DURABILITYANALYSIS OF METAL-PACKAGED FIBER BRAGG GRATING SENSORS

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Abstract-Metal packaging for fiber Bragg grating (FBG) is consider over adhesive packaging due to its stability and resistance to high and low temperature. Currently we are focused mainly on the metal coating methods;enhance the temperature sensing methods, methods to welding into substrate while ignoring the durability of the packing.Which determines the accuracy and lifespan of the metal coated FBG sensors. Inthisinvestigation three metal coated FGB sensors for duration of four years were used. In this we focus on methodsof coating process of the FBG and sensors, experimental design and methods of testing. In research we found central wavelength, sensing capabilities of a prestretched metalized FBG decreases due to natural agingafter 10 months, and its negative strain detection capacity, sensitivity, linearity, and repeatability, which significantly degrade after 48 months.

INTRODUCTION-Electrical sensors are being replaced by the optical fiber sensors due to its intrinsic property of the optical fiber. One of the widely used optical fiber sensors is Bragg gratings (FBGs)due to their unique wavelength-encoded nature, immunity to optical power fluctuations, and its ability to bundle along single fiber[1].An FBG is directly sensitive only to axial strain and temperature variations, while using a special elastic structure which produces axial strain can be used indirectly to measure complex physical parameters such as force, displacement[2], and acceleration[3].In recent studies, metal-coated FBGs have been achieved through vacuum evaporation, magnetron sputtering, dipping, chemical plating and electroplating.Current research focuses on metal coating methods, the enhancement of temperature sensing, chemical gas sensing, and the method of mounting on the substrate. Ignoring the durability of the metal packaging, this determines the accuracy and lifetime of metal FBG-based sensors.In contrast, metal packaging technology has attracted considerable attention due to advantages such as its enhanced temperature sensitivity, resistance to high and low temperatures, and amenability to welding[4]. In recent studies, metal-coated FBGs have been achieved through vacuum evaporation[5], magnetron sputtering[6], dipping[7], chemical plating and electroplating[8]. A metal-coated FBG can be used to measure temperature, and a fully metal-packaged sensor for other physical parameters can be realized by fixing a metal-coated FBG onto an elastic substrate through welding[9], tin soldering[10], or other means. Current research focuses on metal coating methods[11], the enhancement of temperature sensing[12], chemical gas sensing[13], and the method of mounting on the substrate[14].

METAL PACKAGING AND EXPERIMENTAL DESIGN First, metal-coated FBGs were prepared. Using a bare single-mode SiO_2 optical fiber with a Bragg grating was coated with a Cr (chromium) film with a thickness of approximately 20 nm by magnetron sputtering to achieve good adhesion. Then, an Ag (silver) film with a thickness of approximately 40 nm was sputtered onto the surface of the Cr film to provide excellent electrical conductivity. Finally, a Cu (copper) film was electroplated onto the surface of the sputtered Ag film to increase the metal layer thickness until the diameter reached 0.3 mm. Three metalized optical FBGs were obtained via this method.The durability of metal-packaged FBG sensors is investigated using a special spring mass elastic structureto serve as an accelerometer. The configuration includes a FBG metalized optical fiber, two covers, a cylindrical mass, and a cylindrical base. The mass is placed in the through-hole of the cylindrical base with a transition fit, allowing free sliding along the axial direction. Thus producing three metal-packaged accelerometers with central wavelengths of 1556.376 nm, 1556.562 nm, and 1556.502 nm at 20 ◦C were constructed.

EXPERIMENTS AND ANALYSIS-Experimentswere carried on three metals packed accelerometer.Charge-coupled device spectrometer FBG interrogator were used to record central wave length of three sensor(acquisition frequency: 0∼8000 Hz, accuracy: 3 pm, resolution: 0.1 pm).While recording the central wavelengths, the sensors were placed into a temperature chamber that was maintained at 20^{o}C to eliminate wavelength shifts due to temperature variations.In particular, during the first 10 months, the three central wavelengths did not change, demonstrating that the metal packaging also remained stable during this period.the central wavelength began to gradually decrease from month 10 to month 36 and then remained stable up through month 48at a value reduced by 0.514 nm,0.488nm,0.699nm, respectively.The wavelength reductions of all three sensors indicate that the either the metal coating on the fiber or the laser welds worsened over the long term.Scanning electron microscopy (SEM) observations and energy dispersive spectrometer (EDS) analyses of the sensors show laser welded area contained oxygen, while new welded area contain no oxygen.The environment inside the sensor was found to be clean, with no particulates affecting the mass response. The interface between the metal coating and the fiber was well bonded, as observed from an SEM image magnified by a factor of 2500.it shows the adhesion between fiber and metal coating did not produce any inhomogeneous stains on FBG. Resulting in decrease of pretension force due to oxidation and rusting of laser welded area. Theexcitation frequency dynamic responses of each FBG were investigated by amplitude frequency characteristics using sinusoidal excitation in the frequency band from 20 Hz to 2000 Hz, with the input acceleration held constant at 1g (g = 10 m/s2).The flat response region of the three sensors was found to extend up to above 1000 Hz, so 160 Hz was used as the excitation frequency by convention.The amplitude-acceleration responseswere carried out by maintainingexcitation signal frequency at 160 Hzwhile the vibration acceleration was increased from 1g to 8g with a step size of 1g.The sensitivities of all three sensors increased over time, showing a pattern consistent with the decrease in the wavelength. The relative errors on the sensitivity after 48 months reached 14.71%, 16.02%, and 11.38%.The repeatability error was also increased after 48 months.The cause and effect of these changes can be analyzed as follows:The elasticity of the metalized fiber serving as the elastic element decreases along with the dynamic response due the decrease in the pretension force caused by oxidation and rust.Subsequently, the wavelength of each of the three sensors stabilizes. However, FBG would lose its capacity to measure a negative strain, and the elasticity would also disappear, resulting in sensor failure if the pretension force continues to decrease. Thus, for metalpackaged sensorsrealized by means of magnetron sputtering, electroplating, and welding, remains stable for only the first 10 months.

RESULT &CONCLUSION-The durability of the metal coated FBG with elastic structure is tested for a significantly long period. Experimental outcome shows that after 10 month the central wavelength of the metal coated FBG decreases due to natural aging caused due to oxidation and rusting of laser welded area which reduces the sensing capability. Here the sensors were exposed to the natural Indore physical conditions. If the sensors were exposed to rough condition(such as an oxygen-rich and humid environment) it would accelerates the oxidation and rusting resulting in the decreased sensing capability.In this study on the natural aging of metal-packaged FBG sensors for four years reveals lack in current understanding and could serve as an important reference for the research community.

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