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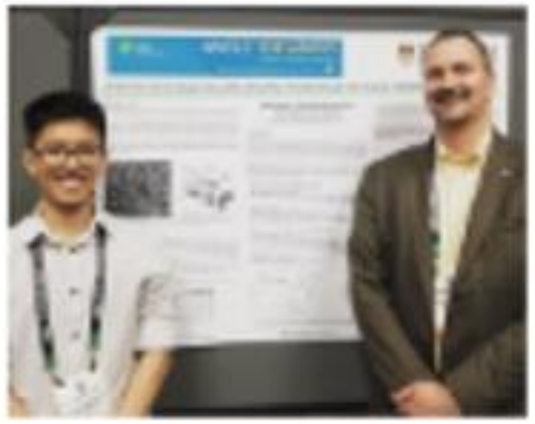
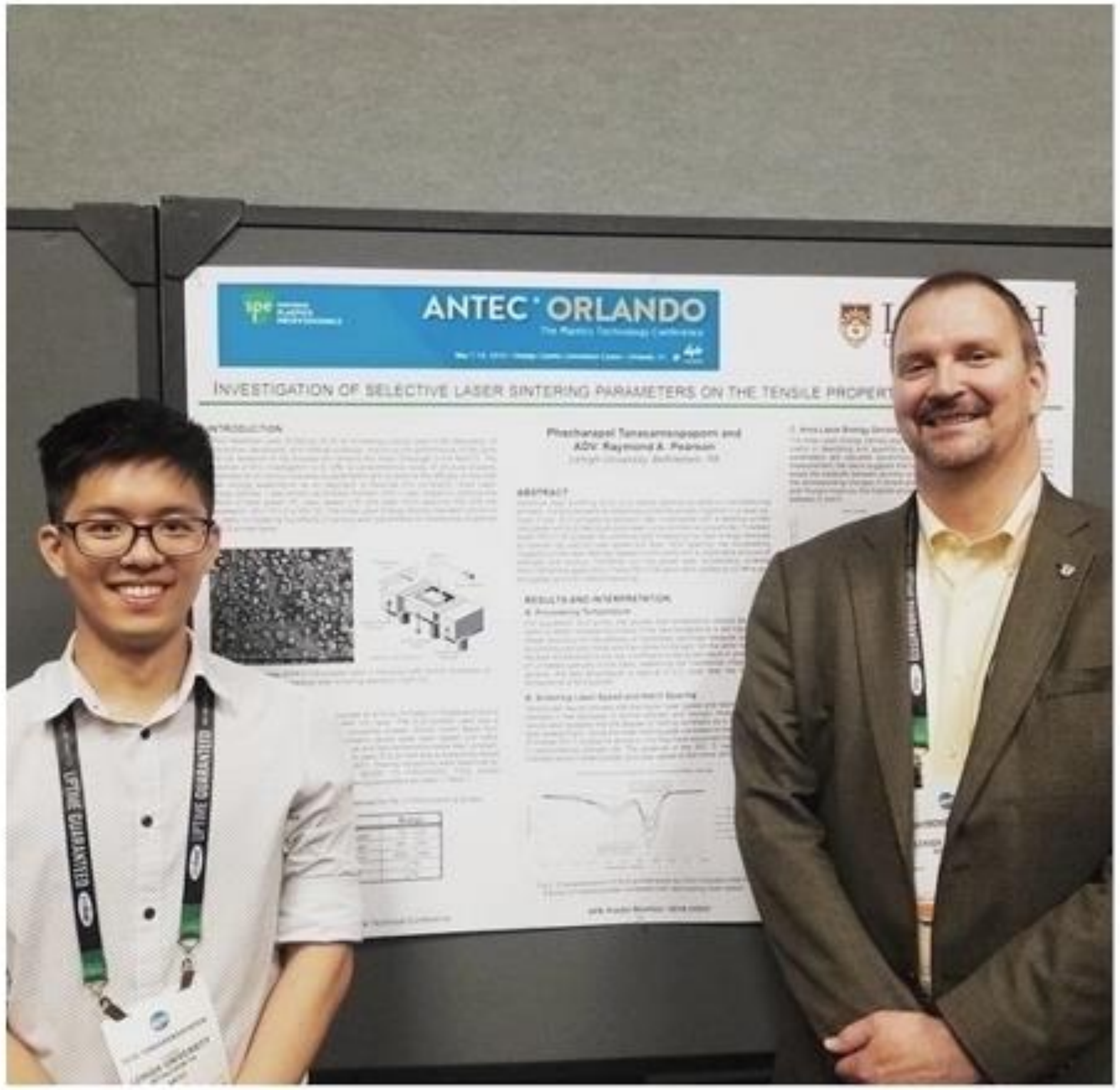
MatSci senior **Tech Tanasarnsopaporn's** work on SLS processing of PA-11 won second place in ANTEC 2018's research poster competition in Orlando -- another first for Lehigh! ANTEC is the largest and most reputed technical conference in the plastic industry. Tech's advisor is **Prof. Ray Pearson.**





