南京航空航天大學 航空学院
NANJING UNIVERSITY OF AERONAUTICS AND ASTRONAUTICS

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Cure Monitoring of Composites Using Encapsulated Cantilever Microfiber Bragg Grating

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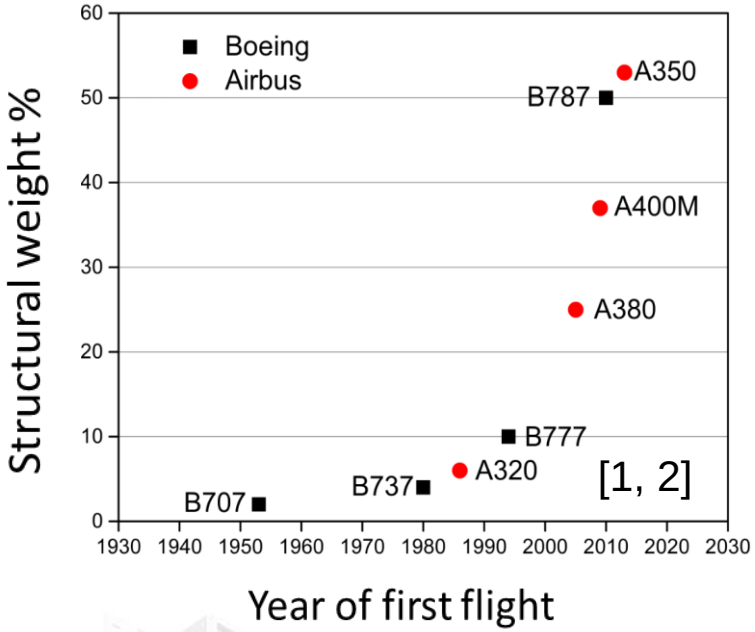
砺志奋进 追梦蓝天

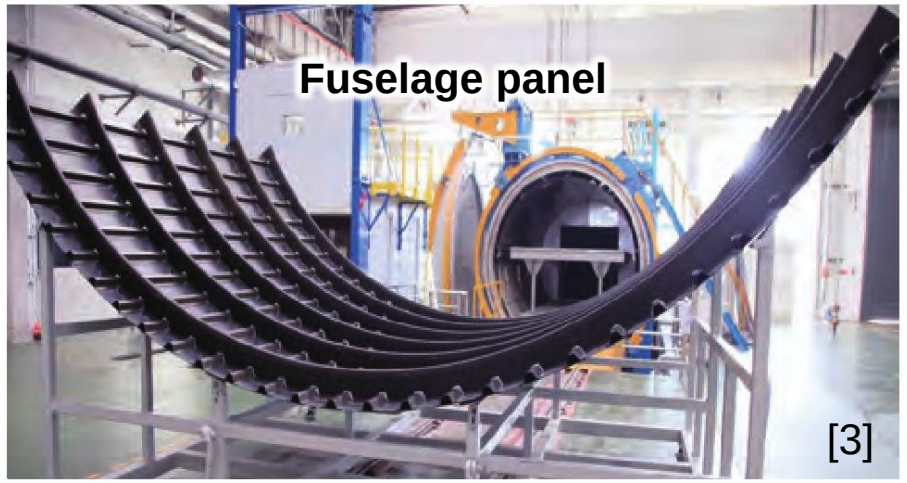
OUTLINE

1 Background

1.1 Composite structures

Composite structures in aviation industry



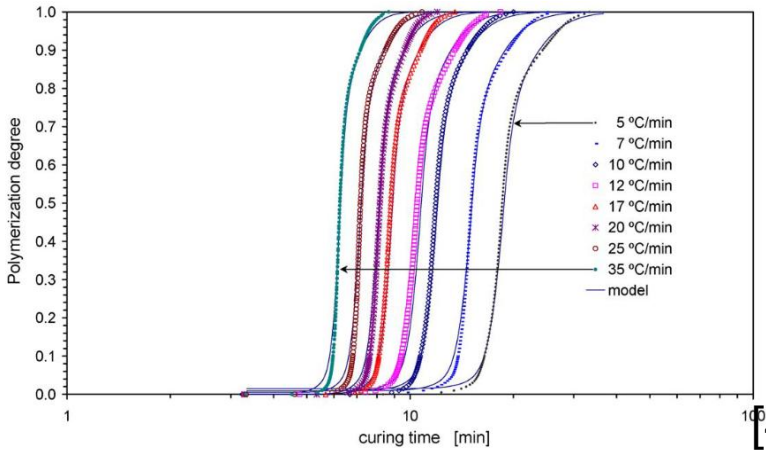


Composites has been widely used in many industries owing to its advantageous properties.

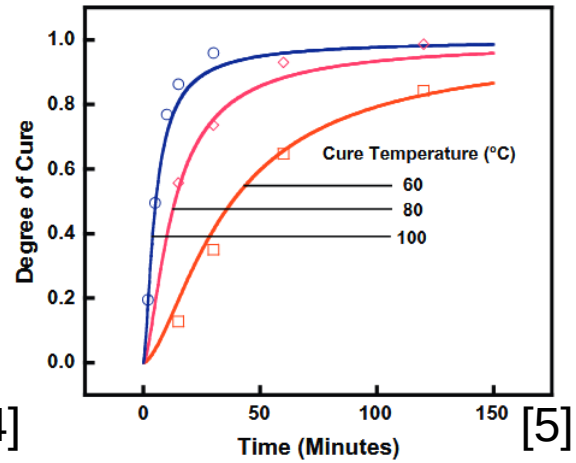
1 Background

1.2 Degree of cure (DOC)

DOC varies with different heating rates and temperatures

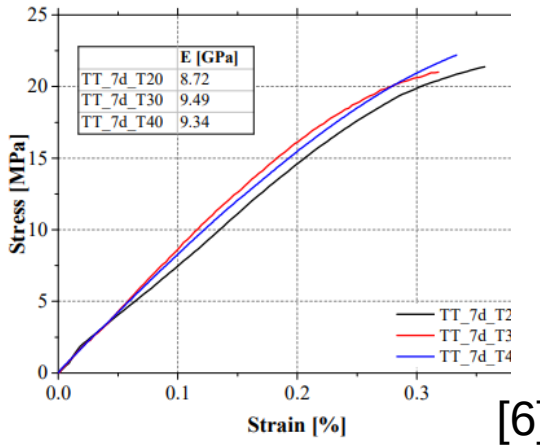


[4]



[5]

