CHARACTERIZING HYBRID CARBON FIBER REINFORCED POLYMER COMPOSITES USING PIEZOSPECTROSCOPY AND DIGITAL IMAGE CORRELATION

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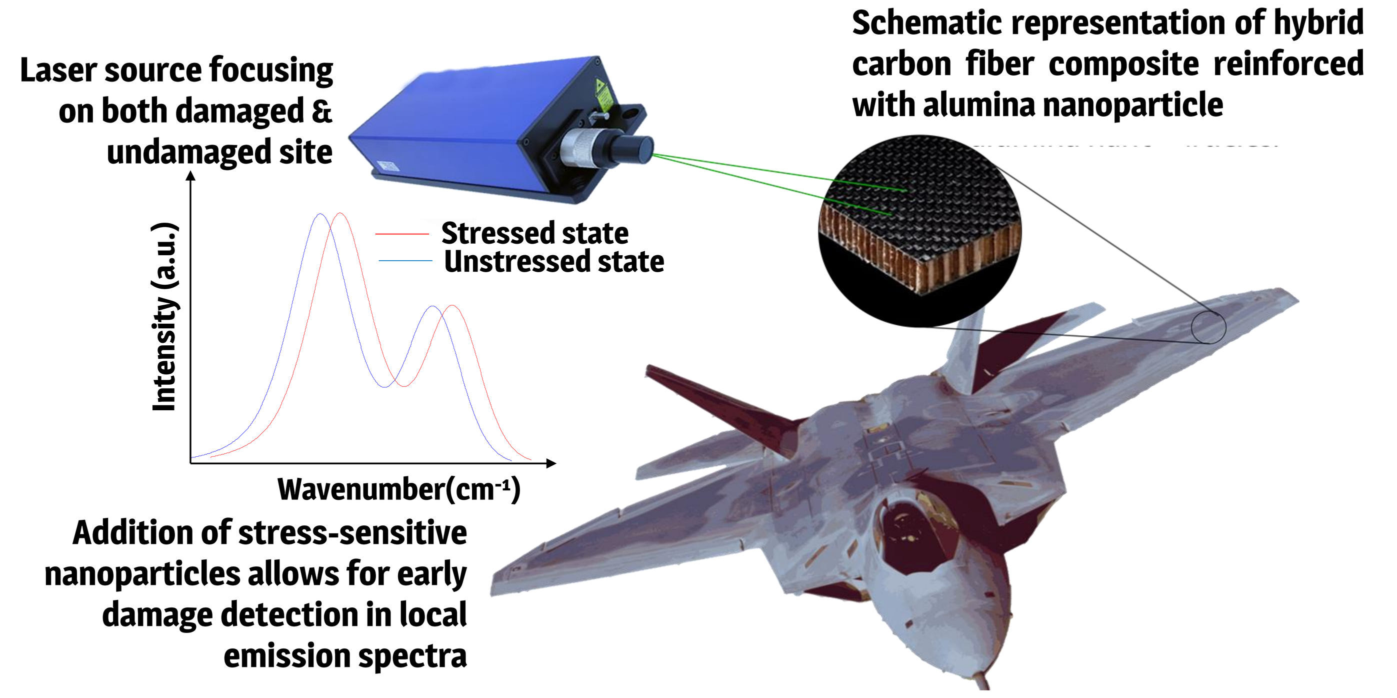
INTRODUCTION

Hybrid carbon fiber reinforced polymer composites **(HCFRPs)** are a new breed of materials currently being explored and characterized for next generation aerospace applications. **Alumina nanoparticle reinforcement** as a secondary particle filler improves material properties such as **fracture toughness and resistance to crack propagation.** Photoluminescence property of the alumina is applied here as a novel way to determine the manufacturing qualities and mechanical properties of the composite material.

