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Piezoresistive Sensor for Strain Measurement on Turbine Blade with Wireless Telemetry Data Acquisition

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Abstract

In the paper, strain-gauge sensor design and its application for wireless measurement of blade deformations and strains are presented. The strain sensor was designed using FEM (Finite Element Modeling) and uses piezoresistive strain sensitive boron doped nanocrystalline layers or insulated silicon layers (SOI). Nanocrystalline Diamond (NCD) is a very promising material for fabrication of harsh-environment devices because of its unique mechanical and electrical properties. The prospective of using diamond is not only in sensors (MEMS) but in RF and power electronic as well. Selection of method for data transfer is the key problem in rotating mechanisms. Traditional approach is using the slip ring, but it is not suitable for multisensor applications due to the requirement of one slip ring per sensing element. Telemetry can be related to transfer a data over any media, but is typically applied on wireless communications. A basic telemetry system consists of a measuring element or sensor, a device for sending the transmission, a receiver, and an output controller which records and displays data.

Key words

Piezoresistivity, nanocrystalline diamond, strain measurement, telemetry, wireless data acquisition.

1. Introduction

Piezoresistivity is one of the widely utilized physical phenomena in different kinds of sensor devices. The basic function of the strain gauge is based on transforming the strain in certain direction as to change its electric resistance.
It allows measuring plenty of non-electrical quantities such as deformation, bending, force, acceleration etc.
A transducer obtains the monitored signal and converts the value into an electrical signal ready for transmission. However, telemetry applications which support large numbers of measured channels are too costly and are impractical when used with separate transmission channels for each measured quantity. Measurements are formatted or multiplexed and transmitted. This paper describes a low cost, low power, embedded wireless transmission system for data acquisition, signal processing using microcontroller and saving of measured data on a PC host.

2. Sensor Design and Fabrication

A. 3D Modeling

The software package Coventor has been used for design of mechanical and thermal characteristics of the structure. The tools enable design, modeling and successive modification of designed MEMS structures. Generally, the software package enables: drawing of 2D layout and its editing, simulation of production process, generation of 3D model from 2D masks, generation of network by the method of finite elements, solution of mechanical, electrostatic, thermal, piezoresistive, induction, optical, and further simulations.
Two different strain gauge topologies were designed and simulated. The first with single resistors or half bridges (of length from 500 μm to 2000 μm and of width from 25 μm to 200 μm,) on single side fixed cantilever beam mechanical transducer (Fig.1), the second with four resistors forming the Wheatstone bridge on membrane mechanical transducer.

B. Technology of Fabrication of Sensors Used

Two different piezoresistive thin layers were utilized in fabricated samples. The first was widely used P-type silicon layer on insulating SiO_2 which enhances the high-temperature performance (SOI). The second was novel technology utilizing boron doped nanocrystalline thin film layers (NCD).