Recycled Battlefield Titanium Scrap for Cold Spray Applications

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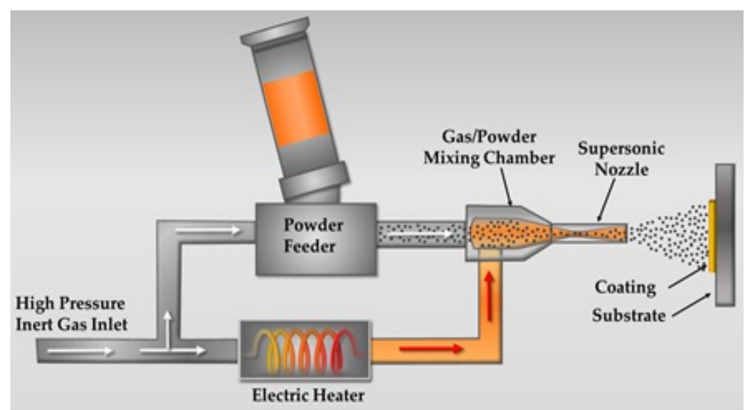
MOTIVATION



Anatomy of the cold spray process and configuration.

To develop a "grave-to-cradle" concept of utilizing materials at the point-of-need to:

- Fabricate parts or repair components to improve operational readiness,
- Overcome traditional supply chain & long-lead time issues
- Reduce the logistics tail of getting spare parts to the battlefield
- Provide a more sustainable materials source

GOAL: *Determine the feasibility of using feedstock powders made from battlefield scrap to develop a trusted source for on-demand recycled feedstock for "in the field" cold spray/AM to support the warfighter, decrease equipment/part downtime, and increase sustainability.*

EXPERIMENTAL APPROACH

Three different recycled titanium powders were provided by the Army Research Laboratory (ARL) for characterization using various methodologies (given below). The recycled titanium was sourced from commercially pure titanium AM build plates and alloyed titanium used to protect armored vehicles. The Greyhound Mobile Foundry, developed by MolyWorks Corporation, was utilized to gas atomize the scrap material into AM-grade metallic feedstock powder of various size distributions. Prior to deposition, all powders were examined and compared based off their composition. Powders were characterized at Worcester Polytechnic Institute (WPI) in the Cote Research Lab.

Sample ID #	Powder Type	Material Sourcing
1	Scrap Ti CP	CP Ti AM build plates used by ARL
2	Scrap Ti Armor Alloy	Ti armor from armored vehicles
3	Scrap Ti Blend	Blended mixture of scrap Ti CP & Ti armor alloyed together

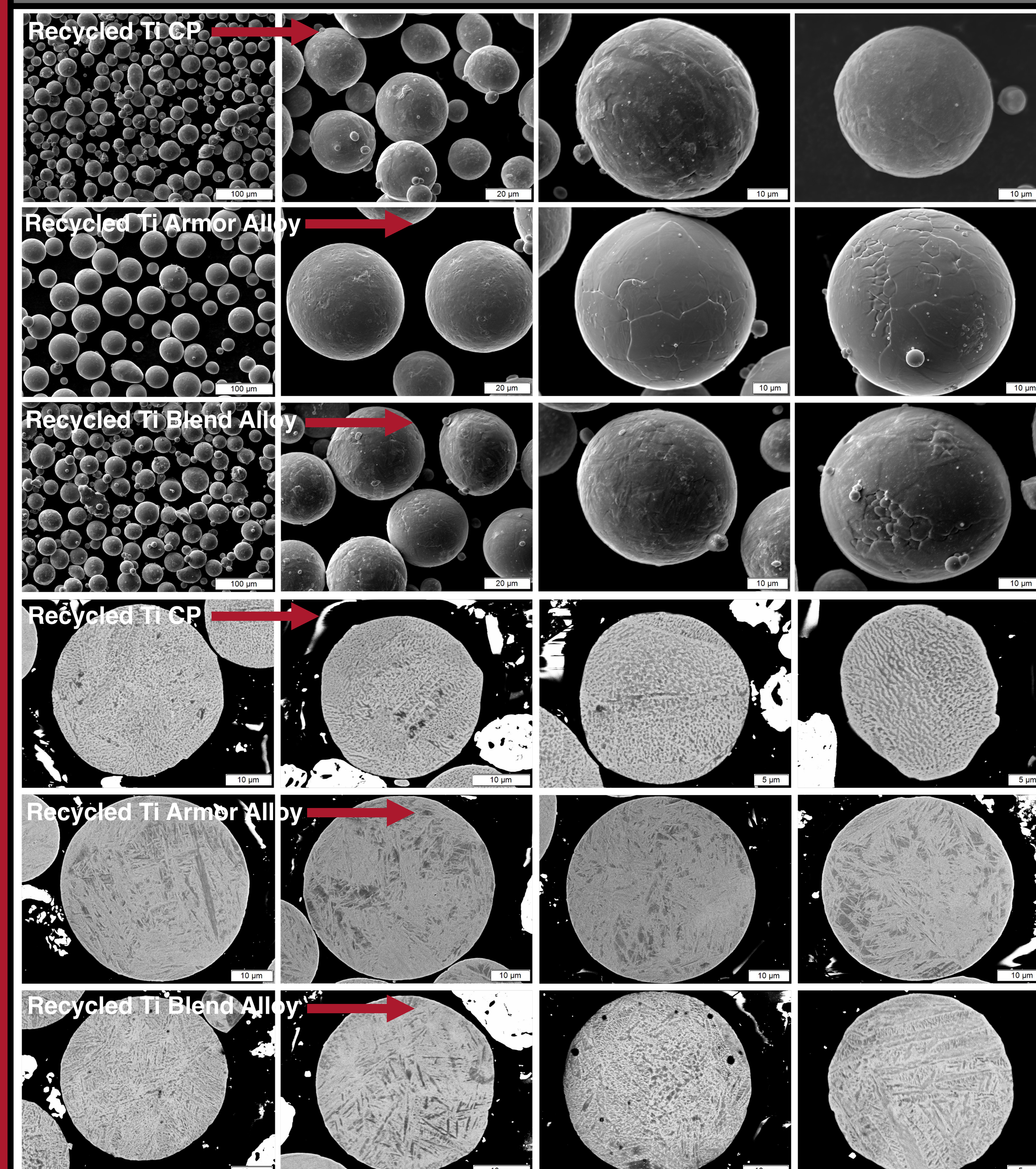
Pre-Deposition Feedstock Characterization

