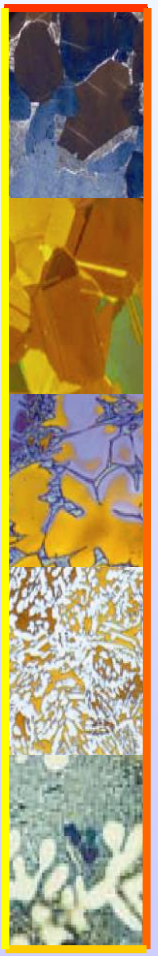
IKA Laboratories (2006) Ltd.

The effect of stabilizing additions on the intergranular corrosion resistance of ferritic stainless steels



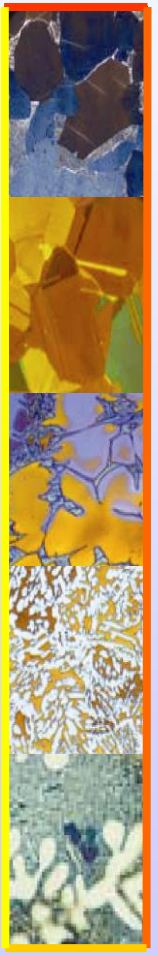
Speaker: Wayne Gordon
(M.Sc. - Materials Science, MBA)

Company: IKA Laboratories

Date: 08 November 2018

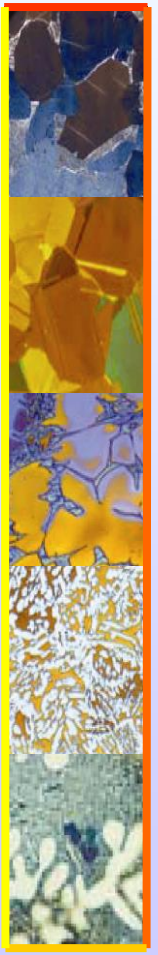
Ferritic SS – the good!

- Ferritic stainless steels (FSS) are the cheapest grade of stainless steels.
- FSS have excellent resistance to C-SCC.
- FSS have excellent corrosion resistance in oxidizing conditions. Better than Hastelloy C in boiling 65% nitric acid.
- FSS have moderate tensile properties.
- FSS have excellent drawability and formability.



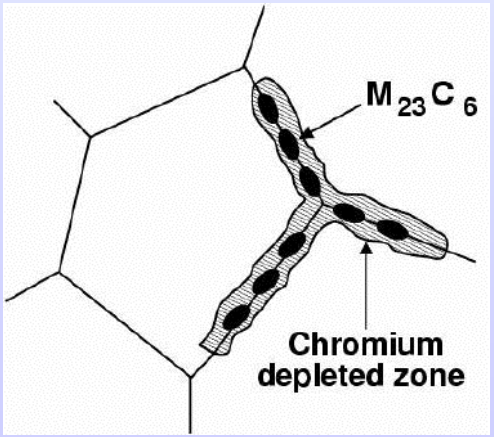
Ferritic SS – the bad

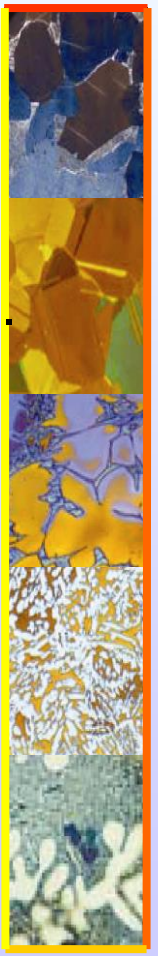
- FSS is limited in strength
  - Cold work drastically reduces elongation
  - Not heat treatable
- FSS are notch-sensitive, which affects their toughness.
  - Industrial grades: DBTT at room temperature.
  - Zone refined Fe-26Cr: Charpy DBTT at -65 ℃.
  - Thin sections: DBTT decreases with section thickness.
- Undesirable strengthening mechanisms
  - Sigma, 475 ℃, high T embrittlement, Chi, Laves
- Poor corrosion resistance in reducing conditions



Ferritic SS – the ugly!

- FSS suffer greatly from sensitization effects.
  - BCC has very low solubility for interstitial elements
  - BCC has extremely slow diffusion rates for substitutional elements
  - $Cr_{23}C_6$ & Cr_2N precipitate on grain boundaries when cooling.
  - Cr-depleted zones adjacent to g.b. precipitates
  - Causes intergranular corrosion

