激光增材制造专用（超）高强韧铁基材料设计及应用

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间隙元素如C、O通常可以提高钢的强度，但由于其易偏聚和析出会导致延展性显著降低甚至脆化。因此，传统理论认为应严格控制（超）高强韧铁基合金中的间隙杂质元素，以减轻其对韧性和耐腐蚀性的不利影响。目前，采用激光增材制造传统（超）高强韧铁基合金存在需极端控制间隙杂质含量，以克服强塑性倒置关系，但所需设备复杂、技术难度大，成本剧增，导致工业应用受限。

南华大学激光先进制造团队将激光熔池快冷特性和金属间隙固溶强化相结合，提出充分利用"激光熔池急冷诱导碳氧杂质元素形成间隙原子短程有序团簇产生显著强韧化效应"的激光增材制造专用铁基材料设计新思路，将C、N、O间隙元素与Cr配位，形成短程有序组合体，研发了高强韧奥氏体钢（强度：800~1100 MPa，延伸率：20~35%）和超高强韧马氏体钢（强度：1500~1800 MPa，延伸率：8~12%）材料，并具有良好的耐腐蚀性能，成功应用到能源化工、重载机械、钢铁冶金、航空航天、核工程等领域大型承力构件的激光增材制造与修复。大幅降低了成本，拓展了激光增材（超）高强韧铁基材料成分设计新区间和应用新领域。

关键词：激光增材制造；（超）高强韧；铁基合金；间隙原子

The strength of the steel could be enhanced by the interstitial elements such as C and O, while their high tendency to segregate and precipitate can lead to a significant reduction in ductility or even embrittlement. Therefore, the traditional theory considers that the interstitial impurity elements in (ultra) high-strength and ductile Fe-based alloys should be strictly controlled to mitigate their adverse effects on toughness and corrosion resistance. Currently, the presence of conventional (ultra) high -strength and ductile Fe-based alloys by laser additive manufacturing requires extreme control of the interstitial impurity content, in order to overcome the strength-ductility inversion relationship. However, the required equipment and technology is complex, and the cost increases dramatically, leading to limited industrial applications. The team combined the fast cooling characteristics of the laser melting pool with the interstitial solid solution strengthening of metals, and proposed a new concept for the design of Fe-based materials for laser additive manufacturing by taking advantage of the rapid cooling of the laser melting pool, in order to induce the formation of short-range ordered clusters of interstitial atoms of carbon and oxygen impurity elements to produce a significant effect of improving strength and toughness. The short-range ordered combinations of C, N, and O interstitial elements were coordinated with Cr to develop high-strength austenitic steel (strength: 800-1100 MPa, elongation: 20-35%) and ultra-high-strength martensitic steel (strength: 1500-1800 MPa, elongation: 8-12%) materials. It has been successfully applied to laser additive manufacturing and repair of large -size load-bearing components in the fields of energy and chemical industry, heavy-duty machinery, iron and steel metallurgy, aerospace, nuclear engineering, etc. The cost has been significantly reduced, and the new intervals of composition design and new fields of application of laser additive (ultra) high strength and ductile Fe-based materials have been widen.

关键词：Lase additive manufacturing；(super) High strength and toughness；Iron-based alloys； Interstitial atoms

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