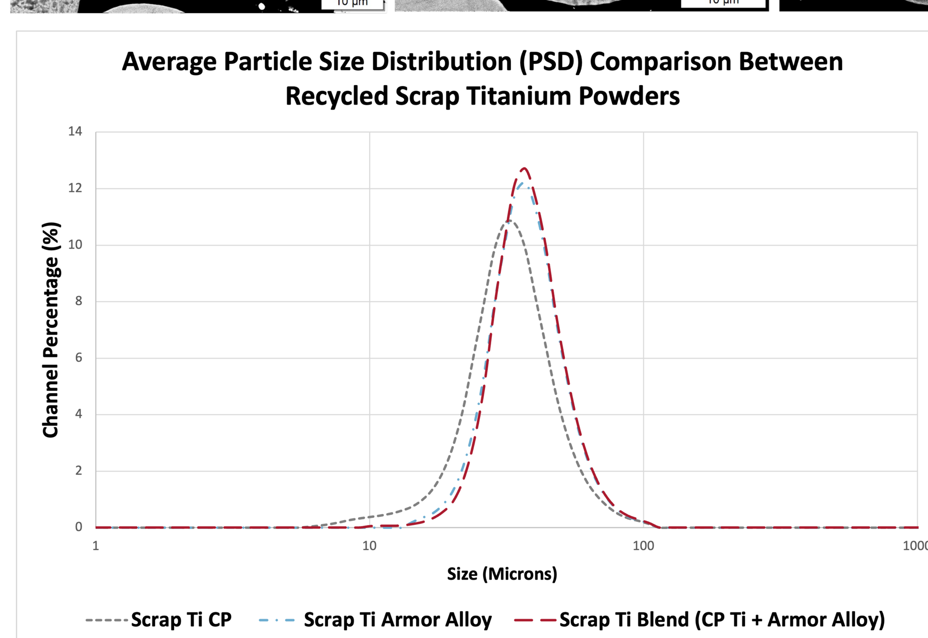
- **Karl Fischer (KF) Titration** for moisture analysis
- **Nanoindentation** to obtain hardness and modulus
- **Particle compression** to estimate ultimate tensile strength (UTS)
- **Scanning electron microscopy** analysis
- **Powder particle compression** to obtain powder compression strength
- **Particle size distribution** (PSD) analysis
- **Oxygen, nitrogen, & hydrogen** (ONH) content analysis

Post-Deposition Consolidation Characterization

- **Indentation plastometry** to obtain engineering stress-strain curves and plasticity parameters
- **Nanomechanical mapping** to measure the percent dynamic recrystallization + degree of mechanical integrity
- **Porosity quantification**
- SEM/EDS & XRD **phase analysis**
- Comparison of mechanical properties of each consolidation for **process parameter optimization**

