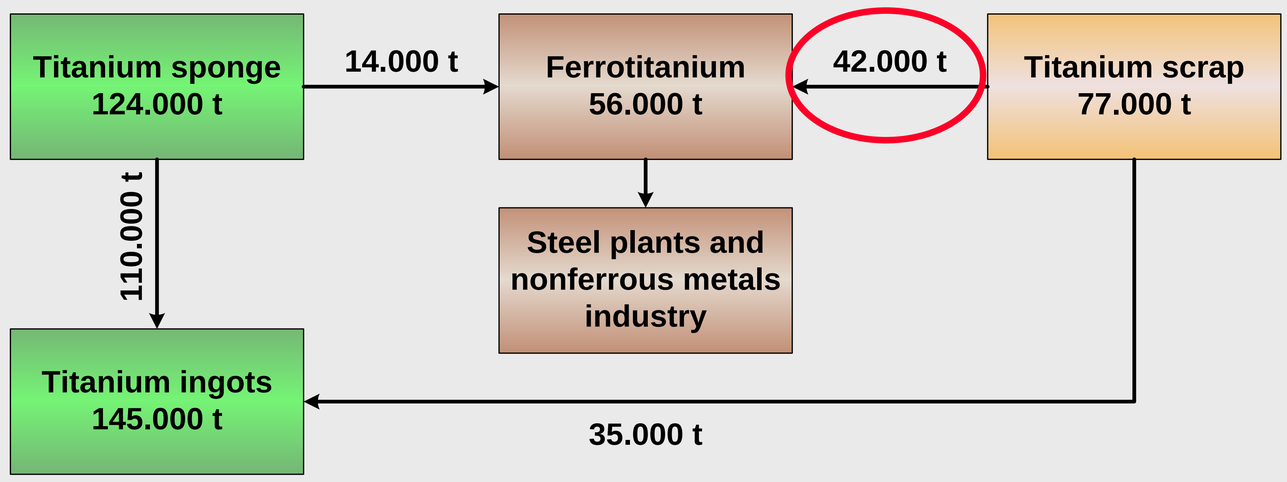
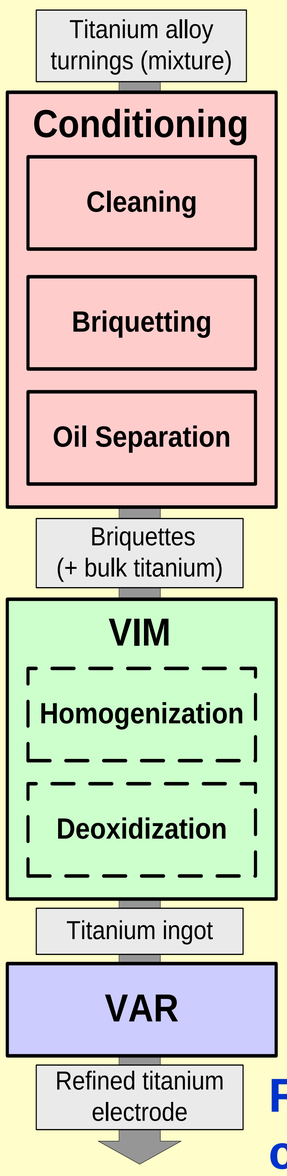
Challenges in Titanium Recycling – Do We Need a Specification for Secondary Alloys?

Background and Motivation

- Due to cost considerations, titanium alloys still play a minor role in mass applications
- Conventional recycling focuses on classified, clean scrap
- Low-grade scrap is downgraded to ferrotitanium alloys



