e (*a, b*) a d e ica (*c*) FCPM e t e f he ec ic ce i h TFCD . Si ce a t he ba e f he TFCD he ec e a e ie ed h a he ba e h d be cha ac e ed b he a i e i f e ce ce. Fig e 7 (*c*) c ea h ha t he ba e f he TFCD i ca ed i he b f he ce . Thi e ti a t a, a he h e t c a ig e ta t he b di g a e f he ce a e i t diffic f he TFCD ba e t a ach he b da ie .

5. Free energy considerations

5.1. *N clea i f ic f cal-c ic d ai*

The a t e ta t a he de f b c ea i t he e d-i d ced ta i i i he ce . Acc di g t [3], c ea i a d g h f he TFCD f a idea a t c f a e i cha ac e ed b he f ee e e g c ed f e a ic, die ec ic a d face a ch i g e , a f hich de e d he di e i - e de a a e e $\rho = a/h$, he e a i he adi f he d ai a d h i he hic e f he ce . N e ha t ρ gi e a ea e f he a i a e i t a t he b di g face i h e ec t t he a e; hi i t θ cha ge f 0 a t he i he f he TFCD (he e he a e bec e a a e t he a e) t i t a i a e $\theta = \text{a c a } (2a/h)$ a t he i t he e he a i e t a i f he TFCD c e he b di g a e . We e he f i g f ee e e g f c i a f he f_b f b e a ic a d die ec ic e e g de i e:

$$f_b = \frac{1}{2}K(\sigma_1 + \sigma_2)^2 + \bar{K}\sigma_1\sigma_2 + \frac{1}{2}B\gamma^2 - \frac{1}{2}\varepsilon_0\, \varepsilon_a(\mathbf{E}\cdot\mathbf{n})^2 \qquad (1)$$

he e σ_1 a d σ_2 a e he t i ci a ca c a t e f he ec ic a e , K i he a e a ic c a t, $\bar{K}$ i he add e a e a ic c a t, B i he c e i bi i t d , ε_0 i he e i i i t f f ee ace, $\varepsilon_a = \varepsilon - \varepsilon_\perp < 0$ i he die ec ic a i t f S A, ε a d $\varepsilon_\perp$ a e he e a i e e ec ic e i i i ie (he b c i t efe t he di ec t **n**), **E** i he a ied e ec ic e d a d **n** i he di ec t . The face a ch i g f a e a ha e i ge e a diffe e t f he a ch i g f e a ic i id c a , a t he di ec t , b ta he a e ed t c t e, i t g di t ed ea he b di g b ta e [2]. F he c ea i be , $\rho \ll 1$, he face a ch i g a t he b di g a e ca be eg ec ed, a e ha e ee e i e a ha t he TFCD c ea e i he b a d d t di t b he a e ed t c t e ea he b di g a e; h e e , i t h d be i c ded i he di c i f he TFCD SD ta f a i , a di c ed a e .

U i g he de [3] de e ed f he ag e ic e d effec ,ta d e i i g e a i (17) i [3] i e f he e ec ic e d (a d eg ec i g he - ca e d effec t), e b ai he e e ce e e g a cia ed i h he a e-a a ce f a TFCD (a c a ed i h he e e g f he if a e de he ac i f he a e e ec ic e d):

$$\Delta F = 2\pi K h\rho\Bigg[\frac{\pi}{2} \quad 2 + L(\text{a cc g } 2\rho) + 2\,\text{a cc g } 2\rho\left(\frac{h\rho}{\xi} - 2\right) + \text{a c g } 2\rho \quad \frac{\rho h}{\xi(4\rho^2+1)^{\frac{1}{2}}} - \frac{1}{\rho} \quad (1+4\rho^2)\Bigg] - 2\pi\bar{K}h[\pi\rho - 2\rho\,\text{a c g } 2\rho + \quad (1+4\rho^2)] + \frac{\pi}{24}\varepsilon_a\varepsilon_0 E^2 h^3[8\rho^2 - 6\rho\,\text{a c g } 2\rho + \quad (1+4\rho^2) + 4\pi\rho^3 - 8\rho^3\,\text{a c g } 2\rho] \qquad (2)$$

