

# Origins of the doping asymmetry in oxides: Hole doping in NiO versus electron doping in ZnO

$\Gamma_1$   $\Gamma_2$   $\Gamma_3$   $\Gamma_4$   $\Gamma_5$   $\Gamma_6$   $\Gamma_7$   $\Gamma_8$   $\Gamma_9$   $\Gamma_{10}$   $\Gamma_{11}$   $\Gamma_{12}$   $\Gamma_{13}$   $\Gamma_{14}$   $\Gamma_{15}$   $\Gamma_{16}$   $\Gamma_{17}$   $\Gamma_{18}$   $\Gamma_{19}$   $\Gamma_{20}$   $\Gamma_{21}$   $\Gamma_{22}$   $\Gamma_{23}$   $\Gamma_{24}$   $\Gamma_{25}$   $\Gamma_{26}$   $\Gamma_{27}$   $\Gamma_{28}$   $\Gamma_{29}$   $\Gamma_{30}$   $\Gamma_{31}$   $\Gamma_{32}$   $\Gamma_{33}$   $\Gamma_{34}$   $\Gamma_{35}$   $\Gamma_{36}$   $\Gamma_{37}$   $\Gamma_{38}$   $\Gamma_{39}$   $\Gamma_{40}$   $\Gamma_{41}$   $\Gamma_{42}$   $\Gamma_{43}$   $\Gamma_{44}$   $\Gamma_{45}$   $\Gamma_{46}$   $\Gamma_{47}$   $\Gamma_{48}$   $\Gamma_{49}$   $\Gamma_{50}$   $\Gamma_{51}$   $\Gamma_{52}$   $\Gamma_{53}$   $\Gamma_{54}$   $\Gamma_{55}$   $\Gamma_{56}$   $\Gamma_{57}$   $\Gamma_{58}$   $\Gamma_{59}$   $\Gamma_{60}$   $\Gamma_{61}$   $\Gamma_{62}$   $\Gamma_{63}$   $\Gamma_{64}$   $\Gamma_{65}$   $\Gamma_{66}$   $\Gamma_{67}$   $\Gamma_{68}$   $\Gamma_{69}$   $\Gamma_{70}$   $\Gamma_{71}$   $\Gamma_{72}$   $\Gamma_{73}$   $\Gamma_{74}$   $\Gamma_{75}$   $\Gamma_{76}$   $\Gamma_{77}$   $\Gamma_{78}$   $\Gamma_{79}$   $\Gamma_{80}$   $\Gamma_{81}$   $\Gamma_{82}$   $\Gamma_{83}$   $\Gamma_{84}$   $\Gamma_{85}$   $\Gamma_{86}$   $\Gamma_{87}$   $\Gamma_{88}$   $\Gamma_{89}$   $\Gamma_{90}$   $\Gamma_{91}$   $\Gamma_{92}$   $\Gamma_{93}$   $\Gamma_{94}$   $\Gamma_{95}$   $\Gamma_{96}$   $\Gamma_{97}$   $\Gamma_{98}$   $\Gamma_{99}$   $\Gamma_{100}$



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Growth Temperature  $T_g$  (K)

(a)

Concentration ( $\text{cm}^{-3}$ )

$10^{14}$

$1000 \times T_g^{-1}$  ( $\text{K}^{-1}$ )

(b)

Li concentration ( $\text{cm}^{-3}$ )

$$\Delta E_{B(A/B)} - [\epsilon_B(A/B) - \epsilon_A(A/B)] + (\epsilon_B^{-n} - \epsilon_A^{-n}), \quad (1)$$

The figure shows two plots, (a) and (b), with a common x-axis labeled  $1000 \times T_g^{-1}$  ( $\text{K}^{-1}$ ). Plot (a) shows Concentration ( $\text{cm}^{-3}$ ) on the y-axis, with a horizontal line at  $10^{14}$ . Plot (b) shows Li concentration ( $\text{cm}^{-3}$ ) on the y-axis. A vertical red dotted line is drawn between the two plots. To the right of the plots is a large, dense block of text containing mathematical formulas and a detailed discussion of energy levels and carrier concentrations in a material system. The text includes equations (1) through (10) and discusses the relationship between growth temperature, carrier concentration, and energy levels. Key terms include  $E^n$ ,  $E^p$ ,  $E_i$ ,  $E_c$ ,  $E_v$ ,  $E_f$ ,  $E_g$ ,  $E_{A/B}$ ,  $\epsilon_A$ ,  $\epsilon_B$ , and  $n$ . The text is oriented vertically and is partially obscured by the plot lines.



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