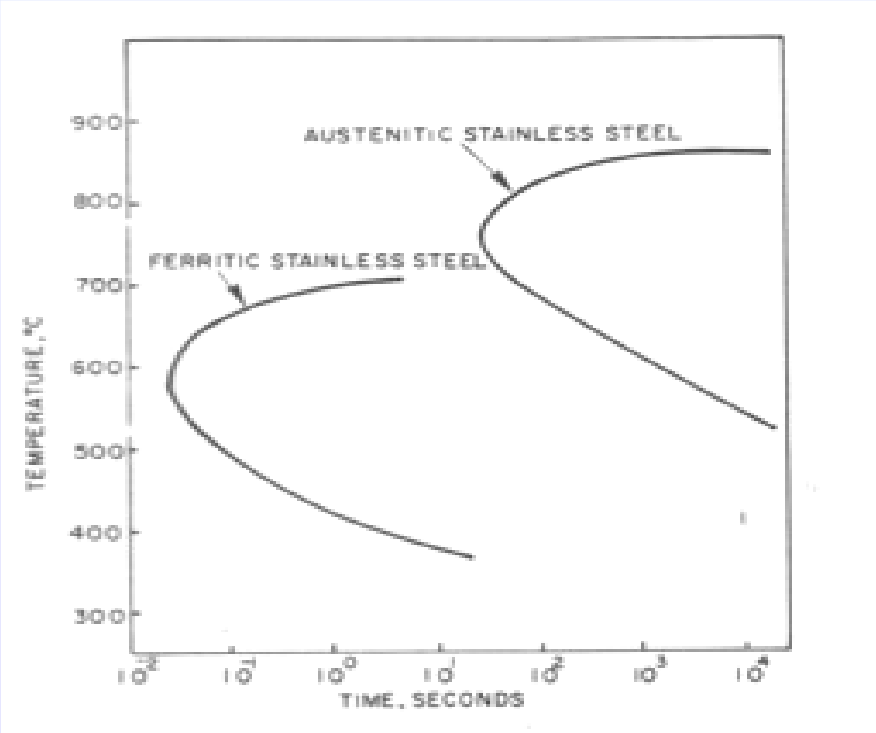


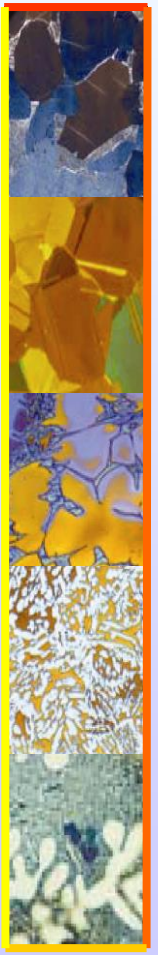


- Sensitization = Industrial problems
  - Significant decrease in weldability.
  - Need very slow cooling rates
  - (furnace cooling) for Cr to diffuse
  - Quenching sensitizes FSS.

Sensitization – TTS curve: Ferritic SS vs austenitic SS

- FSS need fast cooling rate
- De-sensitized by furnace cooling
- Stabilizing elements help

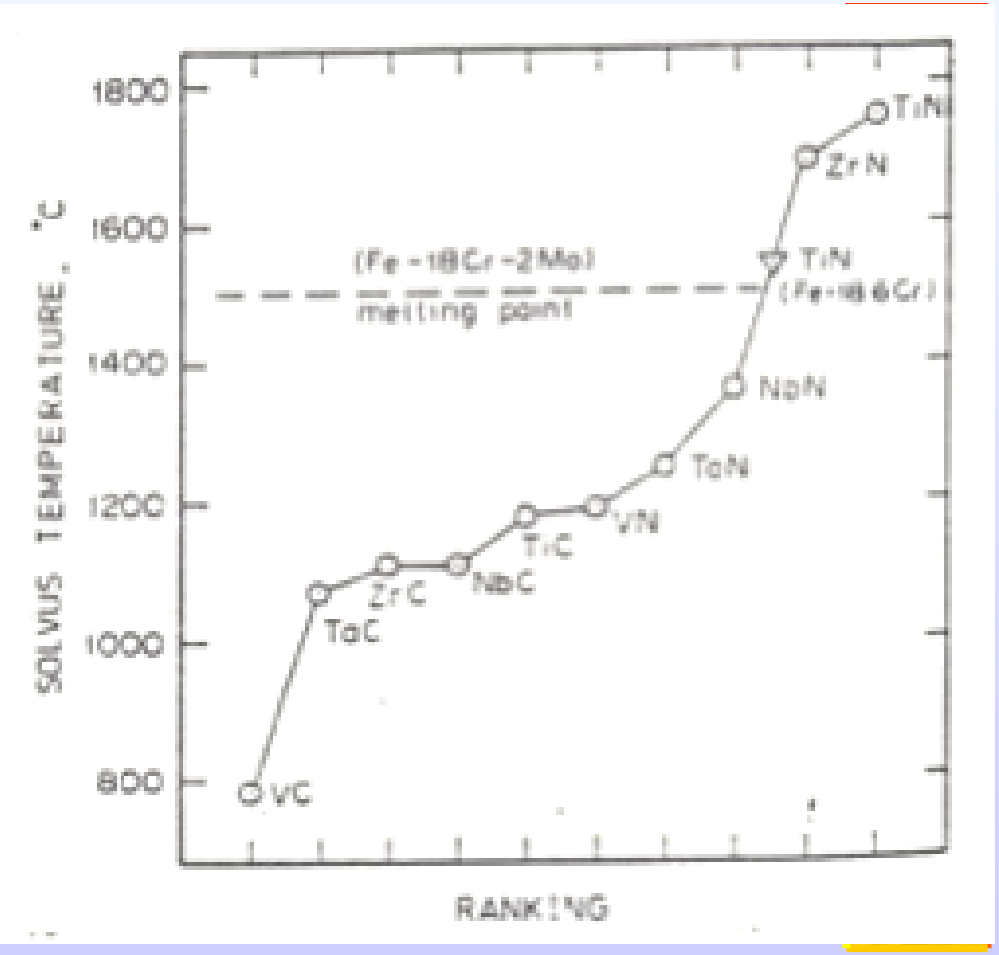




Ellingham diagrams: solvus T ranking

- **Ti** = 4C+3,4N ^{S}
- **Ti** = 0,2+4(C+N) ^{E}
- **Nb** = 7,7C+6,6N ^{S}
- **Nb** = 10(C+N) ^{E}
- **Zr** = 7,6C+6,5N ^{S}
- **Ta** = 27,5(C+N) ^{E}
- **V** = 4,2C+3,6N ^{T}

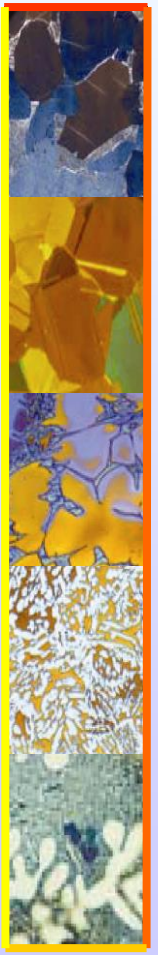
- ^{S} – stoichiometric
- ^{T} – theoretical
- ^{E} - effective



