Wouter Garot, SILICON, examines the role of bright solution annealing in extending the lifetime of crucial components.

In the ever-evolving world of metallurgical engineering, innovation takes centre stage. One such innovation, known as bright solution annealing, has been quietly transforming industries and extending the lifespan of crucial components. This article delves into the far-reaching implications of this process.

Unlocking the power of bright solution annealing

Solution annealing can be carried out in two distinct environments: air or a vacuum. The choice here carries a significant impact on the end product. In a vacuum, the material retains its brightness, devoid of any surface contamination from oxygen. Conversely, in the presence of oxygen, the material's surface darkens, diminishing its aesthetic appeal and potentially compromising its performance. Additionally, it reduces the diameter due to the formation of the oxide scale, which therefore also reduces the mechanical strength at high temperatures because the cross-section is reduced.

A fundamental aspect of solution annealing lies in the restoration of atomic equilibrium. Visualise atoms as interconnected by strings or rubber bands. In their ideal state, these 'rubber bands' are in perfect equilibrium, ensuring

BRINGING EQUILIBRIUM BACK TO ALLOYS

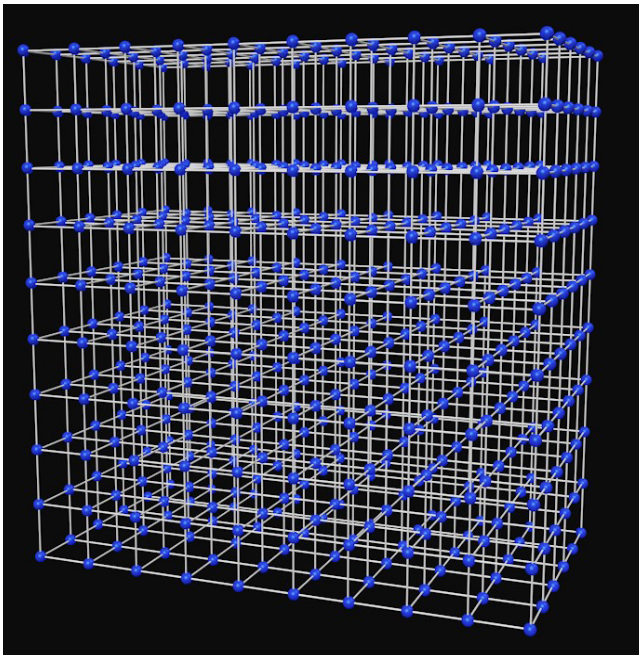

Figure 1. Atoms in a normal state, unaffected by deformation.

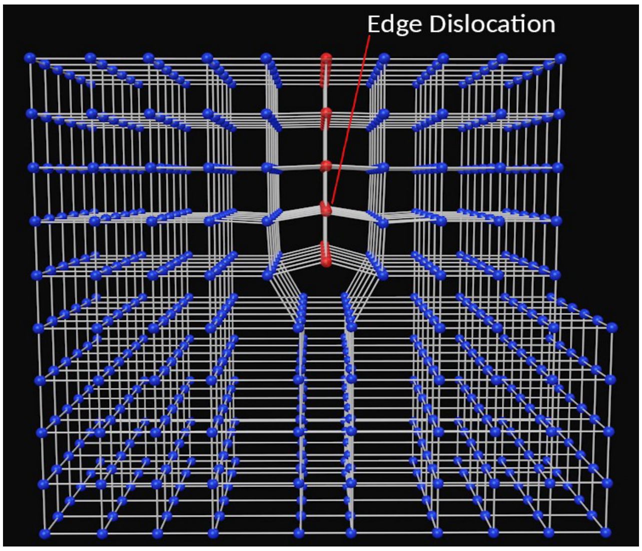

Figure 2. Edge dislocation.

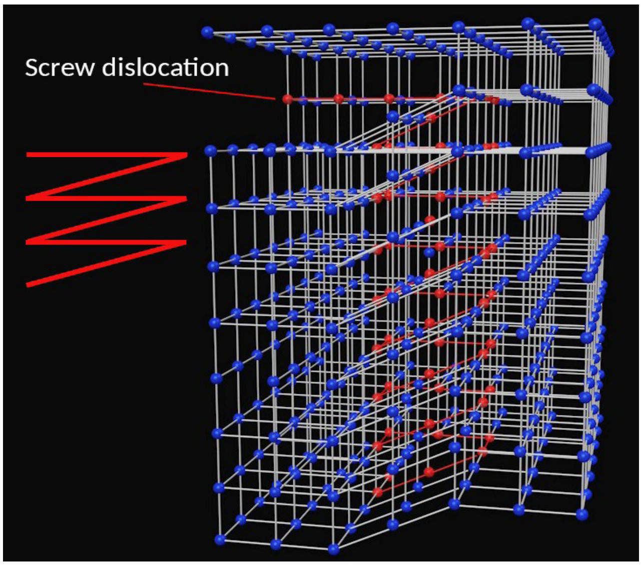

Figure 3. Screw dislocation.