Influence of temperature on mechanical properties



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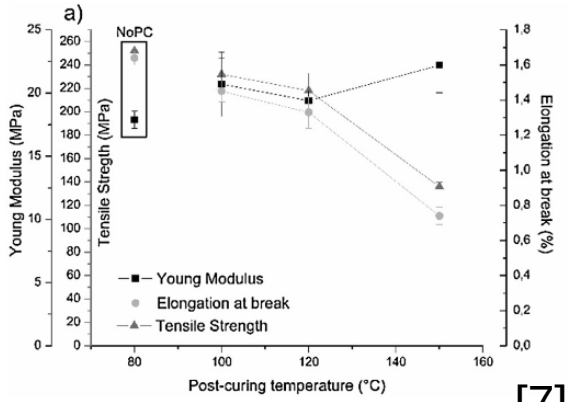


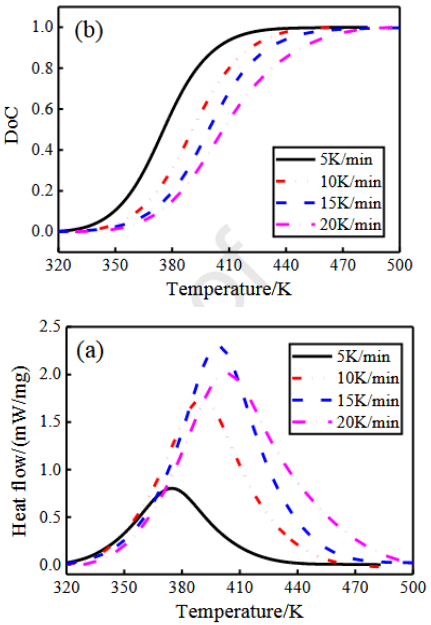
[7]

DOC is influenced by parameters like heating rates and temperature, and affect the mechanical properties of composites.

1.3 Cure monitoring techniques

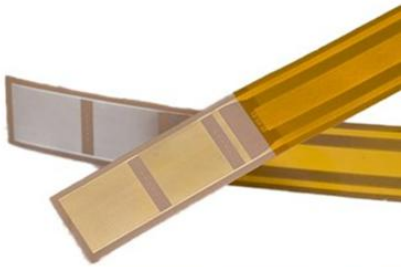
Differential Scanning Calorimetry (DSC)

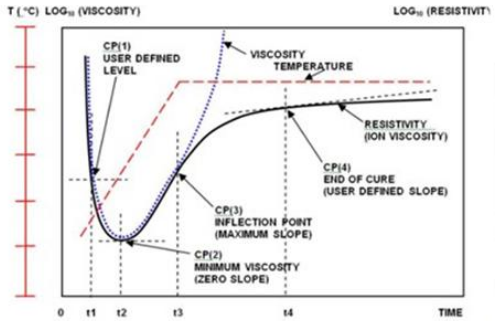
[8]

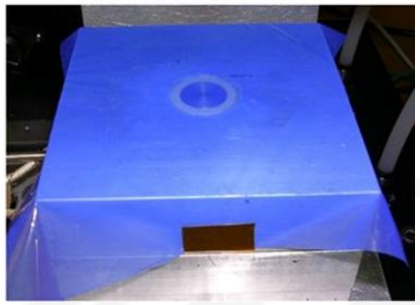


[9]

Dielectric analysis (DEA)



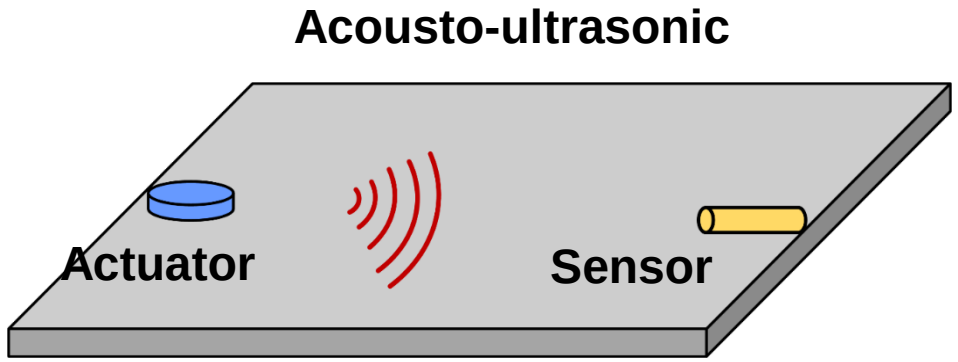


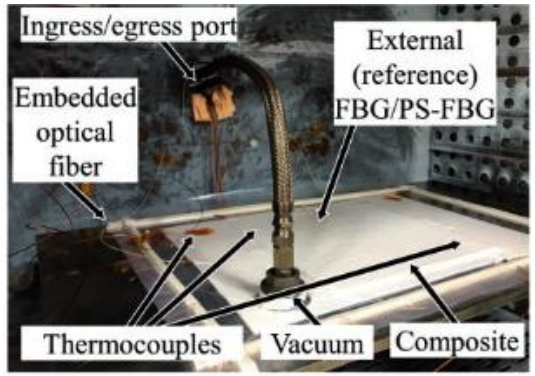


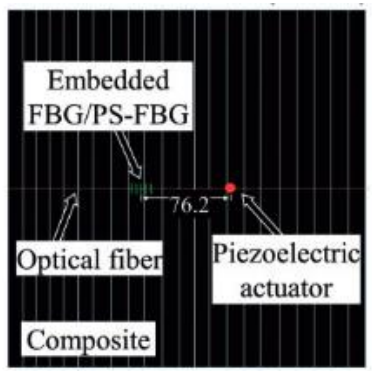
[10]

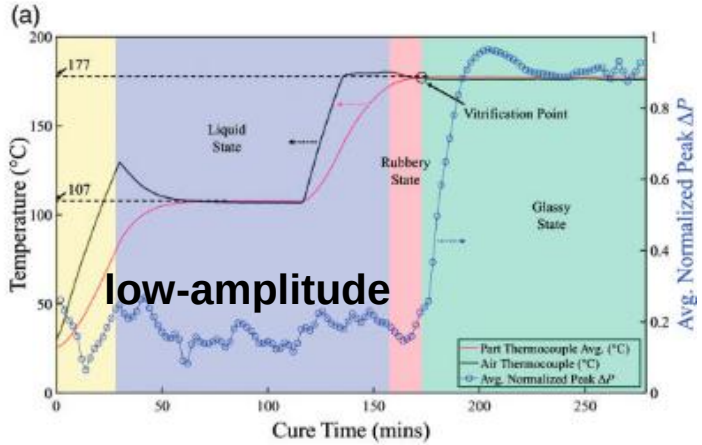
Cure monitoring techniques, such as DSC and DEA, face challenges such as limited sample size and the need for bulk sensors.