Samples

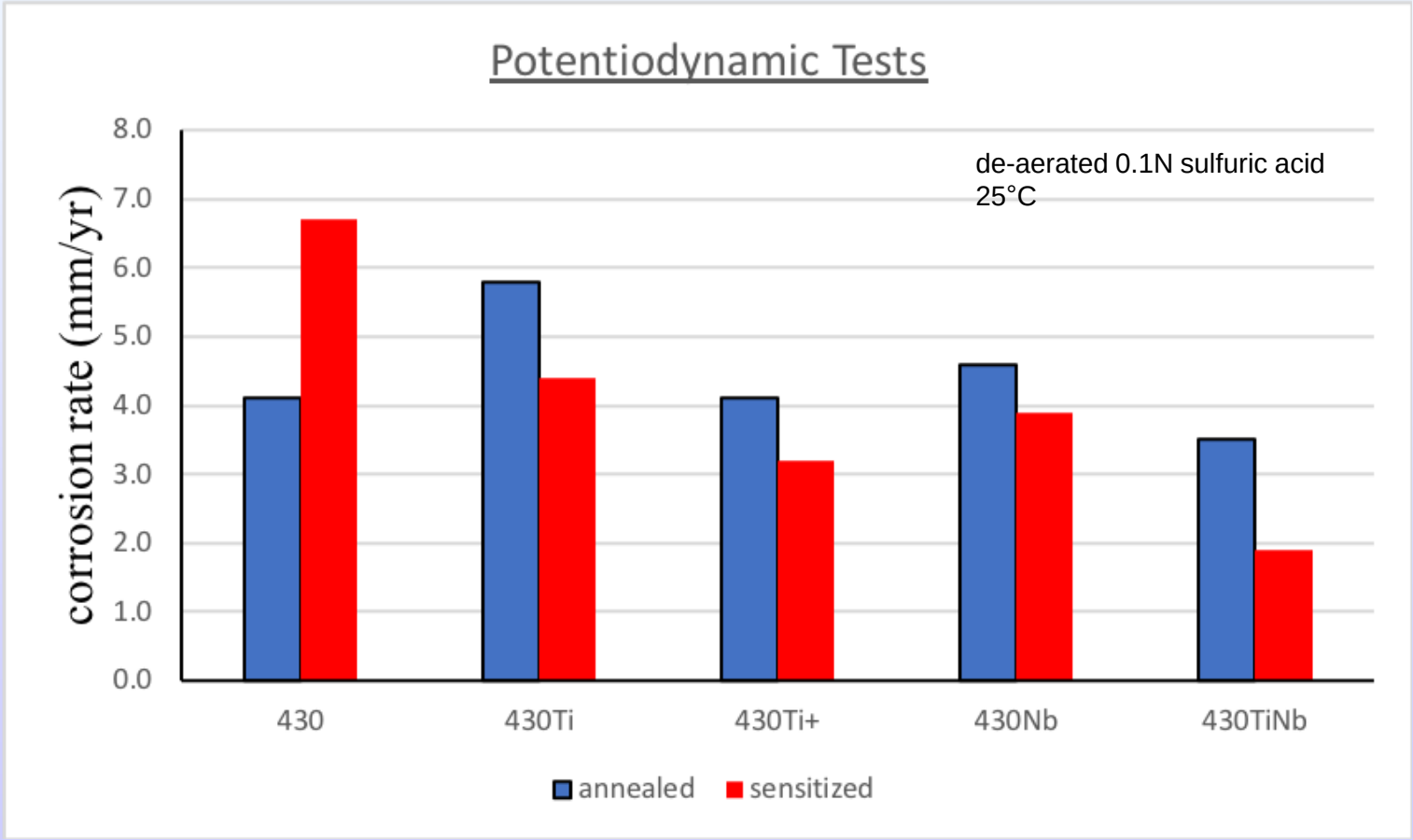
1. Alloy chemistry

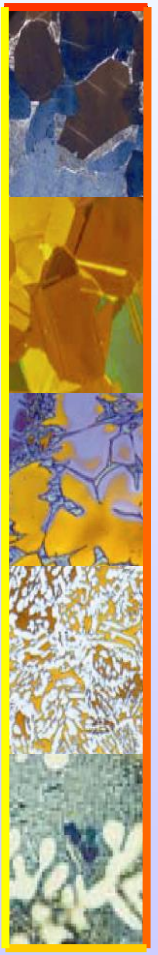
	Cr	C	N	Si	S	P	Others
430	17.1	0.018	0.015	0.52	0.007	0.029	-
430Ti	17.2	0.025	0.015	0.44	0.005	0.018	0.13Ti
430Ti+	17.4	0.020	0.015	0.52	0.006	0.025	0.24Ti
430Nb	17.0	0.017	0.015	0.53	0.005	0.022	0.25Nb
430TiNb	17.2	0.016	0.015	0.54	0.006	0.024	0.12Ti 0.13Nb