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INVESTIGATION OF SELECTIVE LASER SINTERING PARAMETERS ON THE TENSILE PROPERTIES OF POLYAMIDE-11

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INTRODUCTION

While Selective Laser Sintering (SLS) is increasingly being used in the fabrication of automotive, aerospace, and medical products, improving the performance of the parts and the reliability of the process still remains the major challenge in the field [1]. The objective of this investigation is to offer a comprehensive study of physical property dependence on various processing parameters and to explore the efficacy of the total laser energy expenditure as an approach to describe this correlation. Area Laser Energy Density – also known as Andrew Number (AN) – was utilized to combine the effects of laser power (P), laser speed (LS), and laser hatch spacing (HS) with the expression: AN = P/(LS x HS) [2]. The Area Laser Energy Density has been shown to be useful in modeling the effects of various laser parameters on mechanical properties of SLS printed parts.

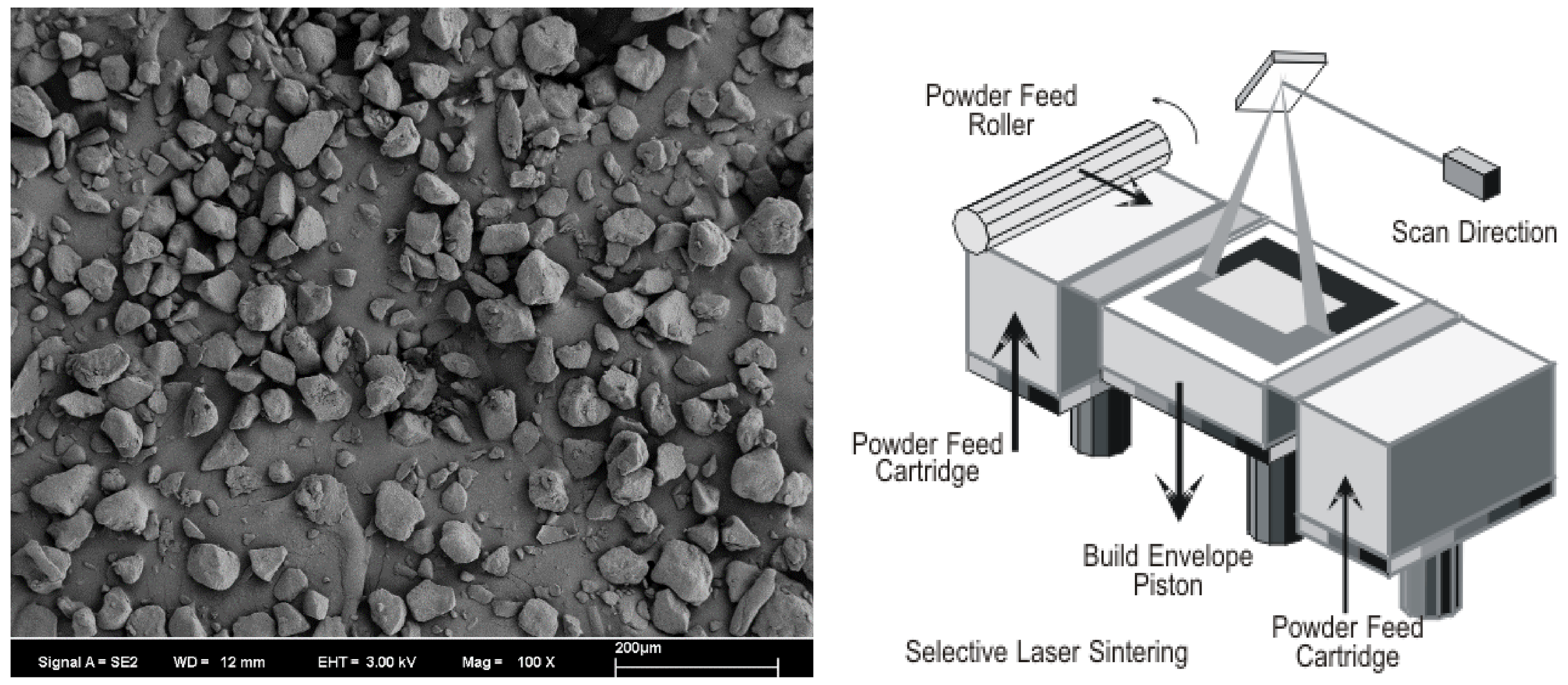

Fig.1. SEM image of PA11/CB powder used in this study (left) and an illustration of selective laser sintering operation (right) [3]

EXPERIMENTAL

SLS printer used in this work was produced as a kit by Sintratec in Switzerland and is equipped with a 2-Watt blue diode (445 nm) laser. The SLS powder used was a polyamide-11/carbon black (PA11/CB) composite powder (Rislan Invent Black from Arkema). Throughout this work, parameters varied were laser speed and hatch spacing. Laser power, surface temperature and bed temperature were kept constant. Type V tensile specimens (ASTM D638-14) were SLS printed and subsequently tested on a universal testing machine (Instron 5567). Thermal transitions were examined by differential scanning calorimetry (DSC Q2000, TA Instruments). Forty tensile specimens were printed with varied processing parameters as listed in Table 1.

Table 1. SLS process parameters examined for PA-11/CB processing studies