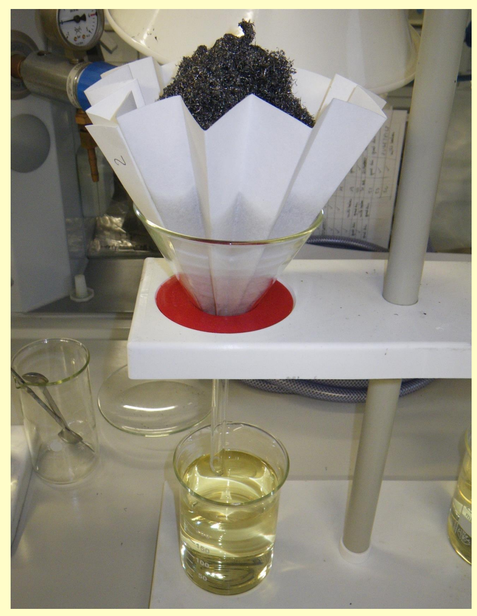
Utilization of the inexpensive low-grade scrap fraction in a recycling process would result in a cost-competitive secondary titanium alloy - however, a new challenge arises with this approach

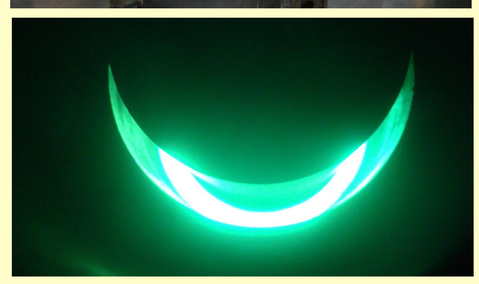


- Removal of lubricants in a 3-step washing process with ethanol to lower carbon contamination
- Briquetting the turnings, enabling inductive coupling and facilitating feedstock charging during VIM
- Removal of remaining volatile impurities by heating up to 400 °C under vacuum

- Homogenization of the feedstock by vacuum induction melting in a CaO crucible
- Deoxidization by introducing $CaAl_2$ into the melt:
  $[O]_{Ti} + [Ca]_{Ti} = <CaO>$ $[O]_{Ti} + \{Ca\} = <CaO>$
- Deoxidization compensates for oxygen pick-up from the crucible

- Calcium and hydrogen degassing during vacuum arc remelting**:**
  $[Ca]_{Ti} = \{Ca\}$ $2\,[H]_{Ti} = \{H2\}$
- Superior solidification structure





Resulting secondary titanium alloy from an examplary scrap mixture and congruency with current titanium specifications (max. concentrations)

Alloy	% in scrap mixture	Al wt.-%	V wt.-%	Mo wt.-%	Cr wt.-%	Zr wt.-%	Nb wt.-%	Fe wt.-%	Sn wt.-%	Si wt.-%	O wt.-%	H wt.-%	N wt.-%	C wt.-%	Ti wt.-%
Ti-6Al-4V	50%	6	4					0,30			0,20	0,01	0,05	0,10	Bal.
Titanium grade 4	25%							0,50			0,40	0,02	0,05	0,10	Bal.
Ti-6Al-2Mo-4Zr-2Sn-Si	10%	6		2		4		0,25	2,00	0,10	0,15	0,13	0,05	0,05	Bal.
Ti-15V-3Cr-3Al-3Sn	10%	3	15		3			0,25	3,00		0,13	0,02	0,05	0,05	Bal.
Ti-48Al-2Cr-2Nb	5%	48			2		2				?	?	?	?	Bal.
Exemplary, polluted Ti-alloy scrap mix	100%	6,30	3,50	0,20	0,40	0,40	0,10	0,33	0,50	0,01	0,80	0,10	0,05	2,00	Bal.
Resulting examplary secondary alloy	**100%**	**6,30**	**3,50**	**0,20**	**0,40**	**0,40**	**0,10**	**0,33**	**0,50**	**0,01**	**0,20**	**0,001**	**0,05**	**0,05**	**Bal.**

Conclusions and Outlook

- Substitution of titanium sponge by inexpensive low-grade scrap is possible in the IME recycling process
- Compliant concentrations regarding the crucial oxygen and carbon levels can be achieved, but utilization of low-grade scrap mixtures implies variation in alloy composition, preventing to meet current Ti-specifications

A new, broader alloy specification is essential in order to open mass-application markets for the resulting secondary titanium alloys

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