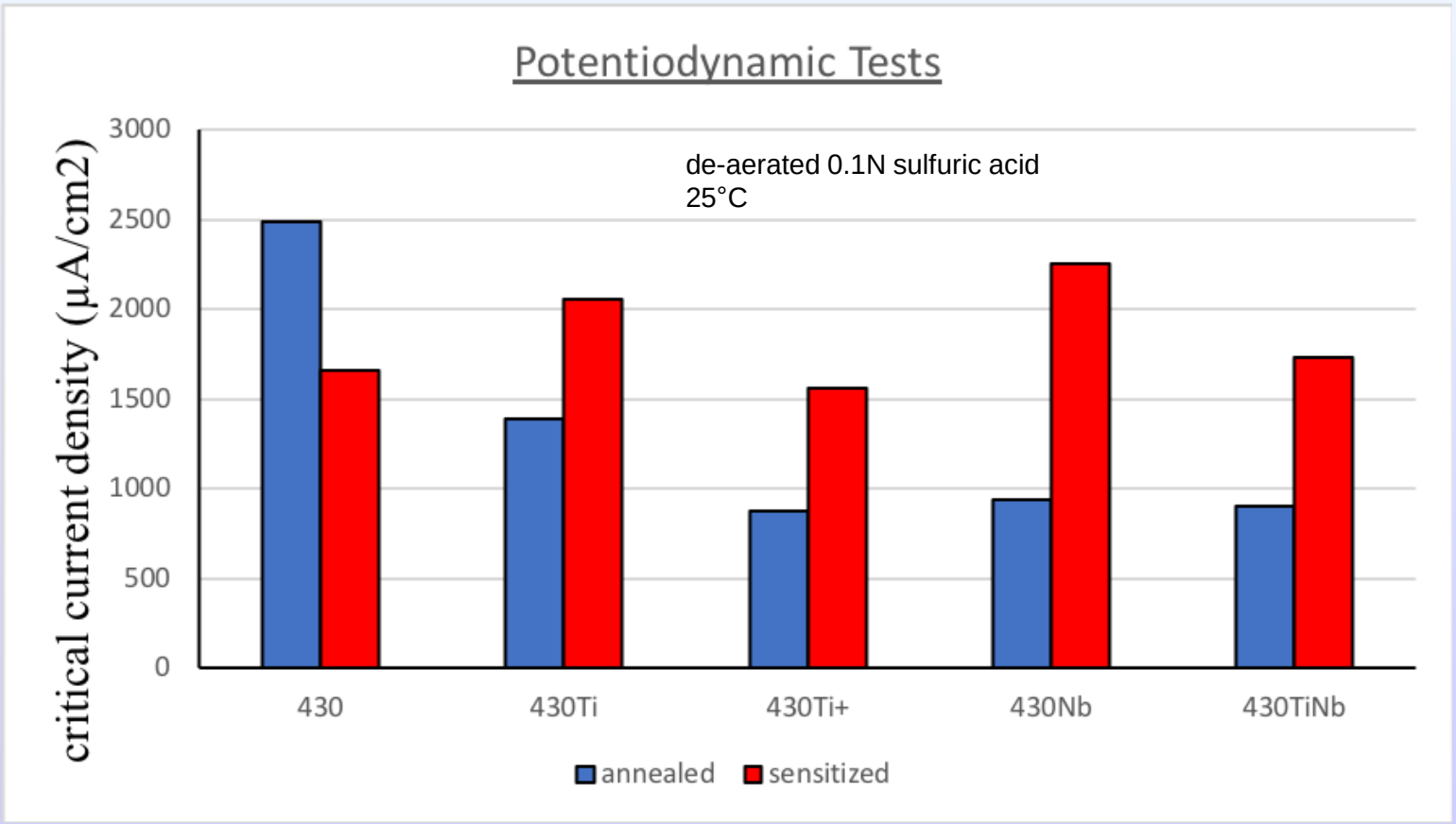
2. Conditions
   a) Annealed (unsensitized)
   b) Heat treated (sensitized)
   c) Welded