Parameter	Range
Layer Thickness, μm	50, 100
Hatch Spacing, μm	40 - 100
Laser Speed, mm/s	300 - 900
Surface T, °C	179
Bed T, °C	179

ABSTRACT

Selective laser sintering (SLS) is a rapidly developing additive manufacturing process. It produces parts by selectively sintering powder together in a layer-by-layer mode. SLS processing behavior was investigated with a desktop printer (equipped with a 2-Watt blue diode laser) on a commercial polyamide-11/carbon black (PA11/CB) powder. By systematically increasing the laser energy received by powder (by varying laser speed and hatch spacing), we successfully mapped out the laser settings needed to print parts with a reasonable amount of strength and ductility. Therefore, our low power laser successfully sintered PA11/CB tensile specimens. These PA11/CB specimens yielded at 53 MPa and elongated up to 65% before fracturing.

RESULTS AND INTERPRETATION

A. Processing Temperature

For successful SLS prints, the powder bed temperature should be kept within a certain processing window. If the bed temperature is too high, part shape accuracy will be partially or completely sacrificed because powder around the part also melts and then sticks to the part. On the other hand, if the bed temperature is too low, insufficient sintering will result in presence of unmelted particles inside parts, weakening the mechanical integrity. In general, the bed temperature is kept at 2~3°C lower than the melting temperature of SLS powder.

B. Sintering Laser Speed and Hatch Spacing

Tensile test results showed that the higher laser speed and hatch spacing resulted in the decrease in tensile strength and Young's modulus. DSC results also revealed that the degree of melting correlates as a function of laser speed (Fig.2). Since the lower melting peak correlates to the formation of smaller PA-11 crystalline domains, this may have explained the reduction in post-sintering strength [4]. The absence of the 202 ˚C melting peak indicates a fully melted powder at a laser speed of 300 mm/s (AN = 6.7).

