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Tensile properties of polyamide 12 / black with 10wt.% copper samples manufactured by laser powder bed fusion

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Abstract: In laser powder bed fusion (L-PBF) of polymers, a proven material for biomedical applications is Polyamide 12 (PA 12) that is used for production of functional prototypes and end-use parts. The aim of this study is to investigate properties of in situ copper-modified polyamide (Sintratec PA12/B) at 10 wt.% Cu by L-PBF. Polymer-metal composites test samples were evaluated for their porosity, Cu distribution and tensile properties.

I. Introduction

Main benefits of additive manufacturing (AM) are design freedom, possibility to combine many parts in one without assembling, waste minimization, shorter time in the chain “idea – design – realization – prototyping - properties optimization - small series production – market”. In laser powder bed fusion, in-situ modification of powder is another advantage that can be implemented. This can reduce cost and accelerate production providing more efficient manufacturing products with required properties.

The enhancement of polymer properties in terms of improvement hardness, scratch and wear resistance, coloration, implementation non-flammable properties, changing electrical or thermal conductivity can be done by fillers: particles and fibers. Minerals, metals, ceramics, bio-based materials, gases, liquids, and even other polymers can be used. As it was noted in [1], “the use of fillers can revolutionize the plastic industry”.

Since pure Cu has anti-bacterial properties, polyamide-copper L-PBF parts will address of providing a protective barrier for infections in biomedical applications.

II. Material and methods

L-PBF samples were manufactured with a desktop Sintratec S1 3D printer. For all experiments, standard process parameters recommended by Sintratec AG for PA12/B powder were used. PA12/B powder from Sintratec has anthracite color. An average particle size was 60-100 µm. A 70% virgin and 30% used black PA12/B powder from Sintratec was used. The employed Cu (–45 µm) (TLS Technik GmbH & Co. Spezialpulver KG) powder has 99.9% purity. A maximum size of Cu powder was compatible with average size of PA12/B powder. A 10 wt.% Cu powder was added to the PA12/B and mixed in the horizontal rotating drum mixing station for 5 hours at 60 rpm to insure homogenous distribution. The material preparation was performed at room temperature.

Six tensile specimens were produced in XY direction and 6 samples in YZ direction. Specimen dimensions were in accordance with ASTM D638-14 standard (Type V). Tensile tests were performed with MTS Criterion universal testing machine. Optical and SEM microscopy, X-ray tomography were performed to evaluate the distribution of Cu particles, porosity and surface fractures.

III. Results and discussion

Experimentally observed mechanical properties are summarized in Fig.1. Ultimate tensile strength of PA12/B samples built in XY and YZ directions was 47-48 MPa that is compatible with pure PA 2200 samples, but elongation at break of PA12/B samples was lower: 10-13% versus 18% typical for white PA 2200 samples [2]. It was found that as-built PA12/B samples had no statistically significant difference (*t-test*, $p<0.01$) in respect of building direction in yield strength, ultimate tensile strength, modulus of elasticity and elongation.

As can be seen from Figure 1, differences in the mechanical properties of pure PA12/B samples with PA12/B + 10 wt% Cu was only in higher standard deviation. In situ modified L-PBF composite samples were more brittle in comparison with PA12/B samples.

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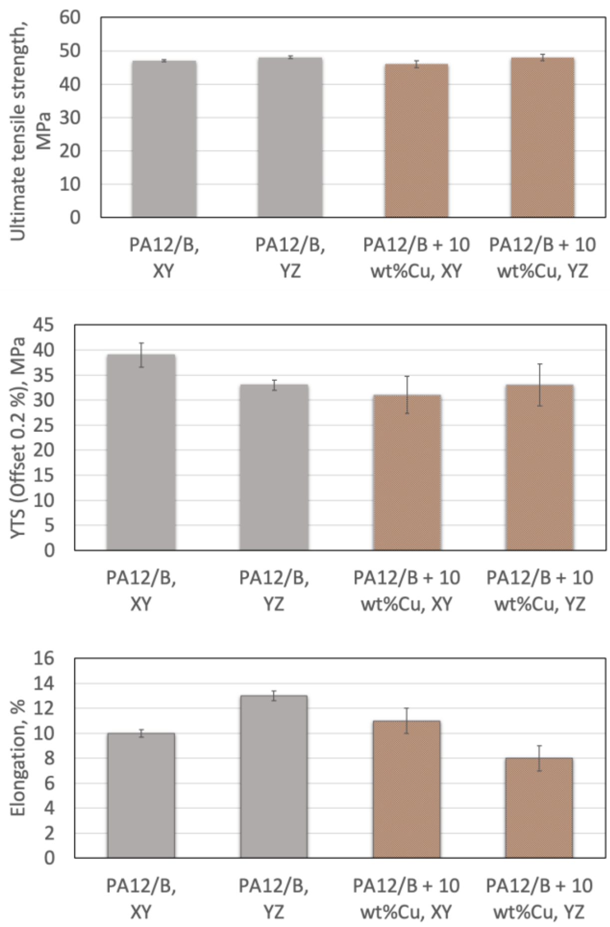