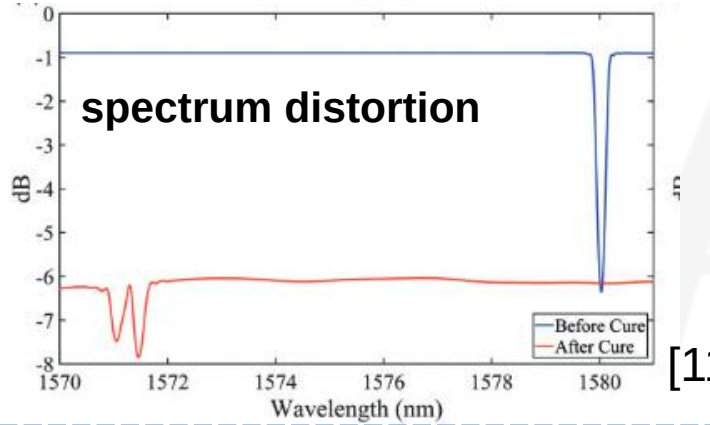
1.4 Acousto-ultrasonic method











[11]

Embedding PZT in composites presents challenges due to its large size; FBG has distortion in the spectrum and lacks the desired ultrasonic sensing performance.

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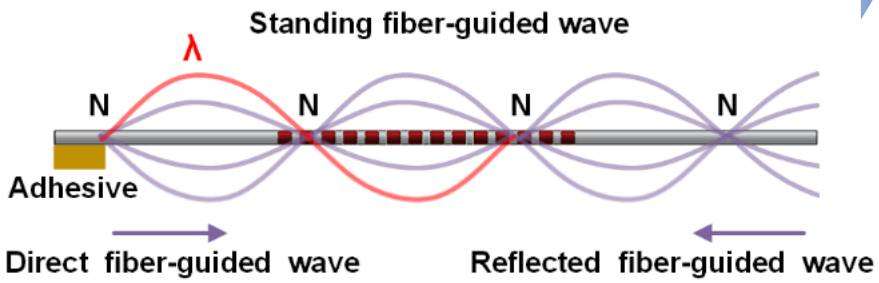
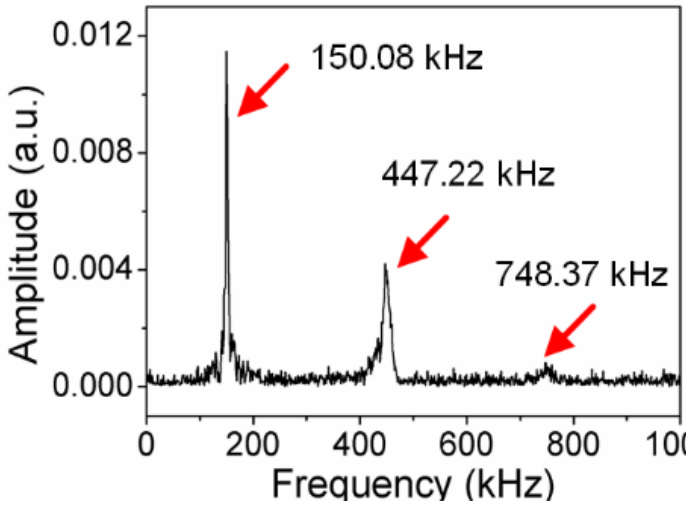
OUTLINE

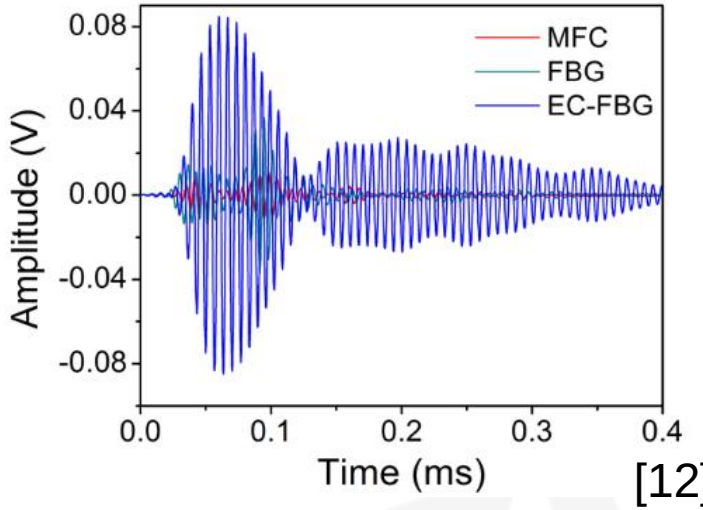
2.1 Encapsulated cantilever FBG (EC-FBG)

Schematic of EC-FBG



Ultrasonic sensing performance



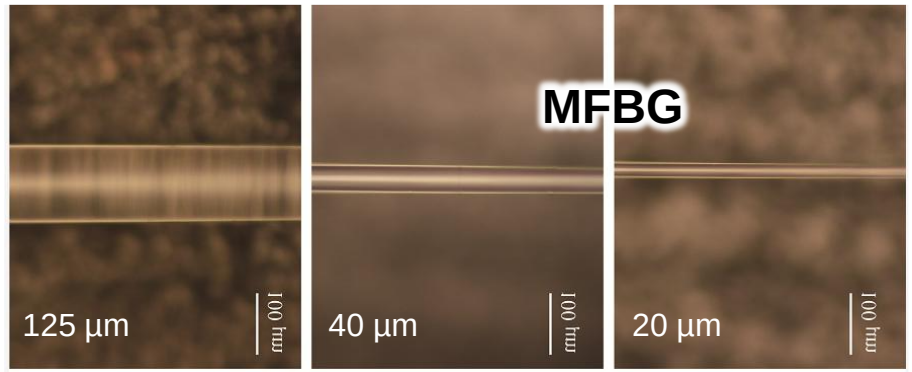


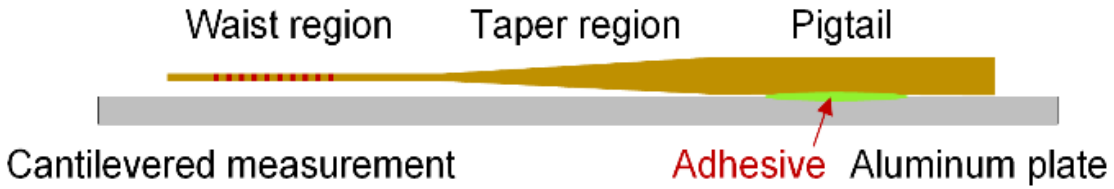
[12]

EC-FBG exhibits superior ultrasonic sensing performance compared to FBG and PZT.