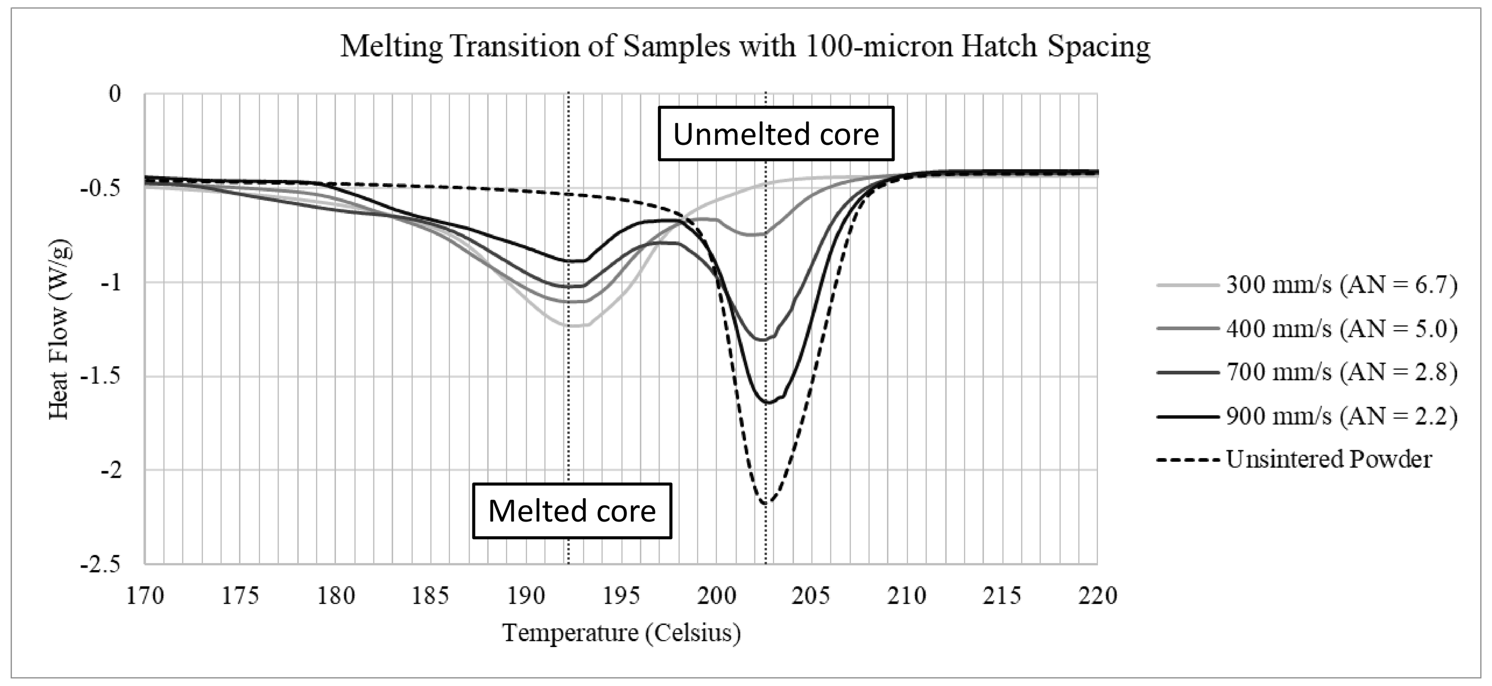

Fig.2. Characterization of SLS printed parts by DSC indicates that the fraction of melted powder increases with decreasing laser speed.

C. Area Laser Energy Density Model

The Area Laser Energy Density approach (quantified by Andrew Number) proves to be useful in describing and quantifying the effects on tensile performance when both parameters are adjusted dynamically. Through DSC analysis and void content measurement, the result suggests that by varying hatch spacing and laser speed, there exists the tradeoffs between porosity and crystallinity in the part that may also explain the corresponding changes in tensile properties (Fig.3 and 4). For both tensile strength and Young's modulus, the highest values can be achieved when the Andrew Number is between 5 and 6.

