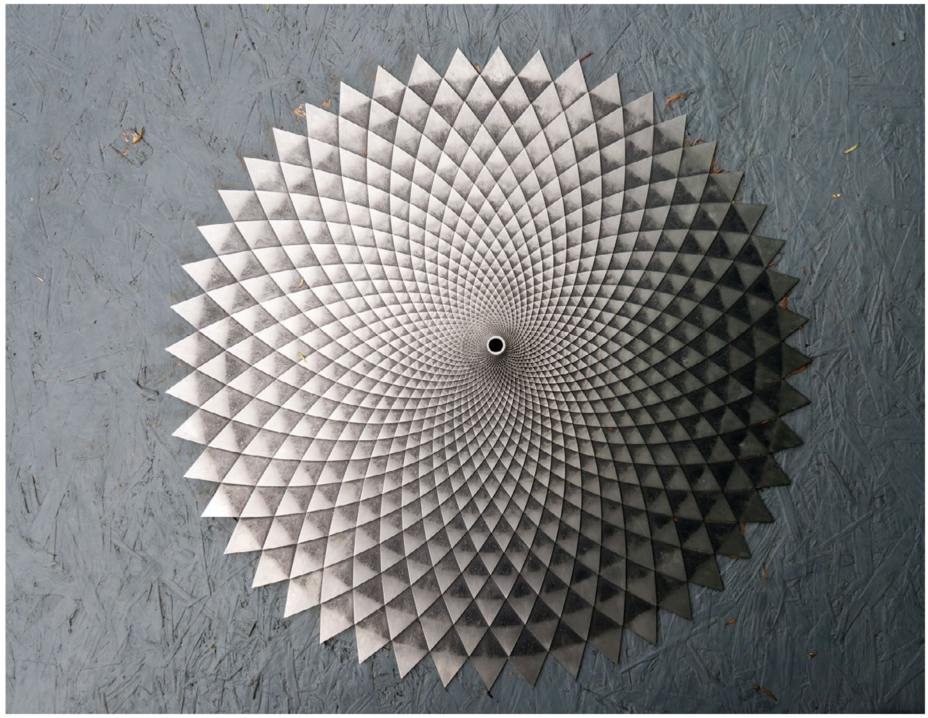
All about alloys

Making useful and interesting alloys depends on the relative concentrations of the elements.



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The concept and benefits of alloying are well known to scientists and non-scientists alike. For a long time, we have been altering the properties of metals by adding a second element, or in some cases, several elements. In one example, discovered just over a century ago, an alloy of iron and nickel — invar — which shows very small expansion or contraction with changes in temperature, was singled out for use in pendulum clocks and other precision devices. Another ferrous alloy, stainless steel (pictured) typically contains just over one tenth chromium as well as a small percentage of carbon. Indeed, many different types of stainless steels, which vary by the precise concentrations of their chemical constituents, are prevalent in our everyday lives.

In this issue of *Nature Synthesis*, we present two studies continuing the quest to make new metallic mixtures with valuable properties by varying the concentrations of an alloy's components. In an Article, Tang et al. report a surface patterning effect resulting from the presence of an infinitesimal amount of one component in an alloy, and in an Article by Wang et al., a method to prepare alloys with up to nine different components in near equiatomic amounts, in only a few nanoseconds, is reported.

Tang et al. observe elegant surface patterns during the solidification of liquid metals, with the most studied alloy in their experiments comprising Ag and Ga. To make the nanoscale patterns, the starting mixture has a very small percentage of one metal (in this case, Ag) within another metal (Ga). The smaller Ag component enriches in certain areas during solidification, leading to phase-separated Ag_2Ga and subsequently the formation of bifurcated patterns. These branched patterns can switch to form simple particulate patterns or converge to form patterns with inverse-bifurcation. The chemical composition, the concentration of the components and the cooling process affect the patterns formed but, as noted in a News & Views by Hendrik Heinz, the challenge lies in fully understanding the formation process and predictability of these surface patterns. With more knowledge, this ability to fine-tune features on the surface of an alloy may be useful in heterogeneous catalysis and corrosion prevention.

Over past centuries, in the industrial domain, only two or three elements were combined to form an alloy, with one metal as the principal component (from which the name of the type of alloy, such as ferrous alloy, was derived). However, in 2004, reports of materials made by the combination of five or more metallic elements, in almost equiatomic amounts, began to show that fascinating properties were possible by mixing a handful of elements in this way[1,2]. The field of high-entropy alloys was born and since, has expanded to include high-entropy oxides, nitrides and bromides, to name a few[3,4].

However, most methods to prepare high-entropy materials require high temperatures and pressures, or an inert atmosphere and, these requirements limit the substrates on which these materials can be formed[5]. Now, in the Article by Wang et al., high-entropy nanomaterials are rapidly synthesized within a laser pulse — a set-up that allows the formation of the nanomaterials on a range of substrates, including thermally sensitive ones. Using their laser scanning ablation method, Wang et al. make a wealth of different high-entropy alloys and high-entropy ceramics.

Though not your conventional materials syntheses, the findings in both papers are welcome additions to the pages of *Nature Synthesis*; showing how the tiniest component of an alloy can have a profound effect on properties, or how in a split-second laser pulse, any of an almost infinite number of alloys may be formed. This ability to yield a vast number of different materials may enable the build-up of data sets on the scale required for machine learning. As these alloys represent the areas of phase diagrams that remain to be investigated, and knowing that concentration means everything in alloys, the task is now to start searching this infinite materials space. ❒

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