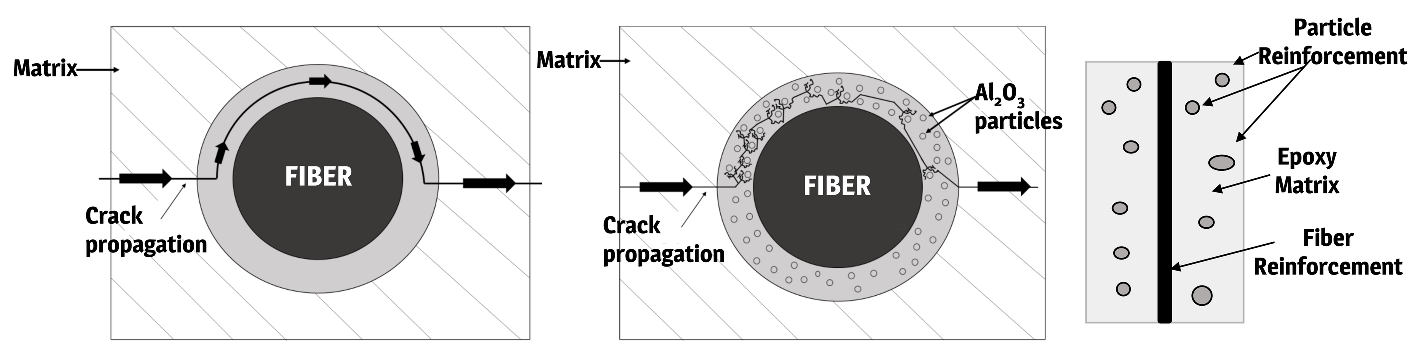


Applications of hybrid carbon fiber composites for aerospace applications, improving material properties and allowing for stress sensing

OBJECTIVES

- **Improve dispersion of alumina nanoparticles by silane functionalization and optimizing weight percentage of the nanoparticles.**
- **Determine dispersion quality using photoluminescence properties of embedded alumina.**
- **Relate mechanical behavior of the material to dispersion quality applying piezospectroscopy.**

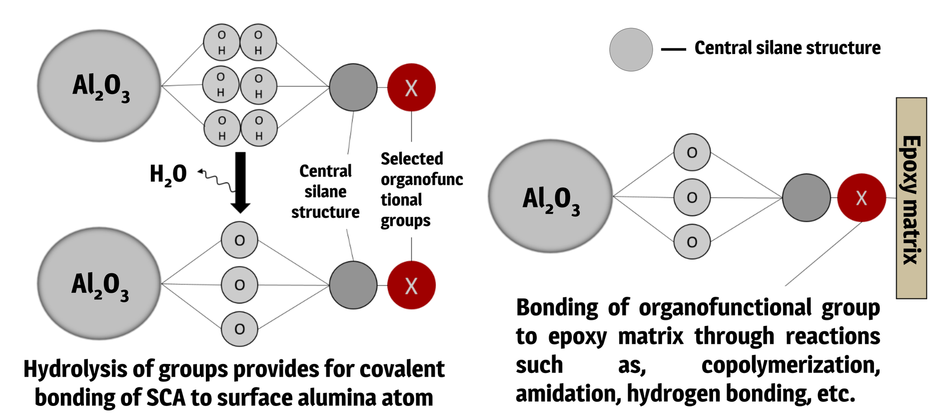
BACKGROUND & MOTIVATION



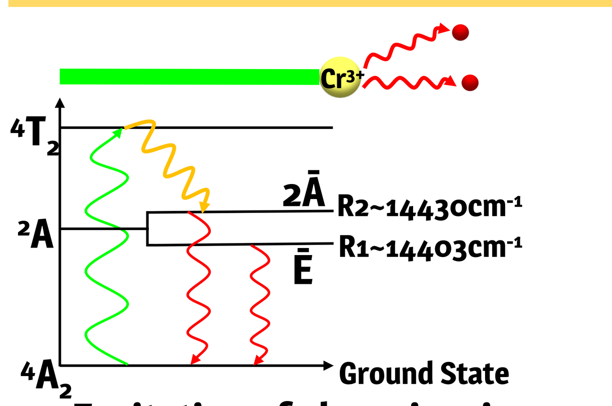
Resistance to crack propagation mechanism

- The secondary reinforcement increase toughness by shear band yielding or debonding & plastic void growth resulting in resisting crack propagation.
- Homogeneous dispersion of alumina nanoparticles ensure homogeneous mechanical properties throughout the material.