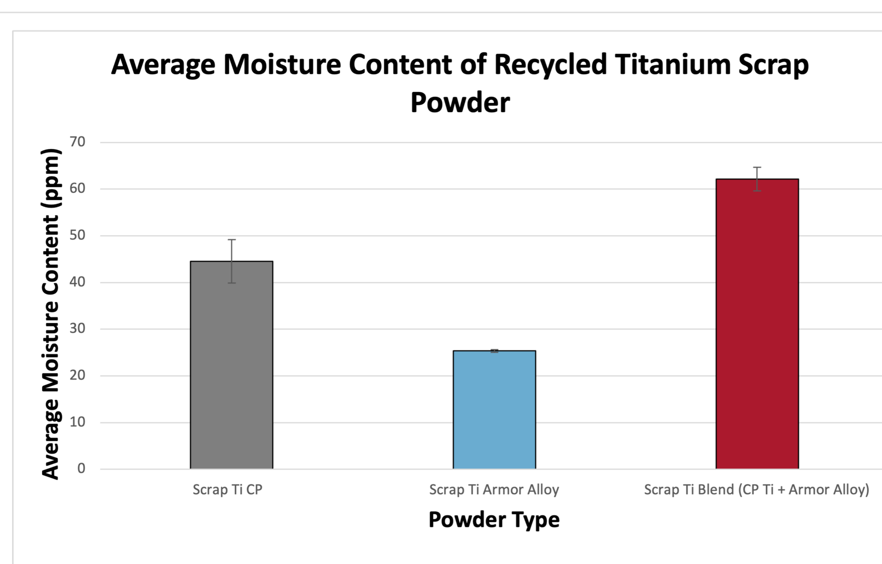
RESULTS





Size Spacing

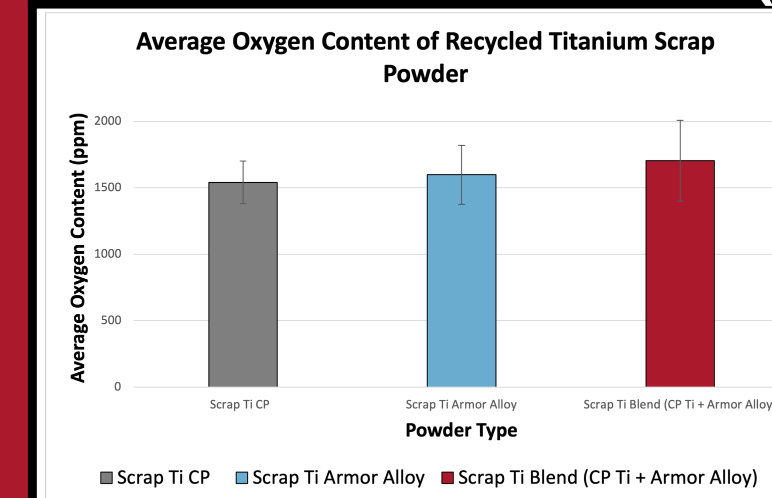
Powder Type	D10 Size (µm)	D50 Size (µm)	D90 Size (µm)
Scrap Ti CP	23.78	35.92	50.27
Scrap Ti Armor Alloy	24.29	39.14	53.51
Scrap Ti Blend (CP Ti + Armor Alloy)	26.77	36.6	48.67

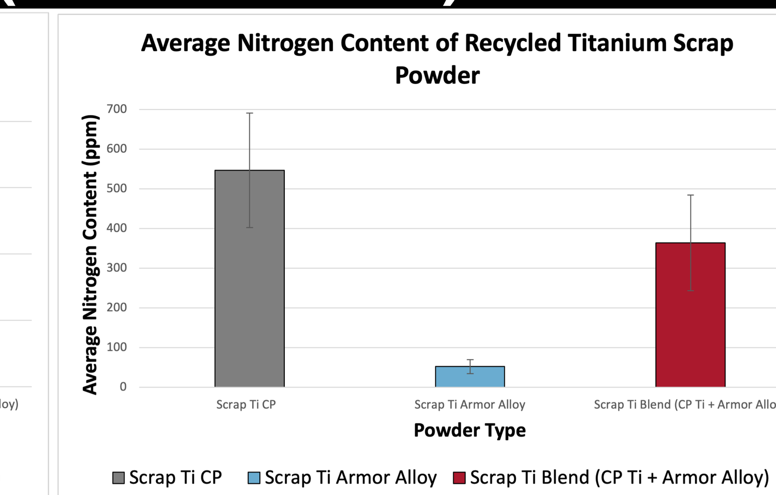


Moisture Content

Powder Type	Average Moisture Content (ppm)	STDV
Scrap Ti CP	44.55	4.61
Scrap Ti Armor Alloy	25.37	0.297
Scrap Ti Blend (CP Ti + Armor Alloy)	62.18	2.53

