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多結晶 Ga As を用いた光ファイバー温度センサー

OPTICAL FIBER TEMPERATURE SENSOR USING Ga As POLYCRYSTAL

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§1. Introduction

Laboratory and experimental testing work on electrical power equipments and in industrial plants with optical fiber and optical sensors has been carried out using GaAlAs LEDs and Si photo diodes. Generally speaking, the fiber optic sensor measurement accuracy is rather worse than for conventional electric sensors, but the fiber optic sensors will be used more in the near future. It is reason that they are electrically passive and largely nonreactive chemically and therefore suitable for use in many hazardous environments and they have significant advantages which are freedom from electromagnetic interference and freedom from insulation break.

There are many different principles involved in making and using optical sensors. One of them is the temperature shift of absorption edge wavelength in semiconductor material. So far, a GaAs single crystal as sensor material and GaAlAs LEDs/InGaAsP LEDs as light sources had been used for this purpose.[1] This report shows experimentally the usefulness of GaAs thin film deposited on the edge face of optical fiber for wider temperature dynamic range and better stability than for a GaAs single crystal.

§2. Absorption edge temperature dependence

Wavelength shift due to absorption edge temperature dependence is expressed by

$$\lambda_g = ch/E_g(\theta)$$

where λ_g is light wavelength, c is light velocity, h is Plank's constant and E_g is band gap energy between conduction and valence band in a semiconductor.

The absorption edge in a semiconductor single crystal, where light transmission changes sharply with wavelength, can be shifted with temperature θ, as shown in Fig. 1. Temperature of a single crystal chip can be measured with a fixed wavelength LED by detecting light intensity through the crystal.

There are several problems involved in applying this phenomenon to the fiber optic temperature sensor. They are: (1) Dynamic temperature range narrowness, and (2) difficulty in binding a crystal to an optical fiber at high measuring temperature.

In order to solve these problems, a semiconductor thin film, deposited at the edge face of silica fiber instead of the single crystal chip, was used. Transmission spectra for the GaAs thin film deposited on silica fiber by chemical vapor deposition are shown in Fig. 2, where the λ_g transmission characteristics inclination is a much gentler slope than for a single crystal. This is believed due to ambiguity in the energy gap, E_g in a GaAs thin film on the surface of the silica fiber edge. Temperature dependency is about 0.23 nm/°C, which is less than for the single crystal's case (0.4 nm/°C). The thin film stickiness to the fiber is considered no problem, since these characteristics have not changed after several heat cycles between room temperature and 300°C in atmosphere.

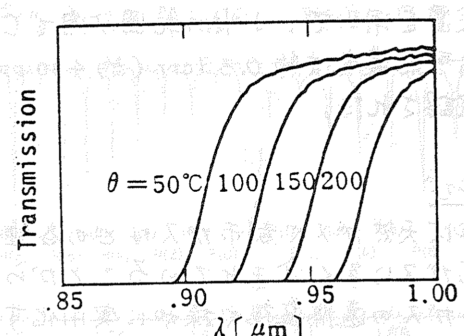

Fig. 1. Spectral transmission characteristics for various single crystal GaAs wafer temperature.

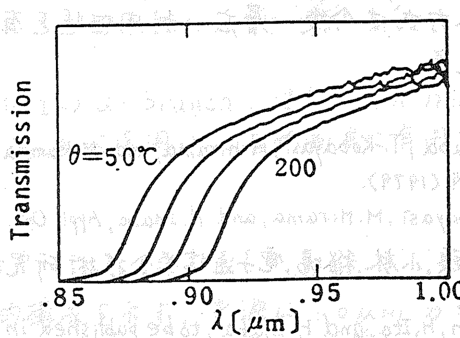

Fig. 2. Spectral transmission characteristics for various GaAs thin film temperatures.

Temperature dependence characteristics in Fig. 3 show transmission light output linearity through a single crystal GaAs and a thin film GaAs using a GaAlAs LED as a light source with 910 nm center wavelength. Thin film linearity is better than single crystal linearity.

§3. Sensor Controlling System with Micro-computer

Transmission loss turbulence or transmission loss variation in an optical fiber caused by micro vibration is one of the greatest problems in using an analog data transmission line. To get rid of the loss turbulence effect and to get high accuracy in measurement using an optical fiber, the two wavelengths method has already been developed,[2,3] in which another LED emits transparent light wave for GaAs material and this LED is used as a reference light source. In this experiment, a InGaAsP LED was used as an 1.06 μm reference light source. Reasons for choosing 1.06 μm wavelength are; (1) transparency in GaAs near sensing wavelength, (2) sensitivity in Si photo diodes, (3) availability ease (commercial devices).

Intensity turbulence effect caused by optical fiber vibration was able to be automatically canceled out by processing the ratio of the alternatively transmitted two wavelength light using a micro-computer, which is shown in the blockdiagram in Fig. 4. The LEDs for both sensing and refering light sources are alternatively pulsed-driven. Detected photo signals in a photo diode (PD-2 in Fig. 4) are processed in the micro-computer and are displayed as numerical temperature outputs. Another photo diode (PD-1) is used as a power monitor for determining output power from the two LEDs. Those output signals are also some of the microcomputer input information.

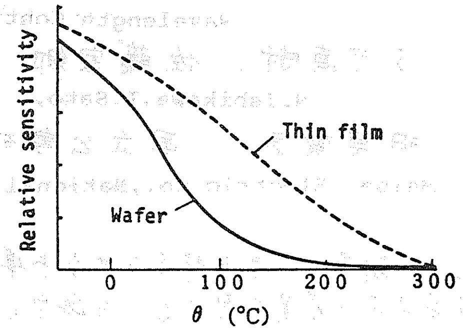

Fig. 3. Comparison of thermal sensitivity between single crystal and deposited thin GaAs film.

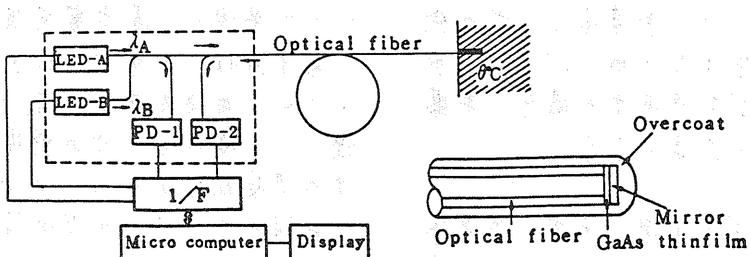

Fig. 4. Fiber optic temperature sensor blockdiagram.

§4. Conclusion

(1) Semiconductor thin films deposited on a glass plate or on an optical fiber edge face are applicable to optical sensing devices with smaller size, lower cost and sensitivity to a wider temperature range, compared to conventional single crystal chips cemented on the optical fiber edge face.

(2) Usage of various input information into a micro-computer such as sensing light power, reference light power, transmission ratio (0.91 μm over 1.06 μm light), and averaging calculation data for a large number of sensing light pulses causes fiber optic sensors to have a higher grade performance, compared to conventional sensors. This performance is needed for industrial automation and instrumentation systems.

References

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2) K. Goto *et al.*: Proceedings of annual meeting of the Japan Society of Applied Physics, p. 76, 8pN4 (Oct. '81).
3) N. Kamata *et al.*: IEEE Transaction of Electron Device ED-28, p. 379, (Apr. '81).