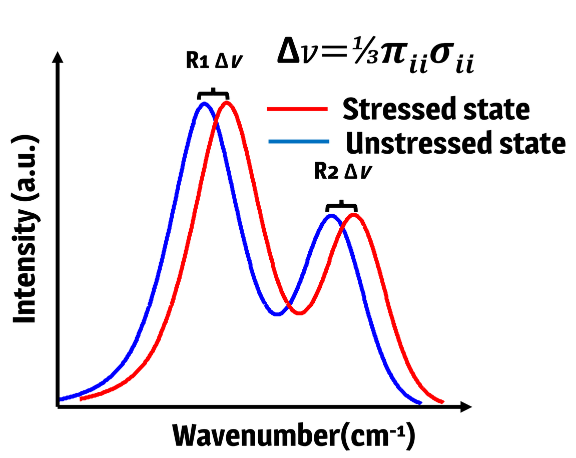
Organofunctionality of silane coupling agents (SCAs) improves dispersion in nanocomposites



PIEZOSPECTROSCOPY (PS)

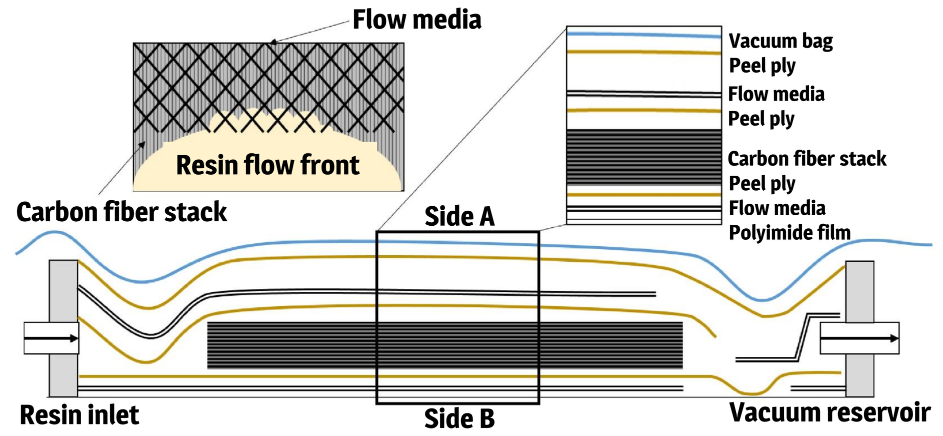


Excitation of chromium ion substitutional impurities results in emission of photons



Emissions comprised of R1 and R2 peaks which create the R-line doublet

SAMPLE PREPARATION

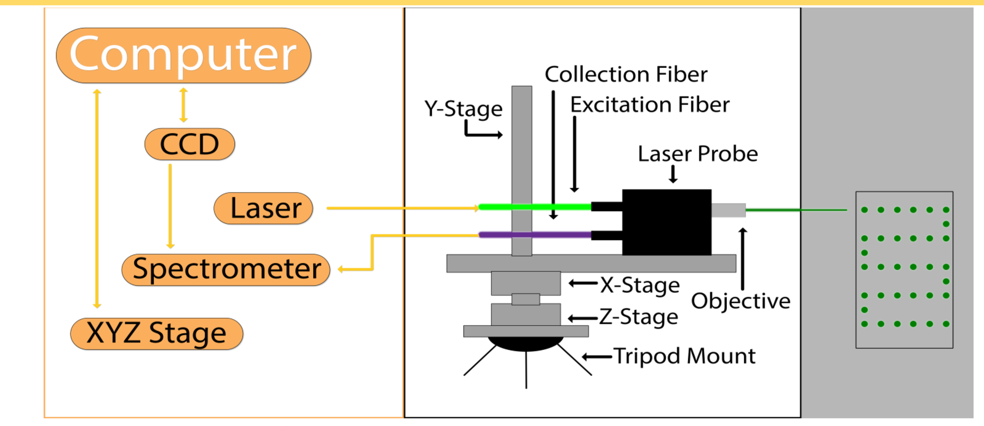


Resin infusion under flexible tooling (RIFT)[1]