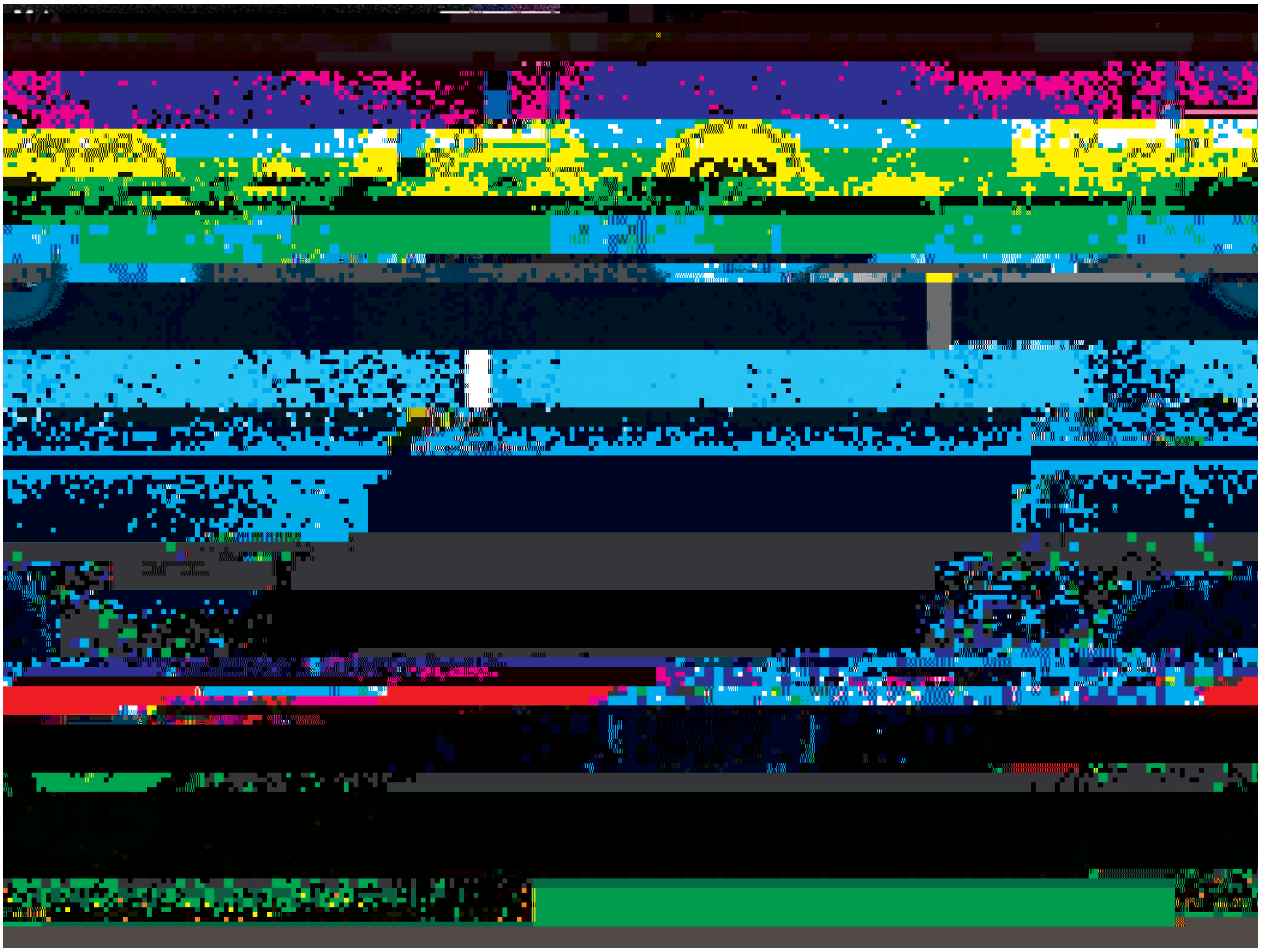


Fig e 7. F e ce ce c f ca a i g ic c e t e f a e d-i d ced f ca-c ic d ai i he ec ic A ha e f CNN-47 d ed i h ia a ce . F a e (*a*) a d (*b*) e e th a (,) ica ice f hic e 1 μ a e f he idd e a e f he ce ha c ai he ba e f he d ai . P a a i f igh i a e t he -a i (*a*) a d t he -a i (*b*). Li e "c" h he ca i f he e ica c - ec i f he ce , de ic ed i f a e (*c*). F a e (*c*) h he e ica ( ) c - ec i f he d ai ; i e "a" a he ca i f f a e (*a*) a d (*b*). The a i e i t f he e ce t igh ti i he egi he e $\hat{\mathbf{n}}\|\mathbf{P}$.

he e ξ i he c e adi f he ci c a defec ta d $L(\ )$ i L bache i f c i

$$L(\ ) = -\int_0 \quad c \quad d$$

$$= \quad 2 - \frac{1}{2}\sum_{i=1}^{?}(-1)^{i-1}\frac{\ 2i}{i^2}. \qquad (3)$$

Fig e 8 (*a*) a d 8 (*b*) h $\Delta F(\rho, E)$ a he f c i f he d ai adi a d he a ied e d, ca c a ed i g e a i (2) a d (3) i h $h = 36\,\mu$ $K = 10^{-6}$ d , $\bar{K} = 0$, $\varepsilon_a = -10$ [2]. L bache i f c i i ca c a ed i h acc ac t he t40 e i e a i (3), i g *Ma he a ica* Ve i 4.2.

The f ee e e g (2) ca be e a ded f a $\rho \ll 1$:

$$\Delta F = A_1\rho + A_2\rho^2 + A_3\rho^3 + A_4\rho^4 + \ldots \qquad (4)$$

he e he c ef cie t a e

$$A_1 = 2\pi^2 Kh(\beta - 2 - \bar{K}/K). \qquad (5)$$

He e $\beta =\ (2h\rho/\xi) \approx c$ (f $a \gg \xi$ he ga i h ic de e de ce i ea);

$$A_2 = 4\pi Kh\left(\ \sqrt{2} - \beta - 3\right) \qquad (6)$$

$$A_3 = \frac{\pi^2}{6}\varepsilon_0\varepsilon_a E^2 h^3. \qquad (7)$$

The i ea c ef cie t A_1 i a a i i e (he i e he S A a a at e d tbe ab e). We i a e $K = 0$. The hır d ɑ A_3 ı deß ed e b he ße d c tıb ıt .

