Temperature Stability and Aging Prediction of the Draw Tower Gratings (DTGs)

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In this paper, we experimentally perform the temperature stability tests for the draw tower gratings (DTGs) from 373K to 723K. These results have been successfully adopted into the proposed mathematical aging model in the Ultraviolet (UV)-inscribed gratings. In the end, a long-term operation of the DTG samples can be predicted by using this model.

Introduction

Draw tower gratings (DTGs) are manufactured during the fiber drawing process prior to applying the coating in order to preserve the mechanical strength of the DTGs. From the point of view of FBG based optical fiber sensors, the stability of the reflected optical power and the Bragg wavelength will be an important parameter to determine the sensing performance of the sensor. T. Erdogan proposed an accelerated aging experiment method to stabilize temperature induced refractive index changes and introduced an empirical approach to construct the aging prediction model in UV-inscribed gratings [1]. Therefore, we will systematically perform this accelerated aging experiment on our DTGs. Then, the aging prediction model of our DTGs for long-term operation can be constructed by using the aging curve approach.

Sample preparation and aging results

In this accelerated aging experiment at different elevated temperatures, around two to three DTG samples with Ormocer®-T coating [2] were directly inserted in a tube furnace (9173, Fluke) for 3000 minutes. At the same time, the optical interrogator (SM125-500, Micron Optics) was used to monitor the variation of the reflected power and the Bragg wavelength. The initial reflectivity of our DTGs was measured at room temperature by the cut-back method and was used to normalize the variation during annealing as we have shown in the figure below. Therefore, the aging curves of the different DTGs are shown in Fig. 1.

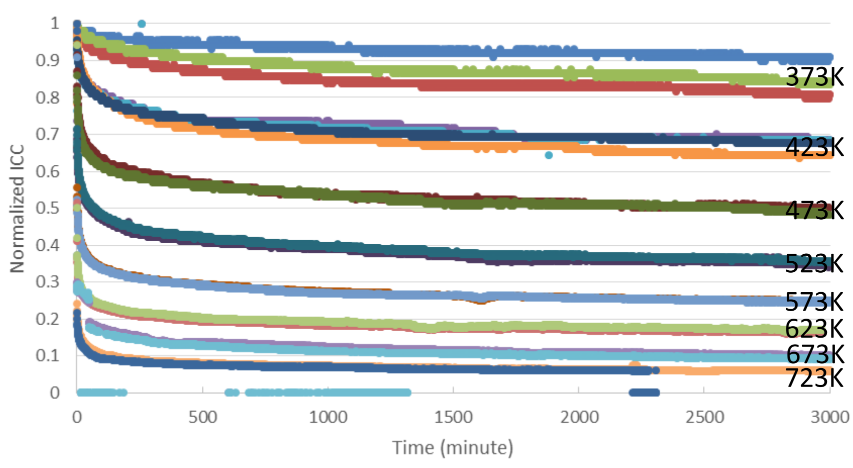

Fig. 1: The accelerated aging test results on DTGs.

Here, the aging result has been converted into integrated coupling constant ($ICC = \tanh^{-1}(\sqrt{R})$) versus time [3]. For each annealing temperature, the reflectivity will experience a sudden drop at the beginning and then gradually approach to a stable value. This drop becomes faster and more significant at elevated temperatures. This behavior also matches the concept of demarcation energy where the unstable component can be removed by either placing the grating at higher temperature or keeping the sample for a longer annealing time period.

Results and discussions

In order to construct the aging model for the DTGs, we will adopt the aging curve approach to analyze the experimental results from Fig. 1. In this method, the result from Fig.1 will be replotted in demarcation energy versus normalized ICC by tuning a fitting parameter for the best overlap between each individual temperature aging result.

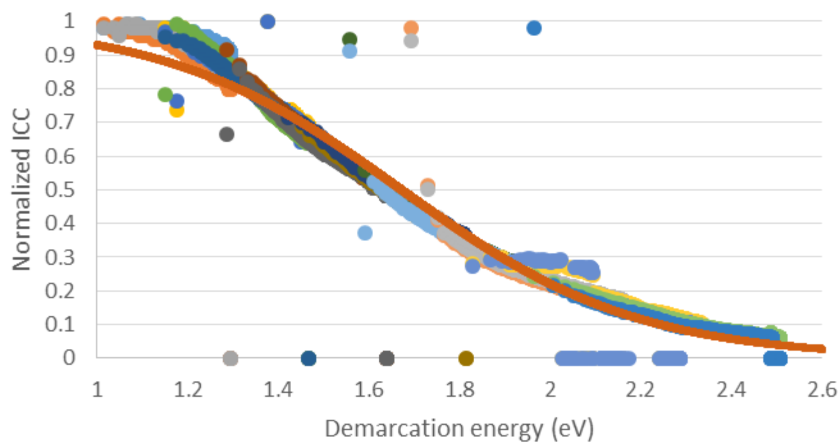

Fig. 2: Replot the accelerated aging test result in demarcation energy versus normalized ICC.

Then, two additional fitting parameters can be obtained by directly fitting the plot in Fig. 2. The fitted result is also presented as the orange curve in Fig. 2. The aging model for DTGs is shown in equation 1.

$$\text{Normalized ICC} = \frac{1}{1+\exp\left[\frac{\kappa T \ln(1E14t)-1.673}{3018K}\right]} \qquad \text{(Equation 1)}$$

where κ refers as the Boltzman's constant, T refers as the temperature in Kelvin and t refers as the time in minutes.

Based on this model, we can predict the stability of our DTGs at any given temperature or time period. More importantly, we can also use this model to estimate the required annealing elevated temperature and time period in order to achieve stable gratings [1]. For example, if we would like to wipe out the amount of unstable component of our DTGs for 1 year at 300K, we could anneal the DTG at 500K for less than 10^{-2} minutes to achieve accelerated aging. After this quick pre-annealing at higher temperature for the DTG, a stable DTG can be obtained at lower service temperature for long-term operation.

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References

[1] T. Erdogan et al., "Decay of ultraviolet-induced fiber Bragg gratings," J. Appl. Phys. **76**(1), 73-80 (1994)

[2] FBGS International NV. *ORMOCER coating* [Online]. Available: http://www.fbgs.com/technology/why-we-have-chosen-to-use-an-ormocer-coating/

[3] P. Yeh, Optical Wave in Layered Media. New York: Wiley Interscience, p. 190 (1988)