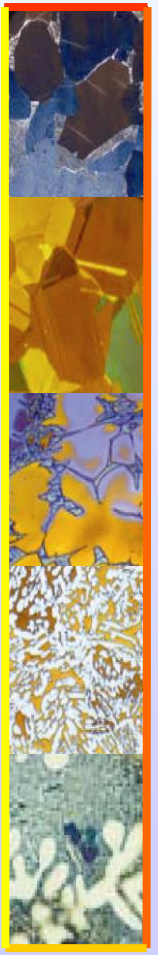
Potentiodynamic Tests



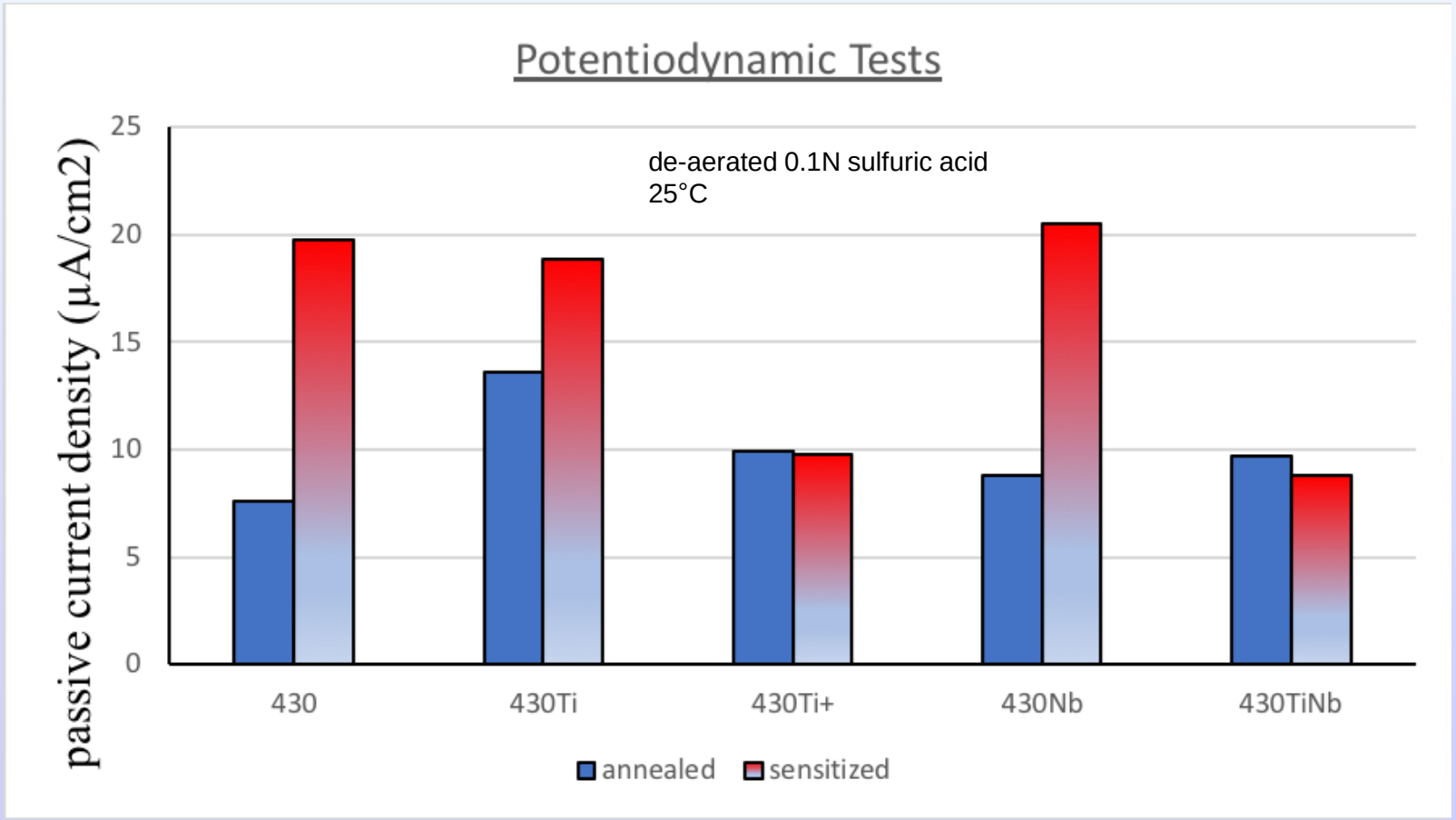


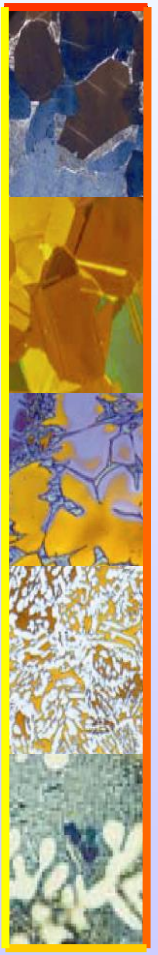
Potentiodynamic Tests



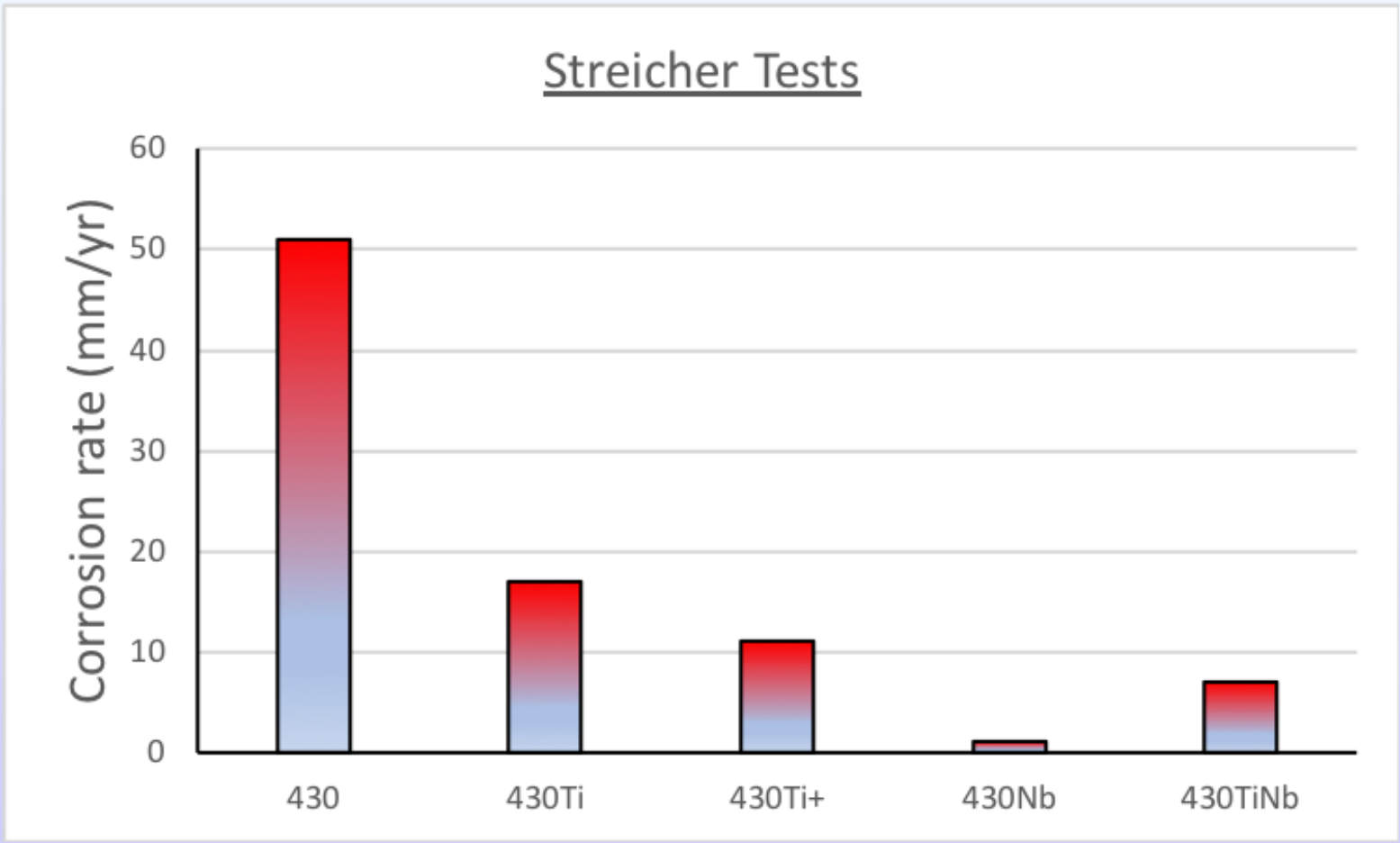