Figure 1: Tensile properties of L-PBF samples.

Figure 2 presents typical fractures of L-PBF samples from PA12/B without and with Cu addition. Samples from PA12/B powder had dimples as well as brittle areas like semi-sintered particles that was decisive factor for lower ductility of PA12/B samples in comparison with PA2200 samples. PA12/B with 10 wt.% Cu composite samples had Cu particles incorporated to PA12/B matrix that decrease ductility of composite samples. Composite specimens manufactured in YZ direction showed more brittle behaviour and lower elongation to failure. Poor particle-matrix adhesion for big Cu particles can cause lower ductility of these samples (Fig. 2b).

No significant segregation of Cu particles was found by CT scans of samples (Figure 3). Samples were solid, without visible porosity.

IV. Conclusions

In situ modified PA12/B with 10 wt.% Cu samples manufactured by L-PBF shows ultimate strength compatible with samples manufactured without Cu. Lower ductility in YZ composite samples in comparison with XY samples indicated that scaffoldings or fine parts could be manufactured preferably in XY direction.

Further studies on antibacterial properties of these material will be done.

Acknowledgments

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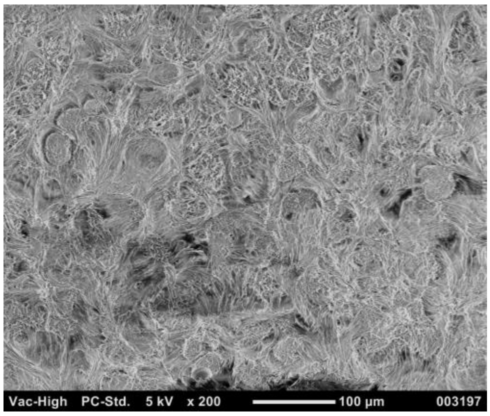

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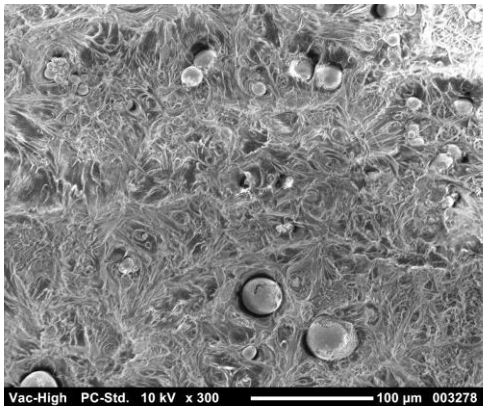

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Figure 2: Typical fracture surfaces of XY PA12/B (a) and YZ PA12/B with 10 wt. % Cu XY samples (b).

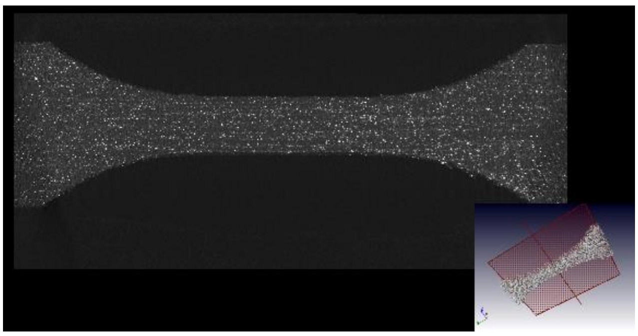

Figure 3: Cu particles (white color) in PA12/B matrix (gray color). YZ PA12/B-10 wt.% Cu sample is shown.

Author's statement

Conflict of interest: Authors state no conflict of interest.

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