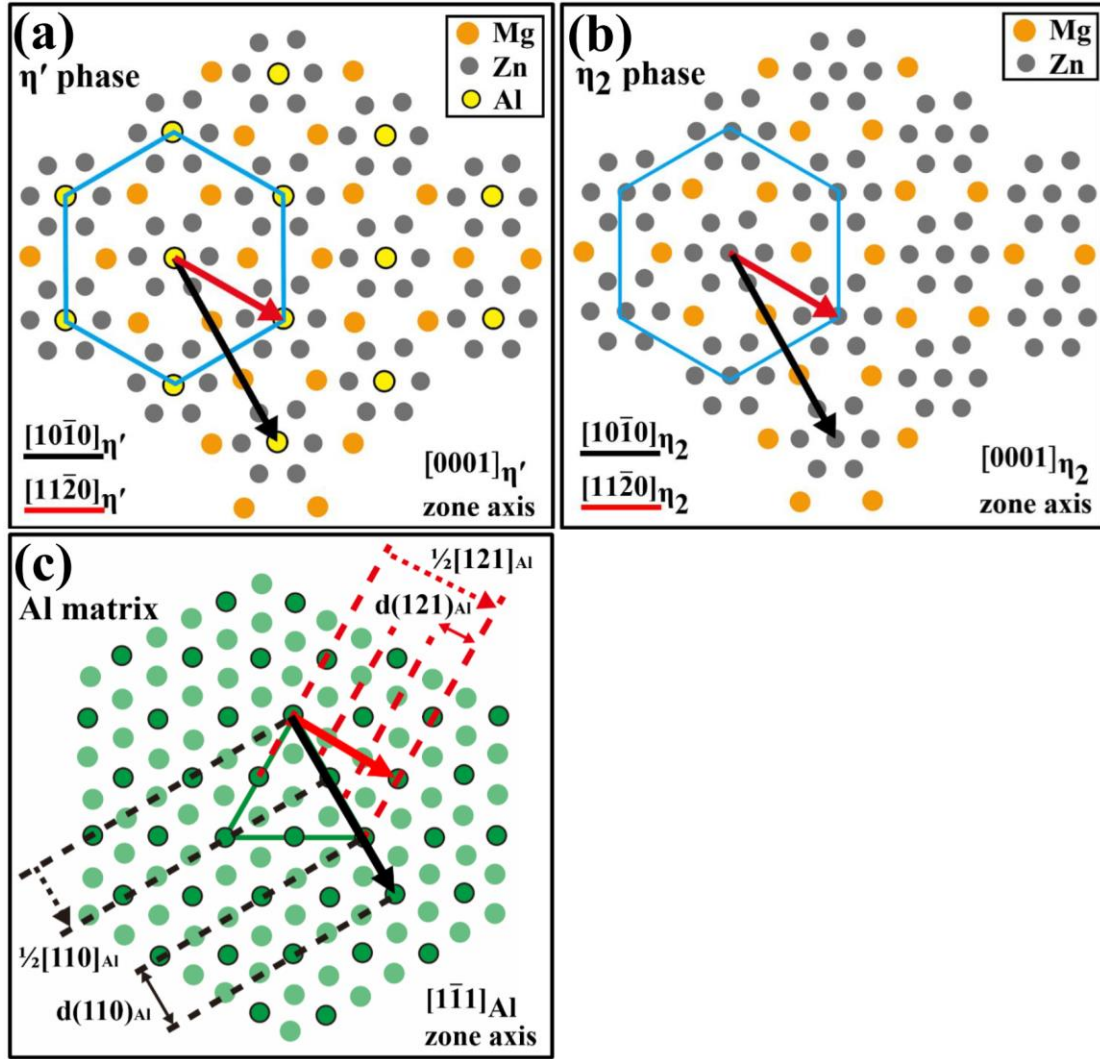
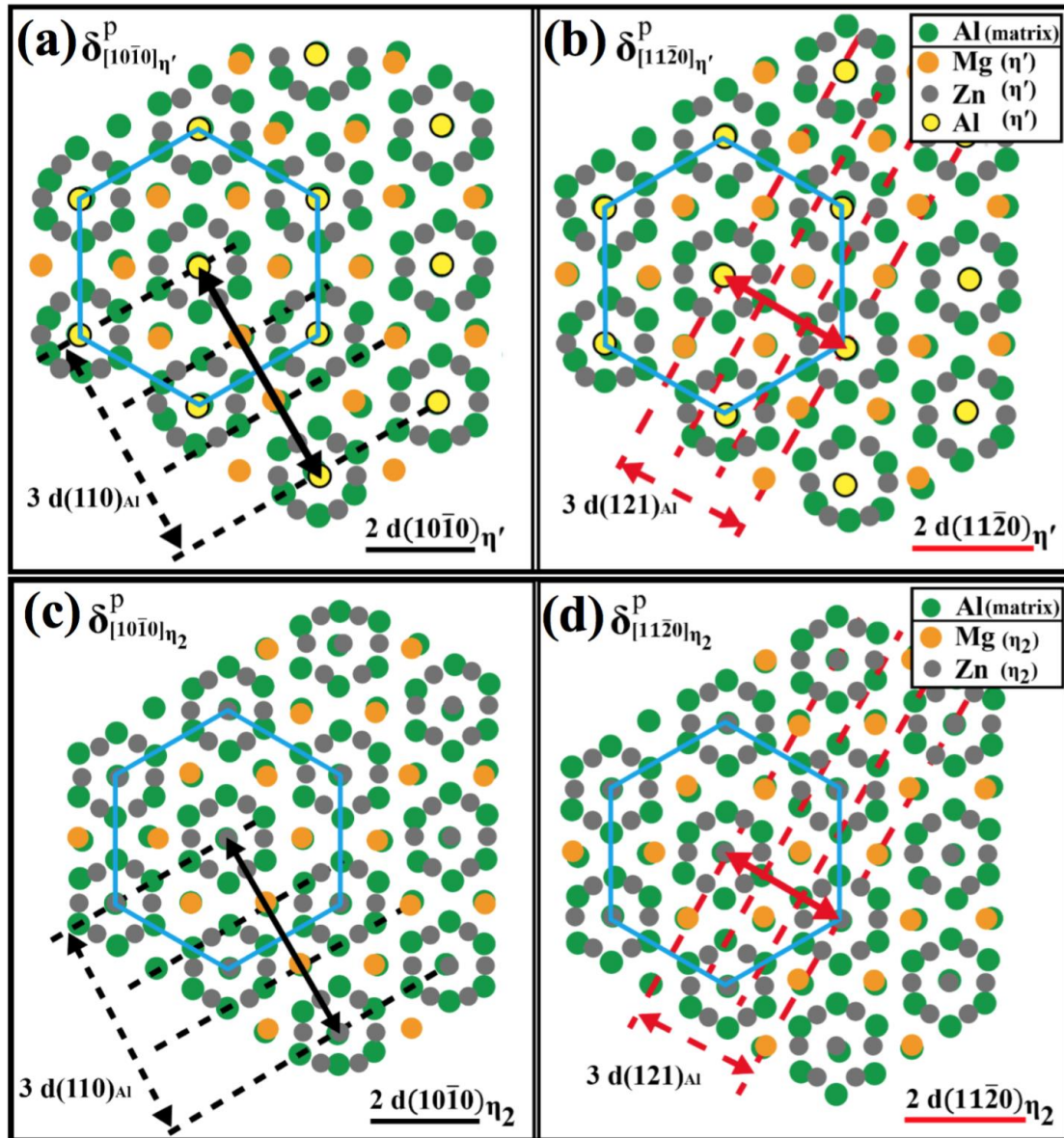


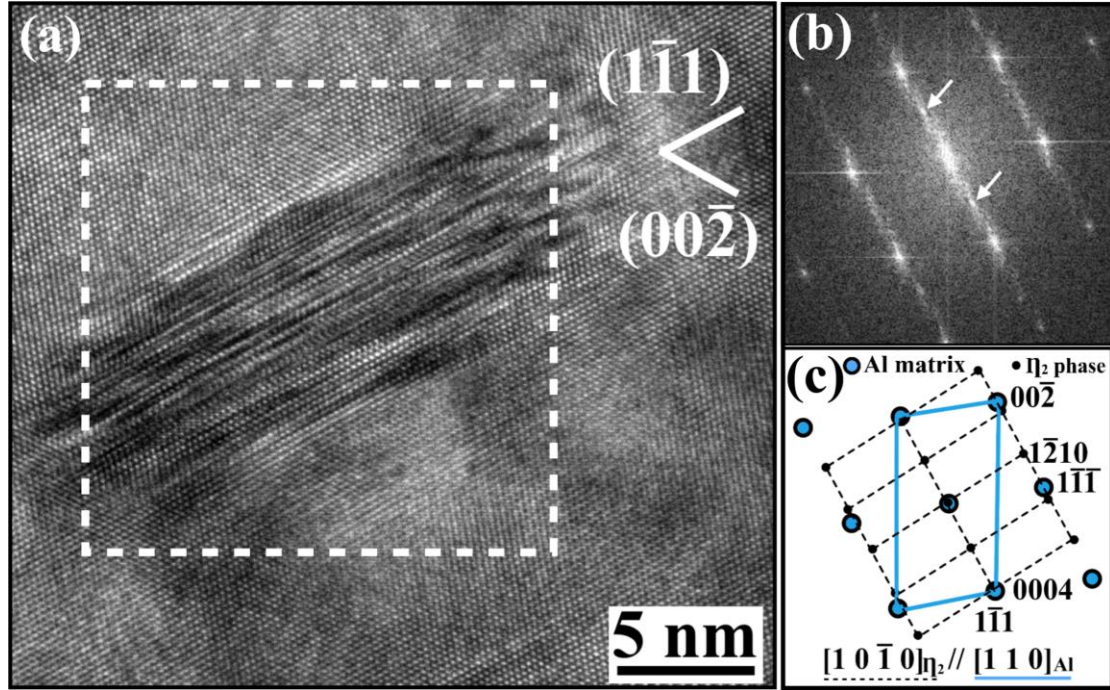
Supplementary Figures



Supplementary Figure 1. The atomic models and specific directions of η' , η_2 precipitates and Al matrix under $[0001]//[1\bar{1}1]_{Al}$ zone axis. (a) The η' precipitate with corresponding $[10\bar{1}0]_{\eta'}$ and $[11\bar{2}0]_{\eta'}$ directions; (b) The η_2 precipitate with corresponding $[10\bar{1}0]_{\eta_2}$ and $[11\bar{2}0]_{\eta_2}$ directions; (c) The corresponding parallel direction between precipitates and Al matrix (i.e., $[10\bar{1}0]//[110]_{Al}$ and $[11\bar{2}0]//[121]_{Al}$). It should be noted that on $(1\bar{1}1)$ plane