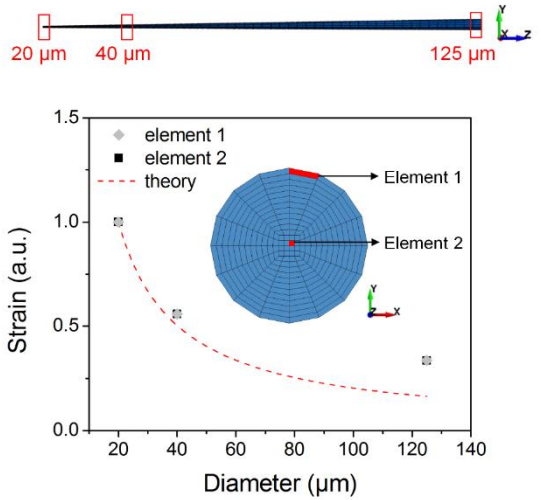
2.2 Microfiber Bragg grating (MFBG)

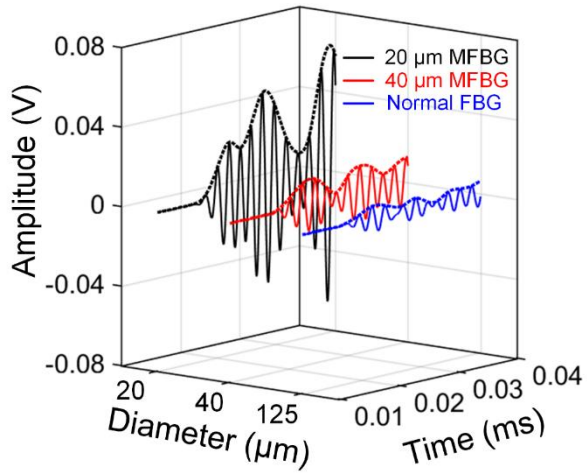
Schematic of MFBG





Ultrasonic sensing performance



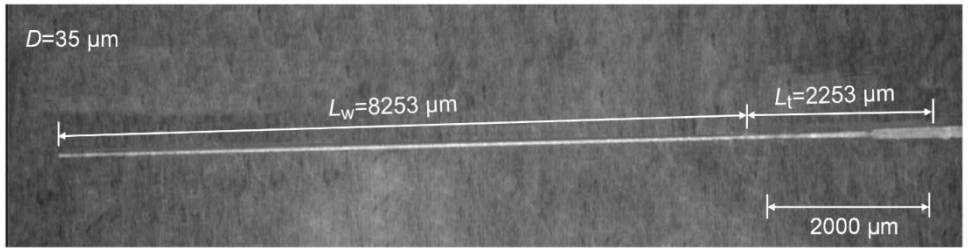


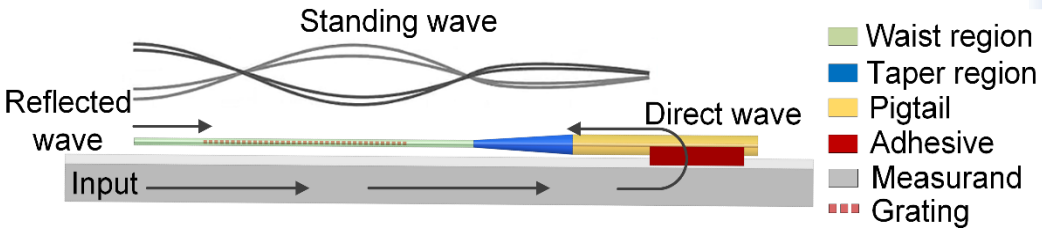
[13]

MFBG is fabricated and ultrasonic sensing performance using cantilevered measurement is investigated.

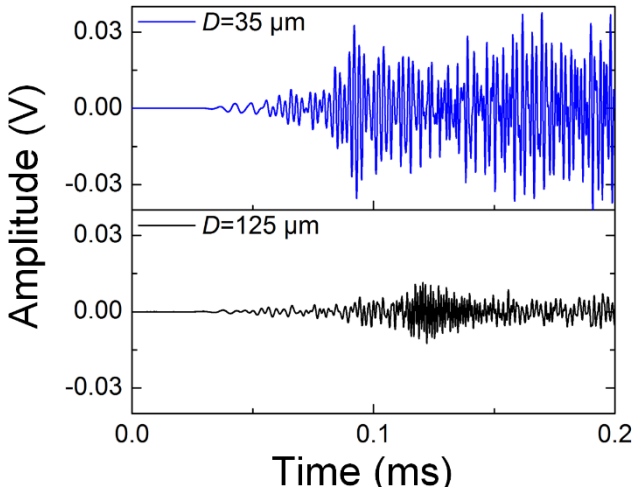
2.3 Cantilevered MFBG (CMFBG)

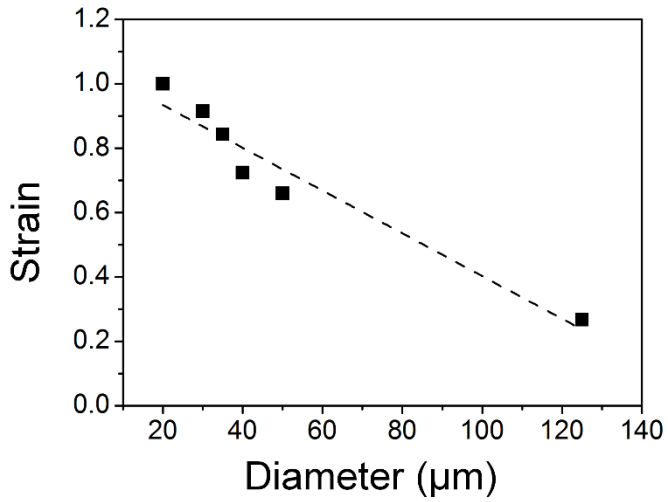
Schematic of CMFBG





Ultrasonic sensing performance





Ultrasonic signals received by CMFBG has a 227% increase in amplitude compared to FBG.