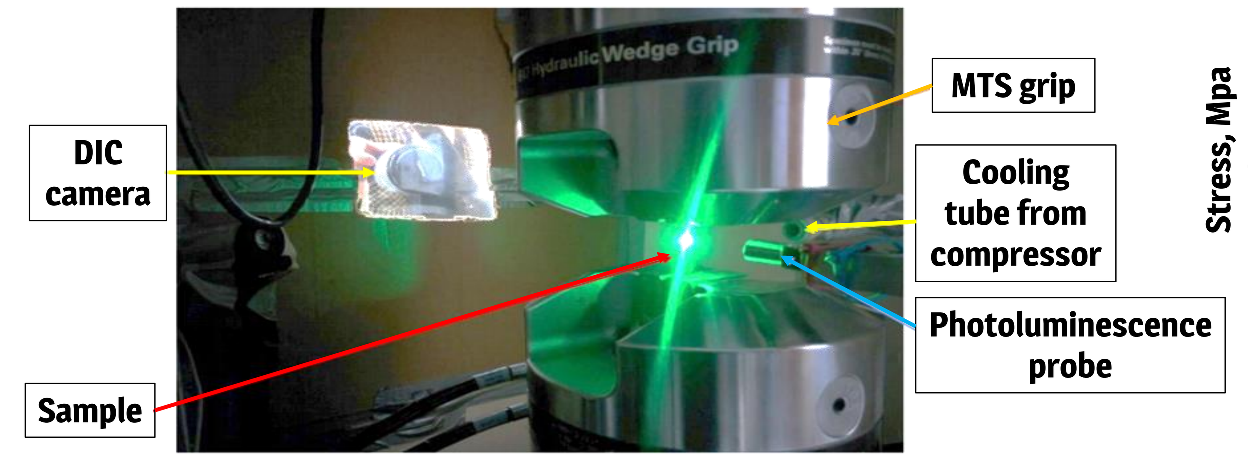
- **6, 9 and 12 wt% alumina nanoparticles** with **reactive silane coupling agent (RSCA)**, **non-reactive silane coupling agent (NRSCA)** and **untreated surface** were embedded in the material using resin infusion under flexible tooling (RIFT) method.
- Two sets from each combination or in **total 18 samples** were cut from different locations of the composite sheets.

EXPERIMENTAL METHOD

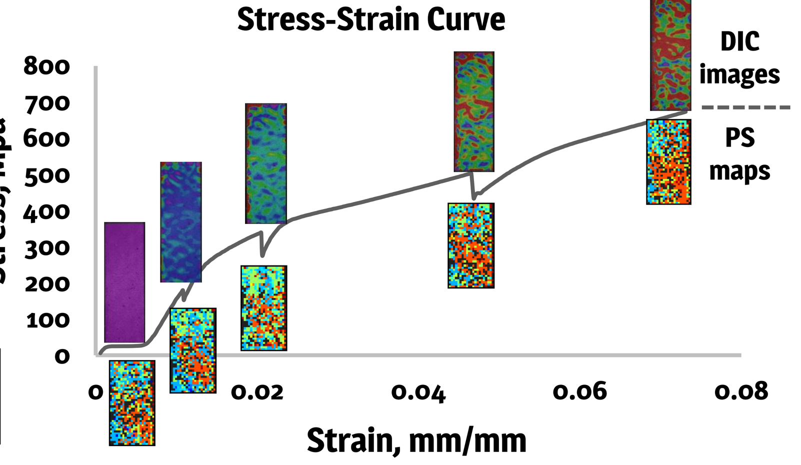
- **Portable piezospectroscopy system** with a 532 nm wavelength diode-pumped solid-state (DPSS) laser was used to scan the sample before and during loading.
- **Uniaxial tensile load** was applied using a servohydraulic universal testing machine fitted with serrated grips.
- Load was increased from **0 kN to 20 kN** and held at each 5 kN increment.



