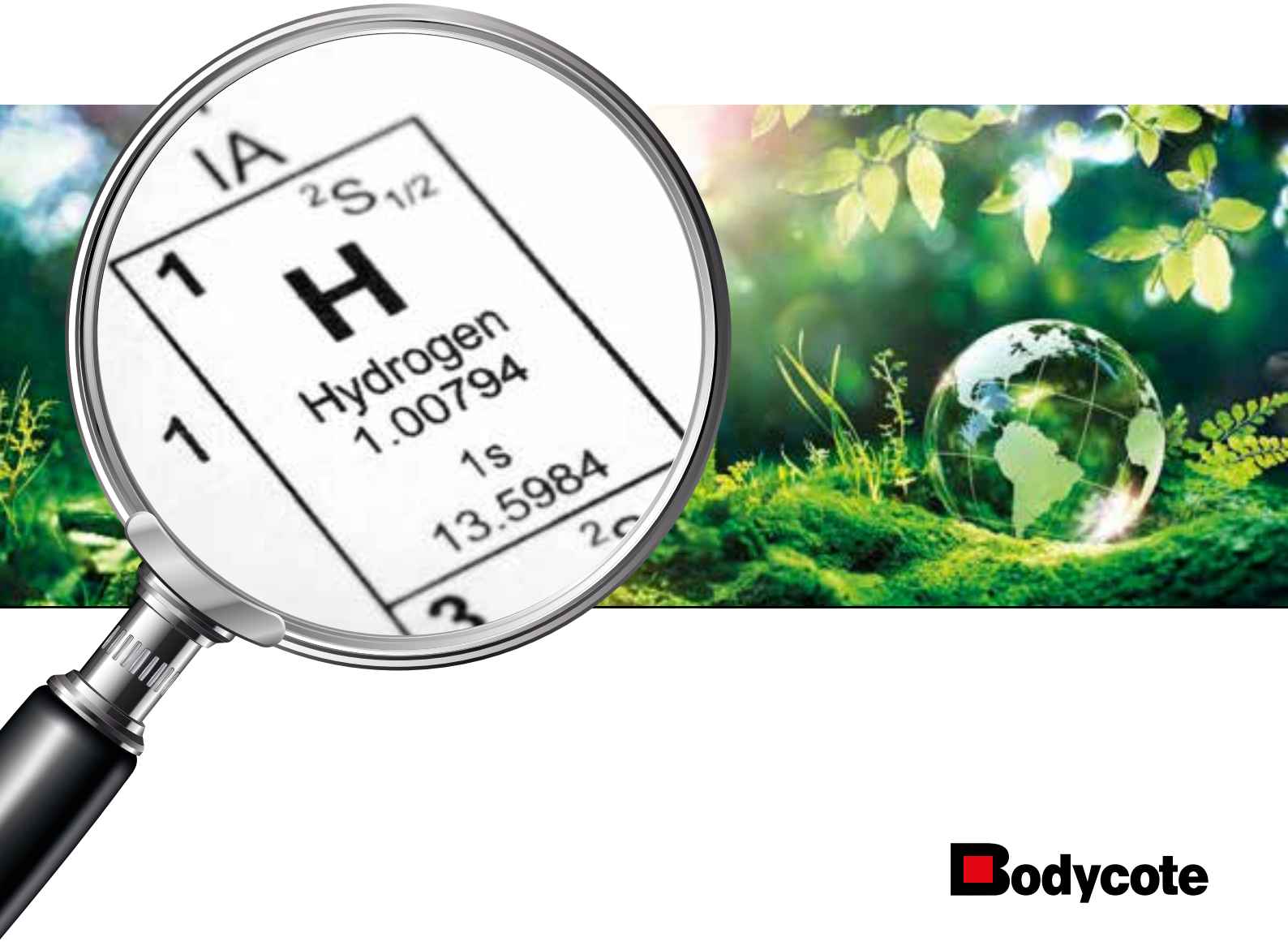
In the SPOTLIGHT

S³P-TREATED STAINLESS STEELS IN HYDROGEN ENVIRONMENTS

- LIMIT HYDROGEN ABSORPTION
- REDUCE HYDROGEN-INDUCED EMBRITTLEMENT
- SECURE SAFE PERFORMANCE UNDER HIGH-PRESSURE HYDROGEN
- MAINTAIN CORROSION RESISTANCE



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S³P – Specialty Stainless Steel Processes
Hydrogen Environments

Hydrogen – A challenge for stainless steels

Hydrogen plays a leading role in the transition from fossil fuels to regenerative and sustainable energy. Nevertheless, it's uptake into the material's microstructure can significantly reduce the ductility and toughness of the metallic raw material. Although austenitic grades are generally considered to be more resistant against hydrogen induced deleterious effects, the microstructure can become remarkably sensitive. Further, the material requirements for such systems (Fig. 1), are much more demanding than for conventional energy systems. Therefore, improving the overall performance is crucial for prolonging component life.