OUTLINE

3 Experimental setup

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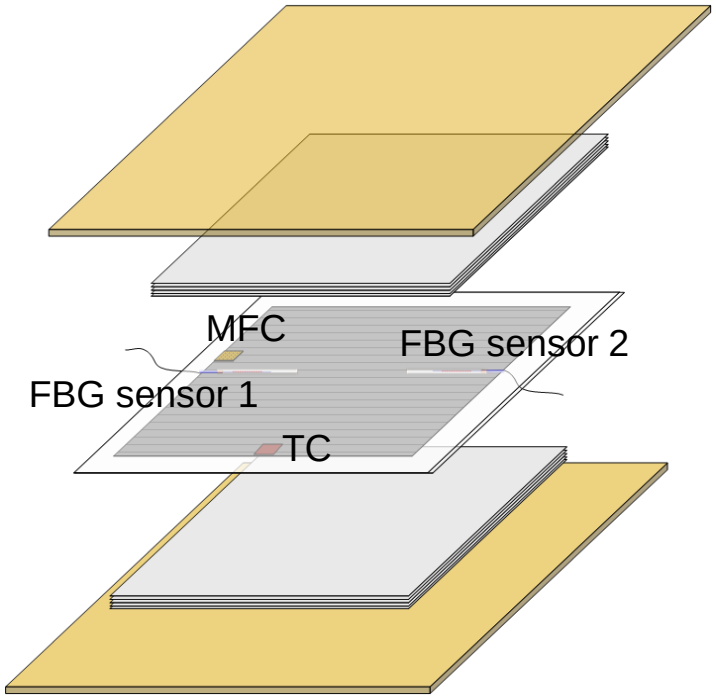
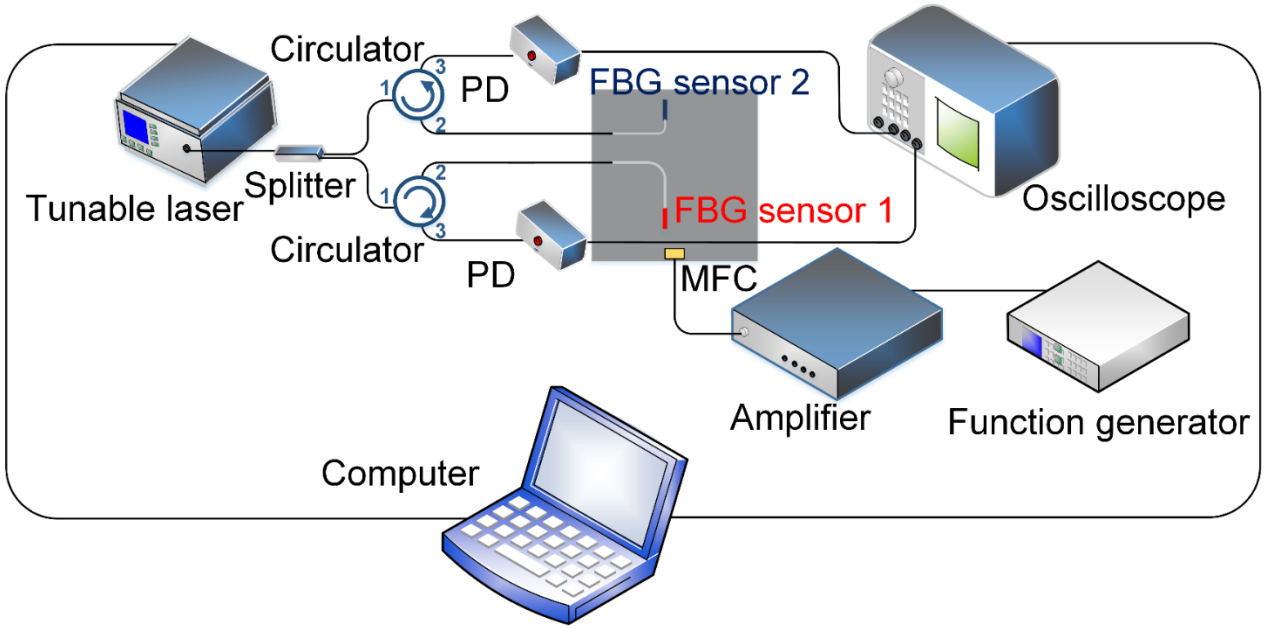
3.1 Experimental setup





FBG sensors, macro fiber composite (MFC) and thermocouple (TC) are arranged on the prepreg. Acousto-ultrasonic system is established, including the excitation and FBG sensing system.

3 Experimental setup

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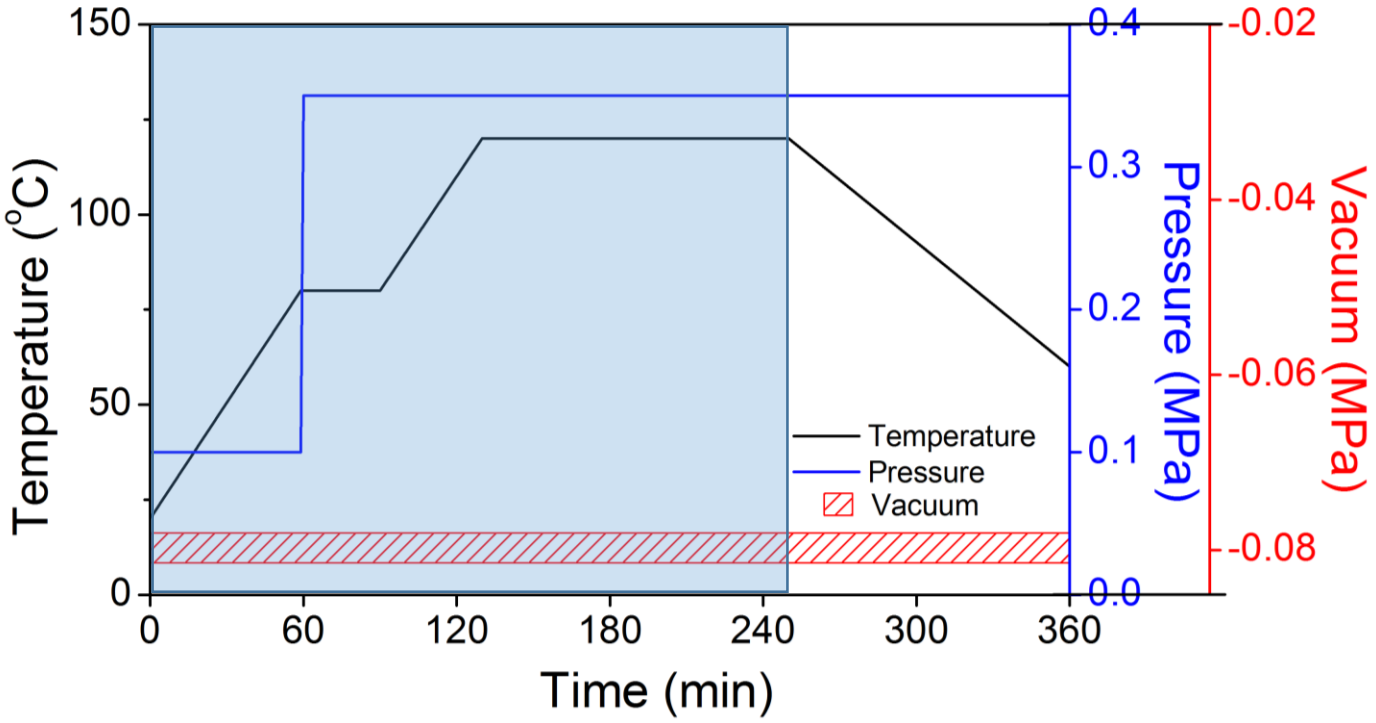
3.2 Thermoforming process