the three closest-packed directions delineate the regular triangle, where the centers of aluminium atoms are designated by the dark green circles; while the light green circles in other areas denote the aluminium atoms with different horizontal heights. The lattice parameters of Al crystal, η' , and η_2 are $a = b = c = 4.05(\text{\AA})$; $a = b = 5.04$, $c = 13.03 (\text{\AA})$; $a = 5.04$, $c = 8.28 (\text{\AA})$, respectively.



Supplementary Figure 2. (a) and (b). The atomic model viewed from $[0001]_{\eta'}/[1\bar{1}1]_{Al}$ indicates the relationship of lattice misfits along the $[10\bar{1}0]_{\eta'}/[110]_{Al}$ and $[11\bar{2}0]_{\eta'}/[121]_{Al}$ directions, respectively. (c) and (d). The atomic model viewed from $[0001]_{\eta_2}/[1\bar{1}1]_{Al}$ indicates the relationship of lattice misfits along the $[10\bar{1}0]_{\eta_2}/[110]_{Al}$ and $[11\bar{2}0]_{\eta_2}/[121]_{Al}$ directions, respectively.



Supplementary Figure 3 (a) In the CAF sample, under the $[110]_{Al}$ zone axis, the HRTEM micrograph showed the given precipitate. (b) and (c) The FFT diffractogram from the overall selected area (white dotted frame) illustrates the η_2 in a single precipitate, and the corresponding simulated diffractogram was derived from the orientation relationship with respect to the Al matrix, $(0001)_{\eta_2} // (1\bar{1}1)_{Al}$ and $[10\bar{1}0]_{\eta_2} // [110]_{Al}$.