Schematic of portable piezospectroscopy system

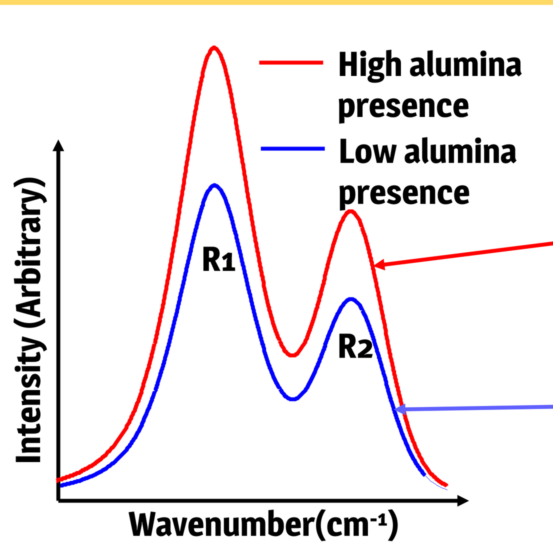


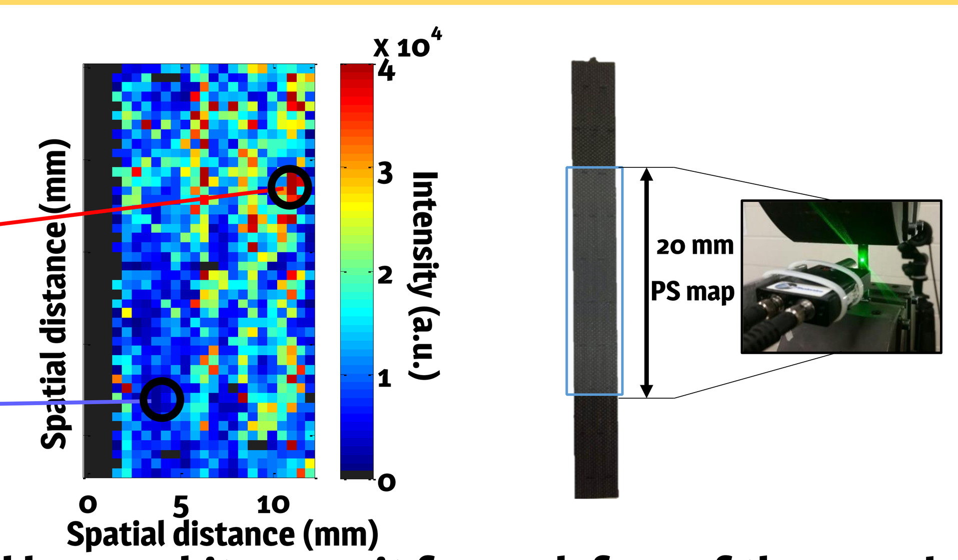
Experimental setup



DIC images & PS maps were collected at each hold

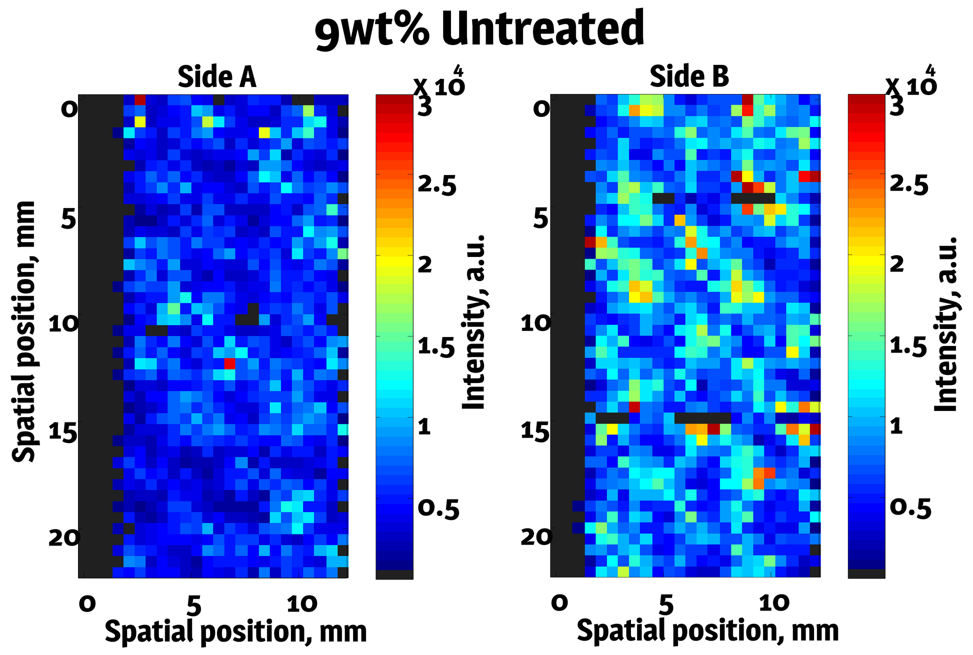
ANALYSIS METHOD





The intensity of photons is measured by an arbitrary unit for each face of the sample[2]