that all atoms are evenly spaced (Figure 1). Solution annealing serves as the catalyst for this transformation. It releases the tension between atoms, creating a tranquil and stable atomic structure – a state of equilibrium ideal for high-temperature applications.

Deformation, akin to stretching or bending the atomic 'rubber bands', induces forces within molecules. These forces manifest as vectors, with some regions under compression and others under tension. Deformation's natural inclination is to return to its original state, but it lacks the necessary energy to do so at room temperature. Solution annealing intervenes, allowing atoms to rearrange themselves, restoring equilibrium.

When a deformation takes place, imperfections are created in the planes of the atomic structure and the physical and the mechanical behaviour of the material is significantly modified. These imperfections are called dislocations, they are complete changes in the standard plane structure. There are various methods in which dislocations occur, depending on the way it is stressed, including shear, pull, bend, edge (Figure 2), and screw (Figure 3).

Tailored temperatures for each alloy

The temperature at which solution annealing occurs is crucial, with each alloy having its unique range. Some alloys necessitate higher temperatures due to their resistance to vibration, while others with larger molecules require additional energy to rearrange themselves. For instance, complex alloys like Inconel 625 require higher temperatures to facilitate atom movement and equilibrium restoration. In addition, different alloys have different soaking times.

Bright solution annealing for enhanced corrosion and embrittlement resistance

Surface tension becomes a critical factor when materials undergo deformation. Deformation increases the stress in materials and, therefore also on the surface. The energy created on the surface is basically unstable and wants to go back to its equilibrium state. The surface tension is automatically high when the material is deformed. Because of this, stressed materials seek to reduce their equilibrium by bonding with corrosive materials in their vicinity, potentially leading to corrosion. However, when materials are in a state of equilibrium, this tendency diminishes, enhancing corrosion resistance.

Figure 4. Sigma Phase formation. Image courtesy of www.rolledalloys.com

The increase in internal stress due to deformation not only triggers corrosion but can also result in embrittlement, particularly in stainless steel. This energy or stress that has been created induces the formation of another crystalline structure called sigma (Figure 4) and can make stainless steel brittle at room temperature, significantly impacting its performance.

Why bright solution annealing matters

Bright solution annealing (BSA) offers numerous benefits, from improved aesthetics to longer-lasting materials. Industries, like the cement industry, apply a lot of refractory anchoring systems that are heavily deformed, and they stand the most to gain from this transformative process. Other industries that already apply it in high quantities include the petrochemical industry.

Cement plants and refineries can substantially reduce failures caused by anchoring issues through bright solution annealing.

Whether due to poor welding, alloy choice, or design, this process can mitigate a wide variety of problems, making it a valuable investment.

Despite initial reluctance from cost-conscious customers, the lasting quality of annealed materials often convinces them of its value.

For example, a cement plant in Turkey was experiencing problems every six months, leading to emergency repairs, resulting in downtime and financial ramifications. When SILICON installed its SpeedBolt® system with the solution annealed material, it lasted four years.

Bright solution annealing is a transformative process that offers significant advantages across multiple industries.

Figure 5. A bright solution annealed anchor after a few turnarounds.

As industries continue to recognise the benefits of bright solution annealing, it is expected that there will be a significant shift in metallurgical engineering practices, with longer-lasting, corrosion-resistant components becoming the new norm.

In order to verify if a material has been bright solution annealed correctly, a hardness test should be carried out on the material. It should be close to the minimum tensile strength that kind of alloy should exert. It should be 'softer' than the original material – a comparison which can be made with the material certificate when it was in its original form. ■

About the author

Wouter Garot, the CEO of SILICON, is a Bath University graduate in Materials Science. He worked with Rolled Alloys Inc. from 1978 – 1984 where he also learnt a lot about metallurgy and the applications of where metals can be used.

In 1982, he established SILICON in The Netherlands. Wouter used his expertise in Materials Science and his experience in applying special high-temperature alloys to develop anchoring systems that were custom-made to suit specific evolving industrial process requirements. He established SILICON to bring his products to European – and ultimately international – markets.