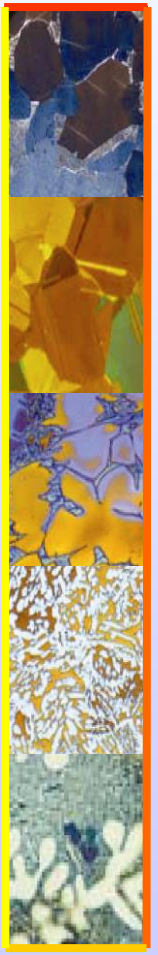
Potentiodynamic Tests



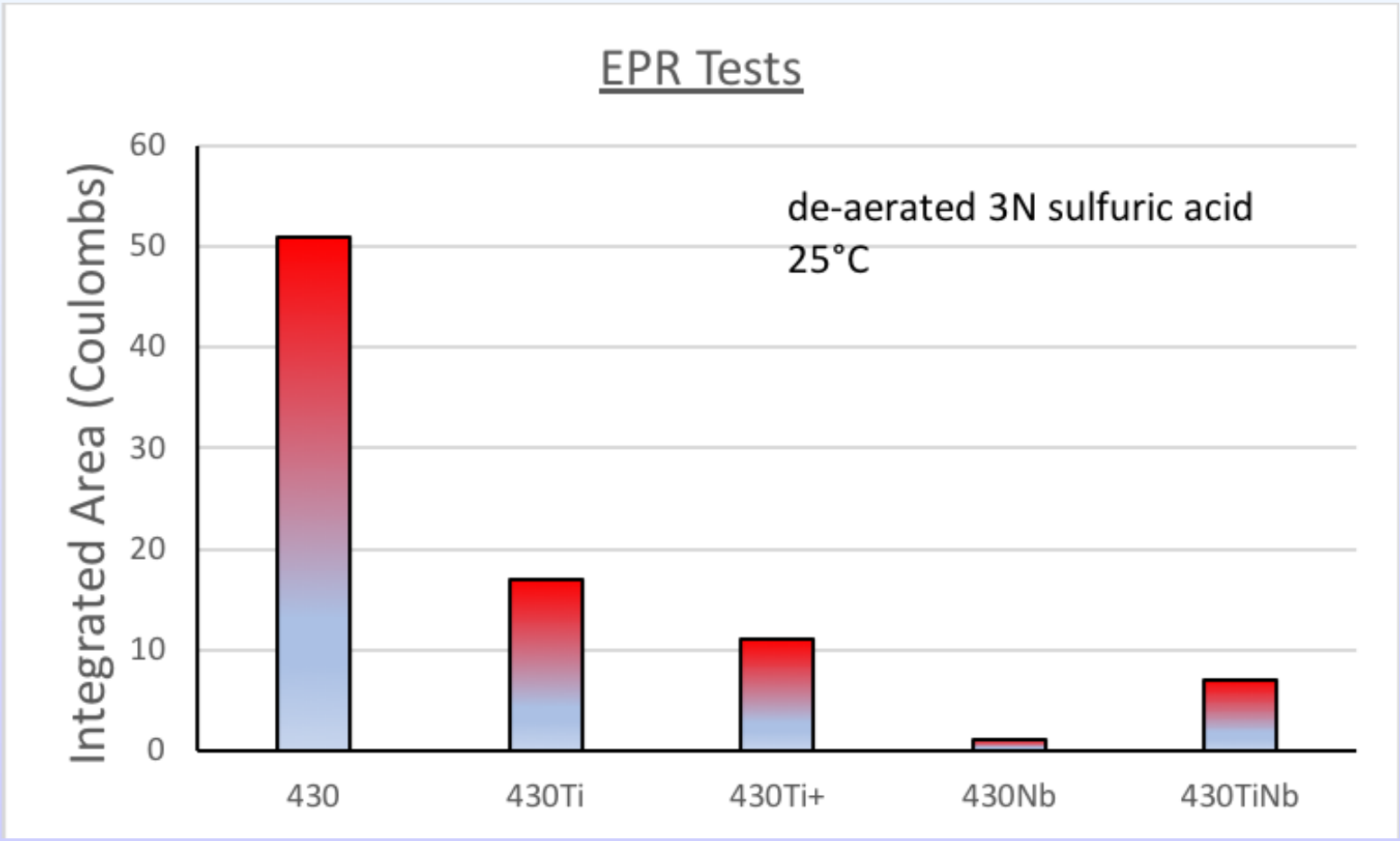


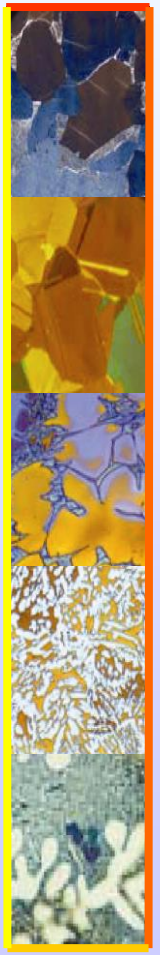
Intergranular Corrosion (Streicher) Tests