9wt% Untreated

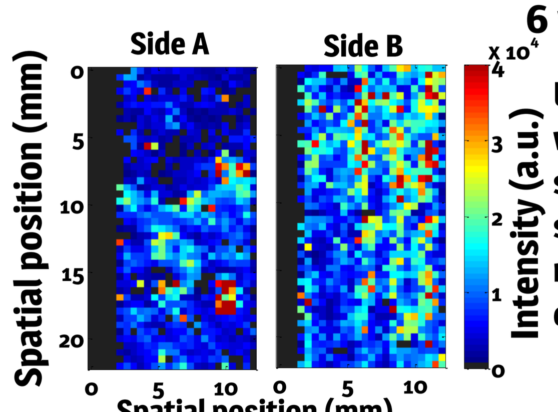


While curing, alumina particles tend to sediment on the bottom face (side B) of the composite which can be observed from the PS maps.

RESULTS & DISCUSSION

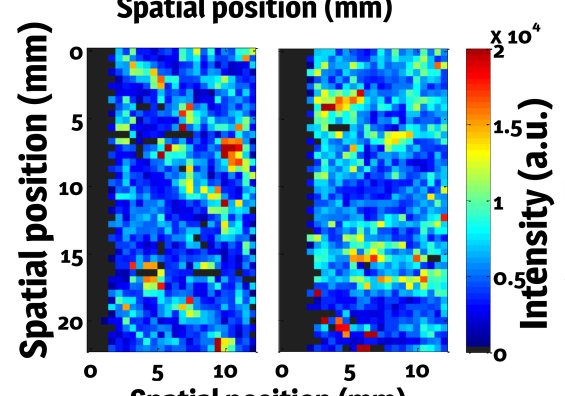
Dispersion & Sedimentation

6 wt% Untreated



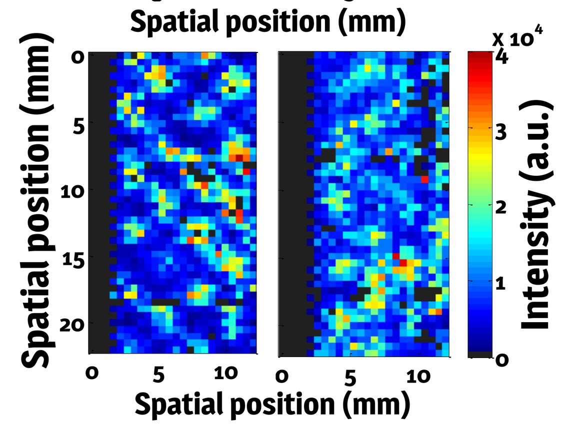
Untreated low weight percentage shows high sedimentation and non-homogeneous dispersion