S³P – Speciality Stainless Steel Processes

Bodycote's thermochemical surface treatments S³P featuring Kolsterising® can provide an excellent combination of improved wear and hydrogen embrittlement (HE) resistance. Low temperature surface hardening (< 500 °C) is characterised by diffusion of carbon and/or nitrogen interstitials. The resulting local non-uniformity in the crystalline lattice hinders plastic deformation by impeding dislocation motion through residual compressive stress fields.

Hydrogen solubility reduced with S³P

There is a difference between reversible and trapped hydrogen. Reversible hydrogen will diffuse into interstitial lattice sites and can move freely between them. It is considered to be the main driver for HE.

Austenitic stainless steel 1.4301 (AISI 304) samples underwent S³P-treatment prior to being electrochemically charged with hydrogen in a H_2SO_4-mixture. S³P can significantly reduce the overall amount of absorbed hydrogen compared to the non-hardened state, as shown in Fig. 2. This is particularly significant for the reversible portion, which can be attributed to the high densification of the surface by S³P, acting like a diffusion barrier.

Maintained mechanical core properties

With Slow Strain Rate Tensile (SSRT) tests the influence of hydrogen uptake on the mechanical properties can be evaluated. For this, the elongation values ε of 1.4301 (AISI 304) with and without prior S³P-treatment after electrochemical hydrogen charging have been compared: the elongation value ε for the non-hardened condition decreases significantly after hydrogen charging with a calculated ε_{loss} of 46.7 %; this indicates a high HE susceptibility (Tab. 1). In contrast, for the S³P-treated material, hydrogen charging does not change the elongation significantly. The calculated ε_{loss} is lower with 11.9 %, indicating that S³P can reduce HE phenomena.

Advantages of S³P

- Compressive residual stresses and interstitial atoms can reduce H absorption
- S³P can suppress hydrogen embrittlement (HE)
- Safe long-term performance in hydrogen applications

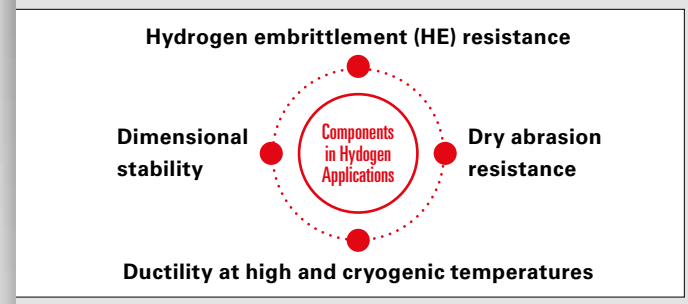

Fig. 1 Requirements of stainless steel components in hydrogen applications

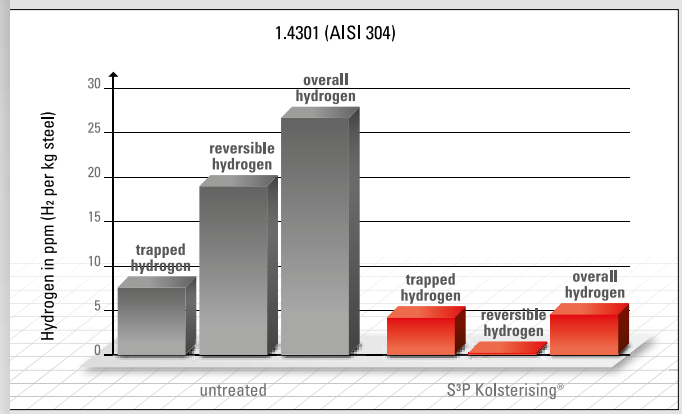

Fig. 2 Overall, reversible and trapped hydrogen content for 1.4301 (AISI 304), without surface hardening (untreated) and with prior S³P, indicating a reduced hydrogen absorption with S³P. Reversible fraction of hydrogen measured based on the glycerol method acc. DIN EN ISO 3690:2018. Trapped fraction analysed by carrier hot gas extraction at 1600 °C.

Condition	Reference	+H	+S³P	+S³P +H
Determined total elongation ε (%)	53.2	28.4	46.7	41.2
Calculated elongation loss by hydrogen ε_{loss} (%)	46.6		11.8	

Tab. 1 Slow Strain Rate Tensile (SSRT) test results of 1.4301 (AISI 304) without (Reference) and with S³P-treatment (+S³P) before and after hydrogen charging (+H). Findings indicate a positive effect of S³P on HE resistance.

Literature:
E. Li et al.: Effect of S-phase on the hydrogen induced phase transition and hydrogen embrittlement susceptibility in AISI 304 stainless steel, in: Materials Today: Proceedings 2-3 (2015) 691-S695

Y. Jiang et al.: Suppression of hydrogen absorption into 304L austenitic stainless steel by surface low temperature gas carburizing treatment, in: International Journal of Hydrogen Energy 44-43 (2019) 24054-24064

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