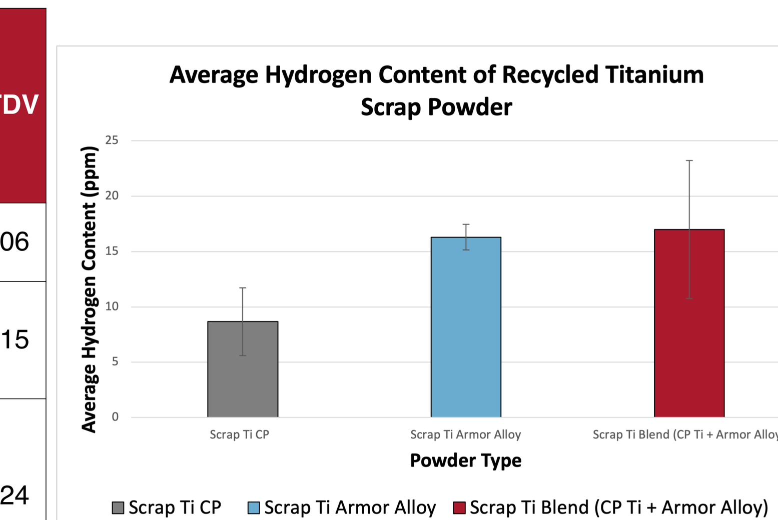
RESULTS (CONTINUED)

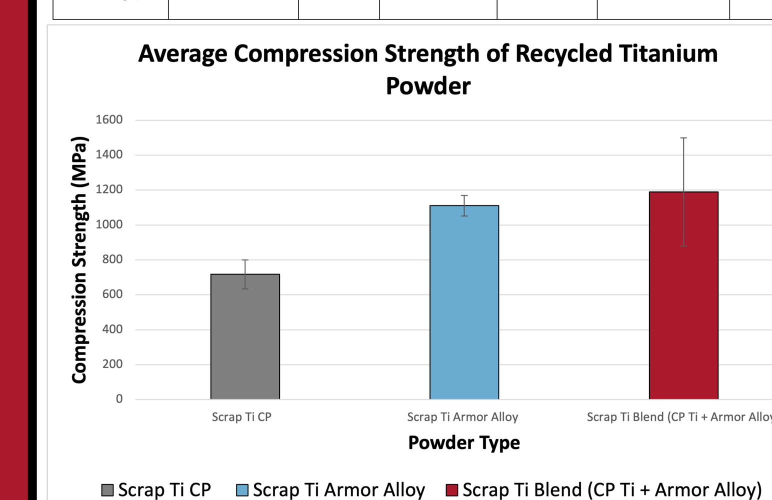




ONH Content

Powder Type	Average Oxygen Content (ppm)	STDV	Average Nitrogen Content (ppm)	STDV	Average Hydrogen Content (ppm)	STDV
Scrap Ti CP	1541	161.2	547	144	8.67	3.06
Scrap Ti Armor Alloy	1599	222.2	52.6	17.6	16.3	1.15
Scrap Ti Blend (CP Ti + Armor Alloy)	1704	303.8	364	120.2	17	6.24





Particle Compression Strength

Powder Type	Average Compression Strength (MPa)	STDV
Scrap Ti CP	717.8	82.7
Scrap Ti Armor Alloy	1110.9	58.6
Scrap Ti Blend (CP Ti + Armor Alloy)	1189.8	308.7

FUTURE WORK

Feedstock Powder Characterization

- Nanoindentation
- Powder rheology (flowability)
- Cross-sectional polishing and microstructural analysis
- X-Ray Diffraction (XRD) phase anlaysis
- Profilometry-based Indentation Plastometry (PIP)

Bulk Cold Spray Consolidations

- Optimize cold spray parameters for "point-of-need" repair using VRC Gen III and SPEE3D CSAM systems
- Determine pre-deposition powder heat treatment (if necessary)

Post Deposition Coating Characterization

- SEM/EDS
- Nano/micro-indentation
- Porosity quantification
- ONH quantification
- Profilometry-based Indentation Plastometry (PIP)
- Ballistic/impact testing

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