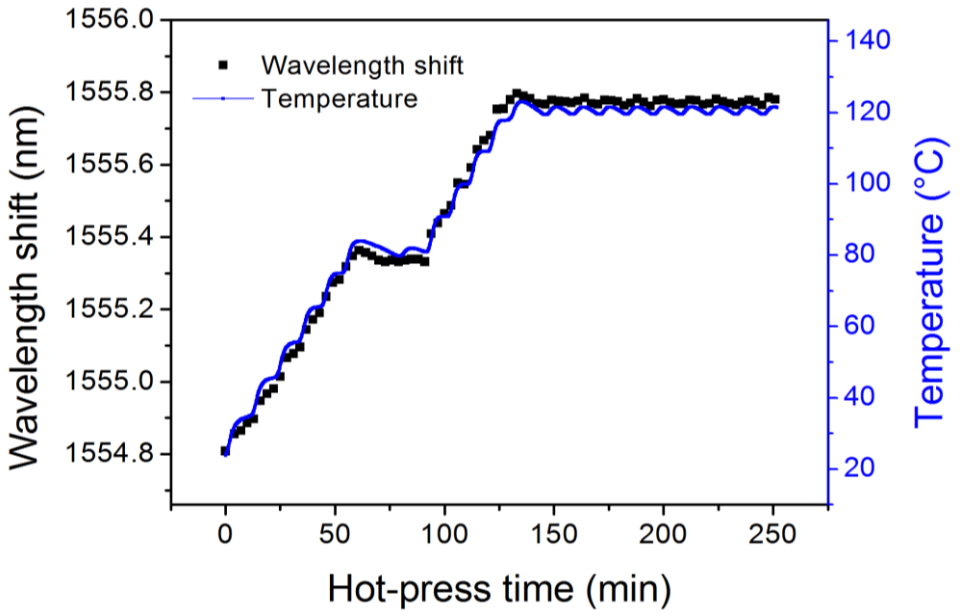


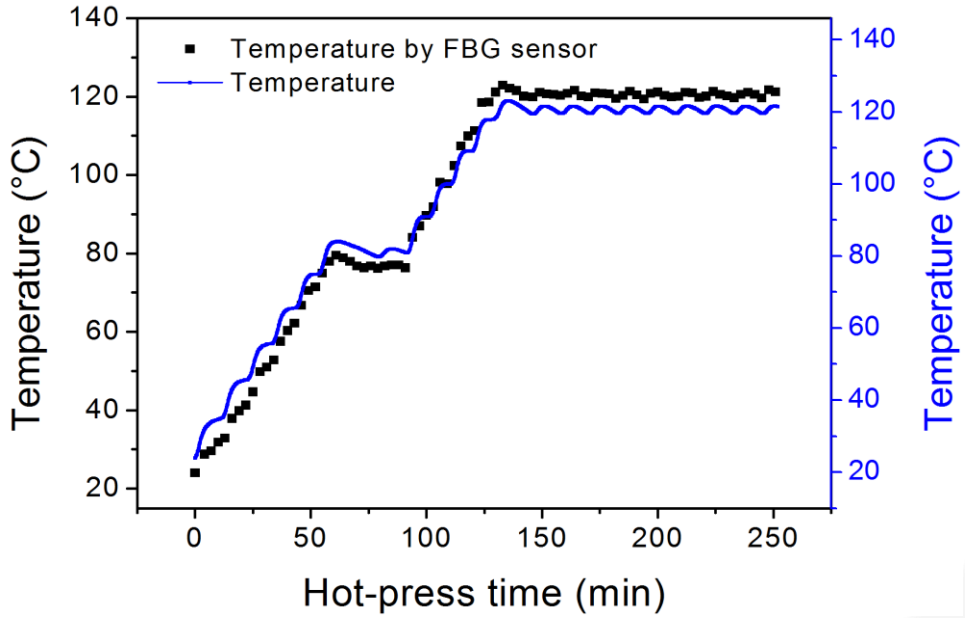
- **Pressure:** The pressure was 0.1 MPa before 60 min, and then increased to 0.35 MPa.
- **Temperature:** The temperature was increased to 80 °C in 60 min, and maintained for 30 min. Subsequently, the temperature increased to 120 °C within approximately 40 min and maintained for 120 min.
- **Vacuum:** -0.08~-0.078 MPa.

OUTLINE

4 Results

4.1 Temperature





The wavelength shift of the FBG sensor closely tracked the cure temperature during the thermoforming process, the average difference is 1.7 °C.