The deﬀe de ce $\Delta F(\rho, E)$ f a ρ, ßg e 8 (*b*), c ea de ta ɑ he ß t de cha ac ɑ f he ta ı ıt . The f c ıt $\Delta F(\rho)$ g e h gh a a ı $\Delta F^* = \Delta F(\rho^*)$ a t e c ı ıtca adı ρ^* ha t deß e he c ı ıtca TFCD c eı. O he TFCD f a ßcıe t a ge adı $\rho > \rho^*$ ta f he e a- ab e ıf a ɑ ı t he ab e defec t a ɑ. The

TFCD ı h $\rho < \rho^*$ (e b) a e ab e a d ı- deca

The e e g ba ıe ha t e a a ɑ he t a ɑ ı- b gh tab b he *i e* eadı g e a ıtc ɑ ı he e a ı (4). Thı ɑ ca e ac ıtca *li ea l* ı h ρ a d hı e aı h he ba ıe a a e ı t a d ı- ca ɑd ı he egı f e a ıt e a ρ: he d ı ı g f ce, ı acc da ce ı h e a ıt (7), c tıb ɑ J/F07.5 Tf-(T fea t e ı- the e t f F ıede ' ' a f ı- e e tabı ı t', hıch at et tha t t TFCD ca t e ta et each the [8, 9]. I the d , the ı- et ac ıt- f t TFCD ı- f et ıc a t e [1, 9].

The g h f $a > a^*$ t $a = a^{**}$ ı- the e a et ıa a t29°C a ea t be faı- ı-ea , fig e 3 (*b*). M e- e thı- g h cc a t c at t age. Thı- beha ı- ı- e ı-ı-ce t f the A a ı- de f c a ıca ı-e ıt the [10]. Acc dı-g t thı- de , ı- t de ta f a ıt- c eı- f the d c t ha e g t each a c ı ıtca e, de de t ıt- e a d et a t e. The h ıca e ıte f ı- at ce a e: (ı)- c ea ıt- a et ı-t e, hıch ı- a f c ıt- f the ac ıt-a ıt- e e g f the ec a ıg a ıt- ı- ed ı- the ta f a ıt- a d the c ı ıtca f ee e e g ba ıe , a d (ıı)- the g h a et f the d c ha e, hıch de d the de c ı-g a t the g h ı- et face [11]. The d a ıc f the

c effıcıe t ı S A t g y de e d he e a ıc c a t, $W = \alpha(KB)^{\frac{1}{2}}$ ı de , e d e ec t W t dec ea e ı h e e a t e [2]. The ef e, ρ^{**} h d de e d e e a t e a d ı ı e y t ı c ea e ı h e e a t e, hıch ı c ı e t ı h e e ı e a da a: a^{**} a ıe f ab t 10 µ a t 22°C ı g e 4 t 50 70 µ f he hıghe e a t e f 29°C a TFCD ı a lhe c He , lhe ı He SD de e Haı ı ta t ea t a ı at ıt e . The aı ea f lhe TFCD SD ta f a ıt ı lhe face a ch ı g. I a e Ha dı g TFCD, lhe S A a e a e a H g e ı e a ge a ge ı lh lhe a ch ı g-ı H ed ıe at ıt , $\theta \to \pi/2$, a lhe TFCD adı ı c ea e . I a e ga ıt g SD, lhe ea c at t ıd lh ρ ı ı t lhe a ı ıt t f lhe S A a e f lhe a ch ı g-ı H ed a ıg e ,t $\theta = $ a c at ρ, $\theta < \pi/2$. The ef e, e ga ıt ıa SD ı e e ge ıtca H efe ab e e lhe ıf e Ha ı f TFCD he lhe face a ch ı g ı e , de H et lhe fac t lha t lhe e a ıtc c t f lhe SD ı hıgh beca e lhe ce ta SD Ha e ı a Ha e defec t f lhe ıt tg aı b da defec t He. The a ıtat ıt e SD de de ta et ı deed lha tab e e c ı ıtca atge U^{**}, lhe e ı a a ge f SD ıd lh f hıch lhe SD ı e et ı bec e ega ıt e, ı H ı g lha t lhe e d aı ı g b ı c ea ı g lheı e g lh. The a ge f lhe SD ıd lh f hıch lhe e e g ı ega ıt e ı a lhe b ad f a $U > U^{**}$, hıch e Haı lhe hıgh ı eg a g lh Ha tet af et lhe TFCD eache lhe adı a^{**}. I lhe d Hed ce , lhe ta ı ıt TFCD SD cc a t e ha t e atge lha ı lhe H e ce , hıch ıgh tbe e a etd t lhe ı ıtga ıt f a ch ı g a t lhe ec ıtc g a