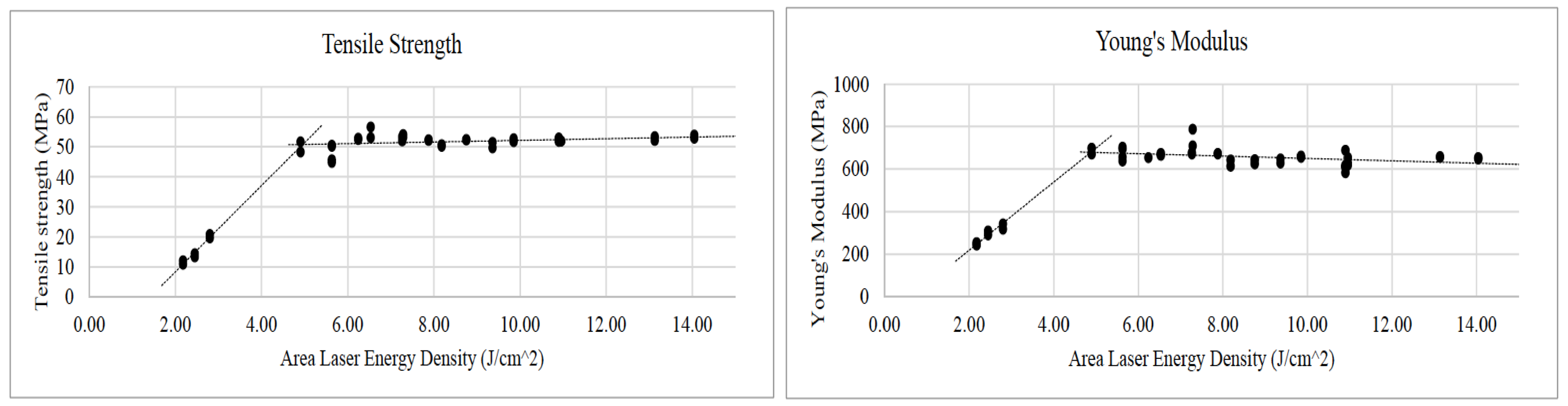

Fig.3. Mechanical properties of PA-11/CB as a function of energy density

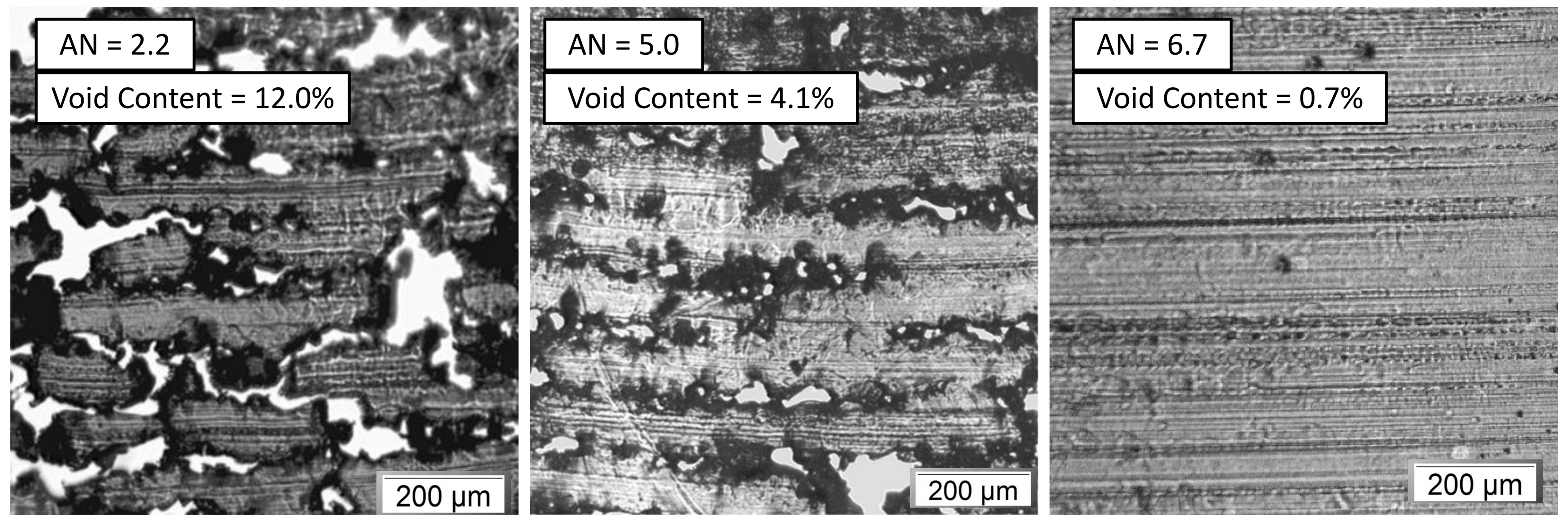

Fig.4. Void content analysis on the light optical micrographs of the sintered parts indicates that part porosity reduces with increasing Andrew Number

CONCLUSIONS

The processing behavior of PA11/CB was investigated. While keeping the temperature of the sample bed constant, two laser parameters (speed and hatch spacings) were varied in a systematic fashion. As expected, the resulting mechanical properties decreased with laser speed and laser hatch spacing, however, clear trends were not always discernible. The use of Area Laser Energy clarified the processing window. Therefore, well-sintered PA11/CB parts with tensile strength greater than 50 MPa and elongation at break greater than 25% may be achieved when the AN ≥ 5.

ACKNOWLEDGMENTS

The authors acknowledge financial support from the Pennsylvania Department of Community and Economic Development (PA-DCED).

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