4 Results

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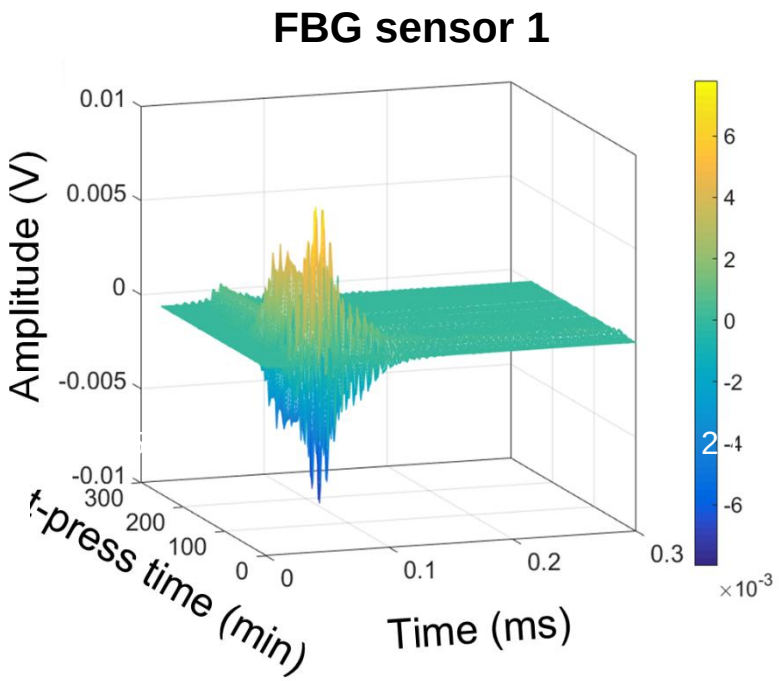
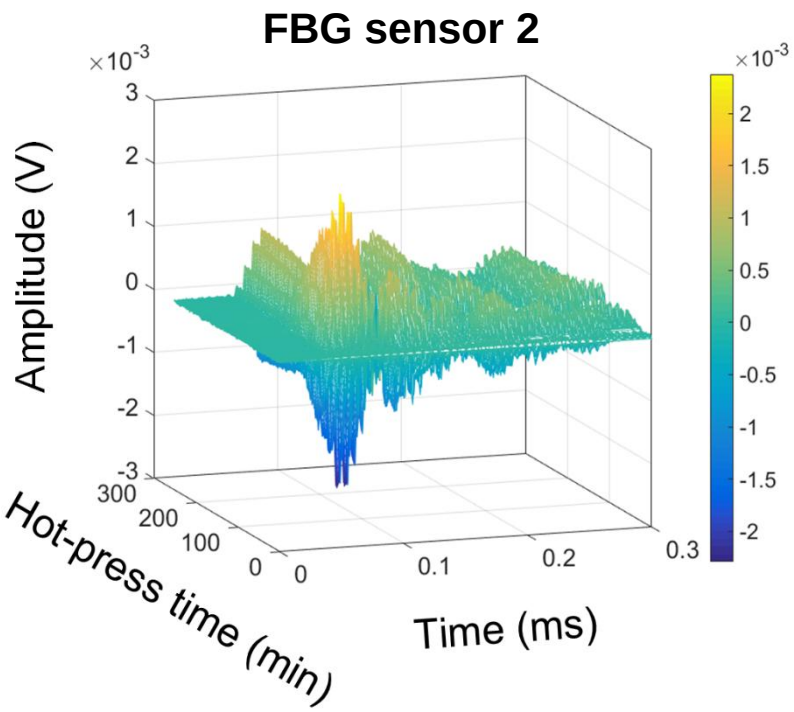
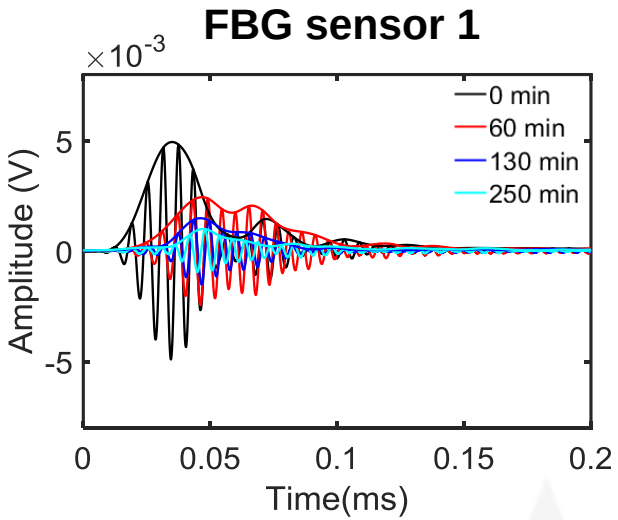
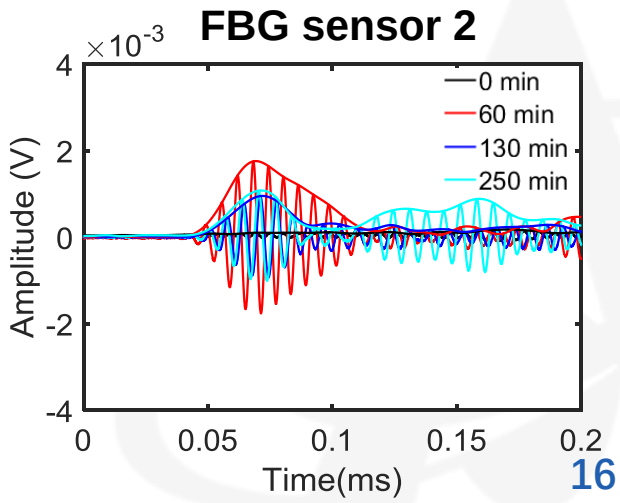
4.2 Ultrasonic signal









Ultrasonic signals received by FBG sensor 1 and FBG sensor 2 were recorded during the thermoforming process.

4 Results

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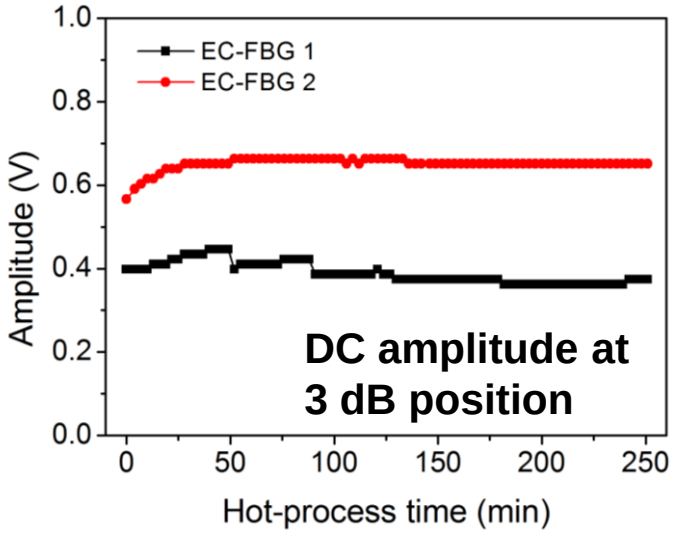
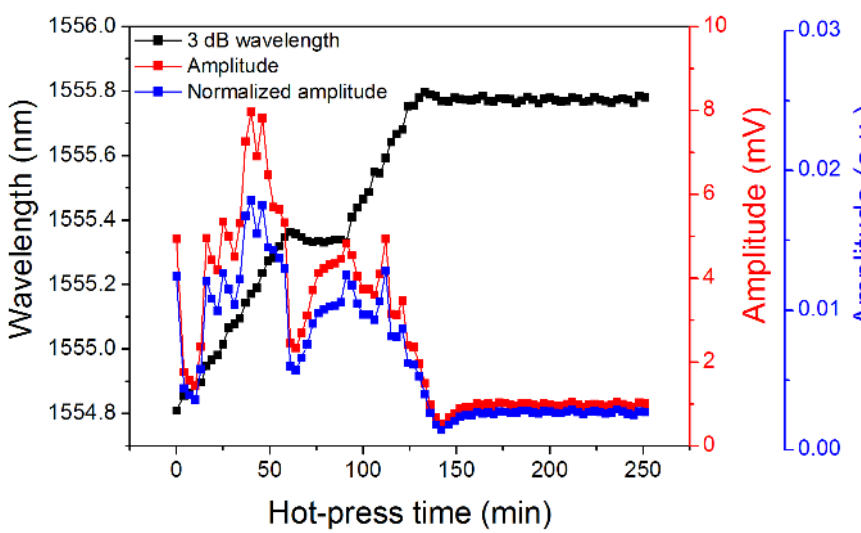
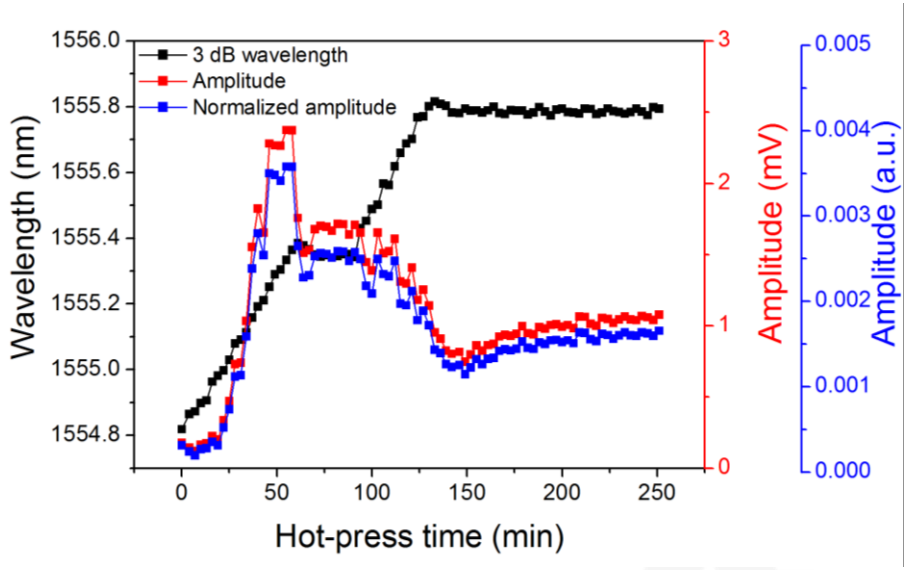
4.3 Amplitude of ultrasonic signal