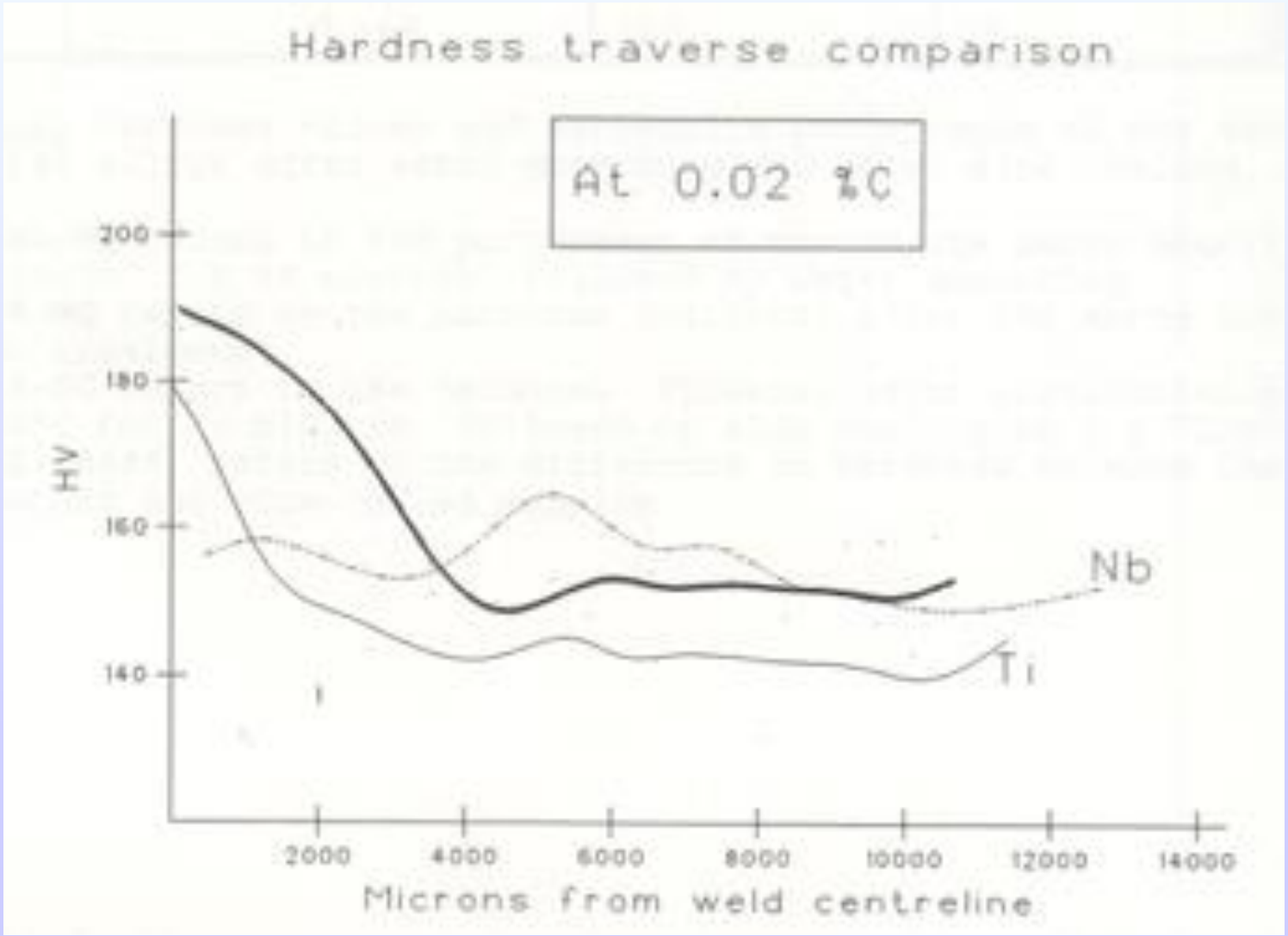


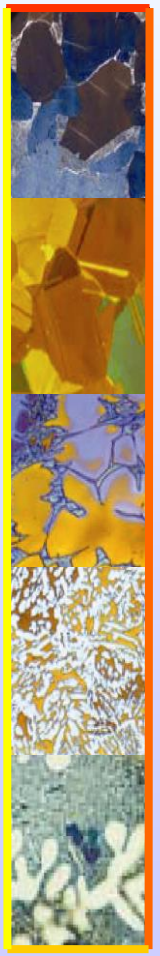
Electrochemical Potentiokinetic Reactivation (EPR) Tests