6 wt% RSCA



RSCA treatment provides better dispersion and low sedimentation

9 wt% RSCA

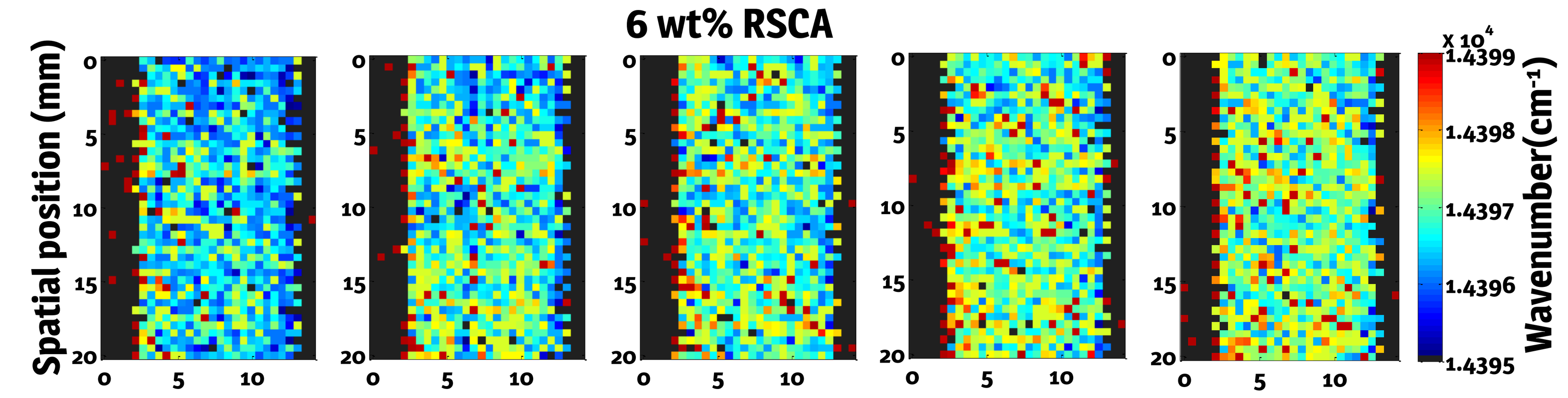


Combination of best dispersion and low sedimentation found for 9wt% RSCA treated alumina particles

Residual Stress Release

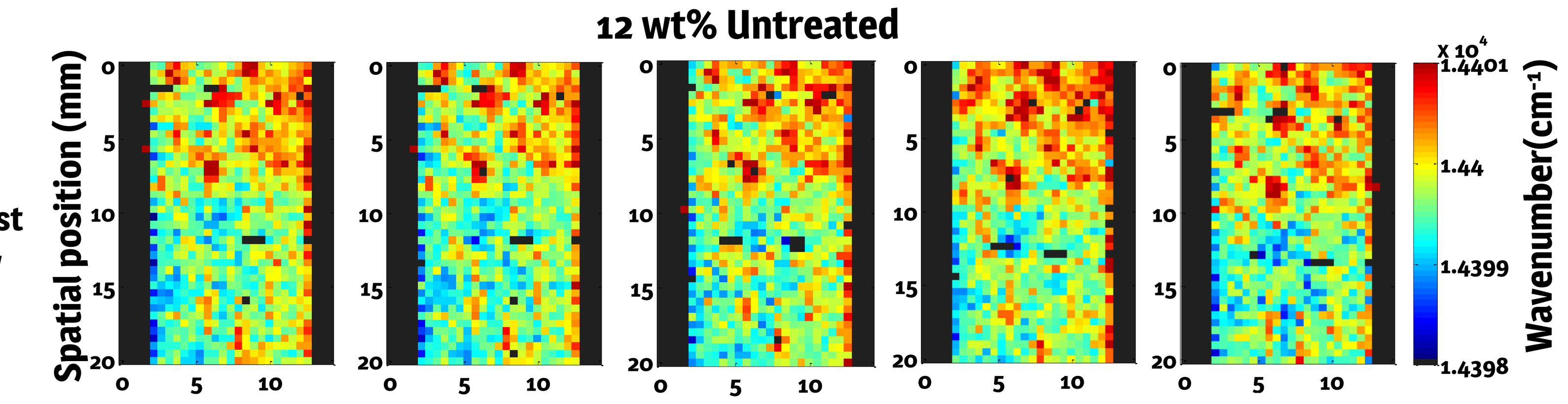
Alumina nanoparticles experience residual stresses during manufacturing which is released during loading.

6 wt% RSCA



With increasing load, alumina particles release residual stress

12 wt% Untreated



Poor dispersion results in non-uniform stress release over the sample during loading

CONCLUSIONS

- Reactive & non-reactive surface treatments improve particle dispersion and decreases sedimentation.
- Better dispersion & less sedimentation provides uniform stress state throughout the material while undergoes loading.
- Thus, surface treatment of the alumina particles results in better homogeneous material properties throughout the composite.

REFERENCES & ACKNOWLEDGEMENTS

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