FBG sensor 1

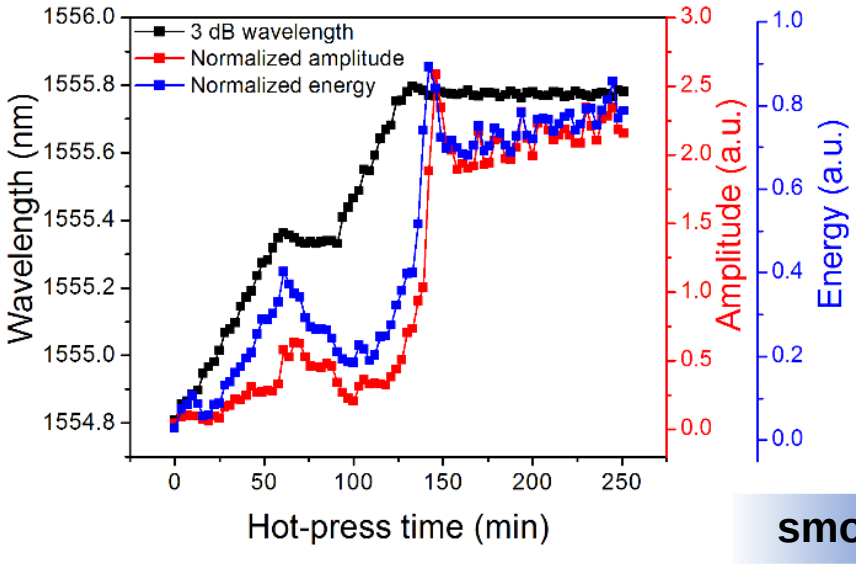


FBG sensor 2

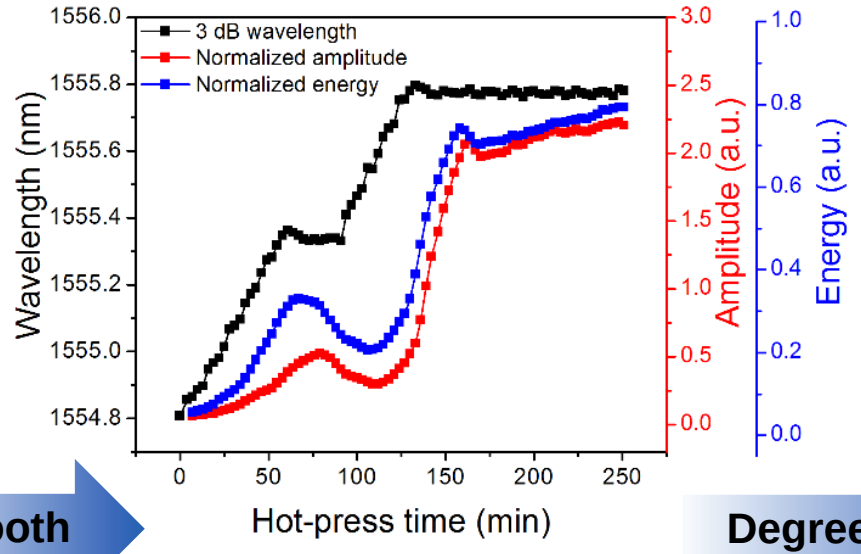


The amplitude of the ultrasonic signal fluctuates during the thermoforming process. The effect of the reflectivity of spectrum is eliminated.

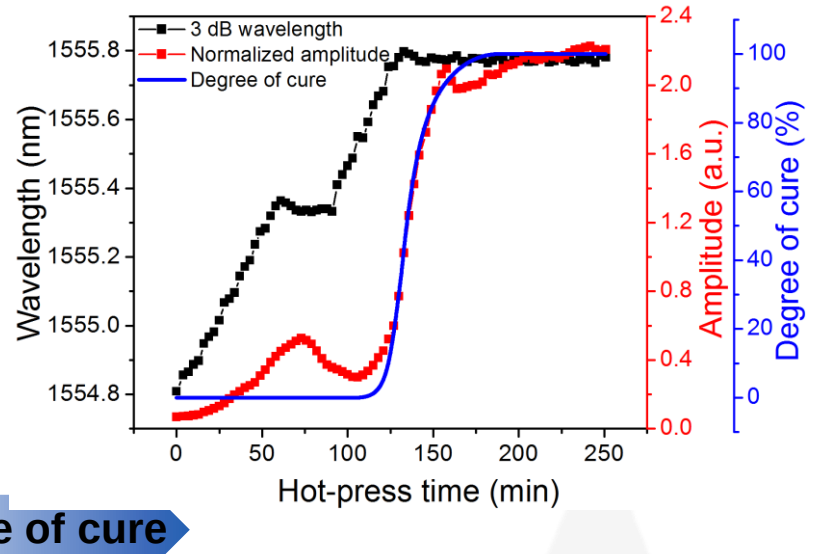
4.4 Normalized amplitude



smooth



Degree of cure



Normalized amplitude was calculated using the amplitude of signals received by FBG sensor 1 and 2, showing an upward trend as crosslinking reaction progresses.

OUTLINE

5 Conclusion

1. The ultrasonic sensing performance of CMFBG is investigated.
2. The ultrasonic sensing characteristics of CMFBG can be adjusted by controlling the geometric parameters.
3. Temperature and ultrasonic signals during the thermoforming process can be detected by FBG sensor.
4. DOC can be monitored by analyzing the normalized amplitude of ultrasonic signals.

In-situ monitoring of the temperature and DOC of CFRP can be achieved by integrating the FBG sensor based acousto-ultrasonic method, which has the potential to enhance control and optimization of the thermoforming process.

Acknowledgement & Reference

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Acknowledgement

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