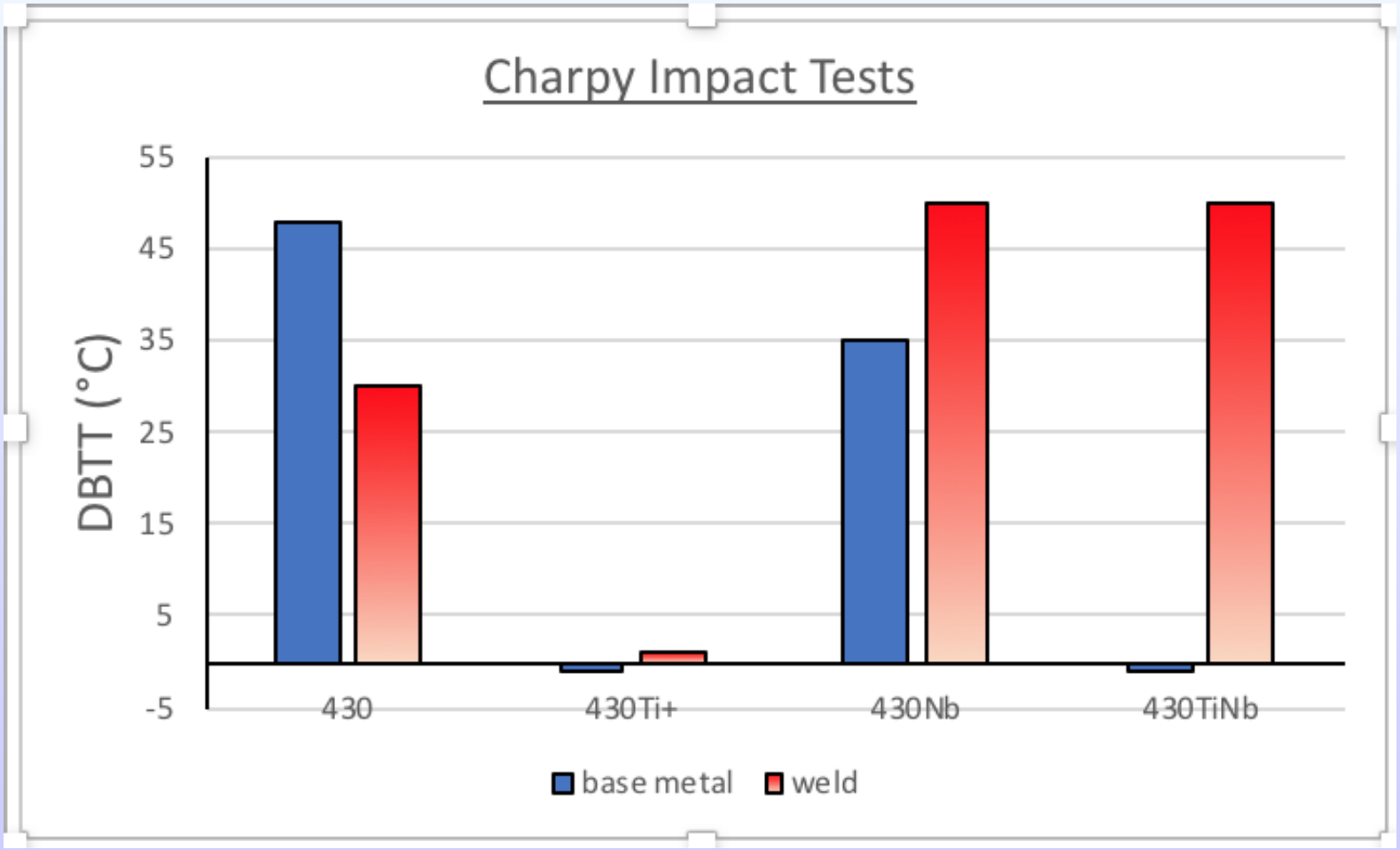


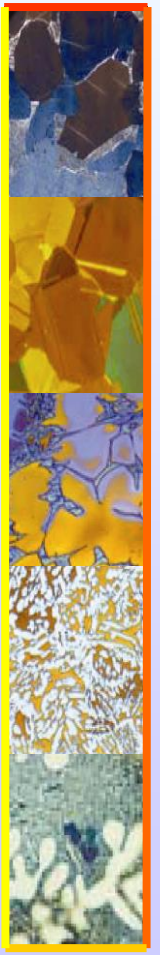
Hardness Profile Tests





Charpy Impact Tests



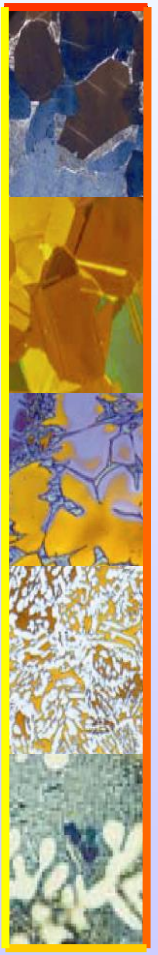


Conclusions

1. FSS can be made resistant to sensitization by stabilization.

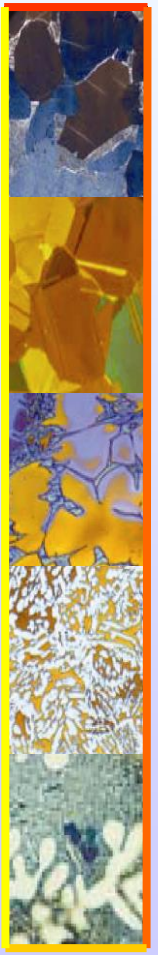
2. Stabilization with Ti, Nb, or Ti+Nb is effective for resistance to sensitization.

3. Stabilization with Nb reduces weld toughness.



IKA LABORATORIES

- Quality Assurance (ISO 17025- Israel Laboratory Accreditation Authority, “Nadcap” - Aerospace, Boeing, Rolls-Royce ….)
- 16 scientists, engineers - experience in Israel & abroad.
- Workshop, mechanical testing, corrosion testing, metallography, chemical analysis, replicas, NDT, SEM and micro-electronics testing.
- Failure Analysis, Reverse Engineering, Consulting Services.



THANK YOU!

- Wayne Gordon

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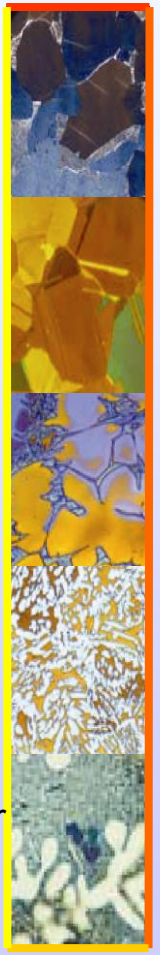

W. Gordon, A van Bennekom. (1996). “Review Of Stabilization Of Ferritic Stainless Steels”, Materials Science And Technology. Institute Of Materials. London. Vol. 12, No. 2. pg. 126-131.

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