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## Low-temperature negative thermal expansion in Al doped $\text{La}(\text{Fe},\text{Si})_{13}$ compounds

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Negative thermal expansion (NTE) materials, which contract rather than expand when heated, can be blended with materials showing positive thermal expansion to form composite for obtaining precisely tailored thermal expansion coefficient. Low-temperature NTE materials have wide potential applications in cryogenic engineering. The  $\text{NaZn}_{13}$ -type  $\text{La}(\text{Fe},\text{Si})_{13}$ -based compounds are recently developed as promising NTE materials, the NTE properties of which, in this study, were modified by doping minor Al element in order to make it more suitable for practical applications in cryogenic engineering. The results indicate that the NTE operation-temperature window shifts toward a lower temperature region due to the decrease of the Curie temperature ( $T_c$ ) with increasing the amount of Al element in  $\text{LaFe}_{11.5}\text{Si}_{1.5-x}\text{Al}_x$  compounds. Furthermore, the NTE operation-temperature window of  $\text{LaFe}_{11.5}\text{Si}_{1.5-x}\text{Al}_x$  was broadened with increasing Al content. Such  $\text{La}(\text{Fe},\text{Al},\text{Si})_{13}$  compounds with noteworthy NTE properties in low temperature region promote their potential applications for cryogenic equipments and precise instruments.

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