بسم الله الرحمن الرحيم

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شبكة المعلومات الجامعية

التوثيق الالكتروني والميكروفيلم

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Wide Spectral Range MEMS FTIR Spectrometer

A Thesis

Submitted in partial fulfillment of the requirements of a Master of Science degree in Electrical Engineering

Submitted by:

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B.Sc. of Electrical Engineering

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Faculty of Engineering – Ain Shams University

Electronics and Communications Engineering Department

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Degree: **Master of Science in Electrical Engineering**

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Statement

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering (Electronics and Communications Engineering).

The work included in this thesis was carried out by the author at the Electronics and Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

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ABSTRACT

This thesis aims to study the development of ultra-wide band mid-infrared (MIR) Fourier Transform Infrared (FTIR) spectrometer based on microelectromechanical systems (MEMS) technology and its applications in attenuated total reflection (ATR) sampling method. The spectrometer's core engine is a Michelson interferometer micro-fabricated on a single silicon chip. Different aspects related to the MEMS spectrometer spectral range are investigated. Silicon absorption and dispersion effects are modelled based on extracted optical constants of silicon wafers. Demonstration of gas sensing, lubricant oil and food analysis applications has been achieved up to wavelength of 9 μm using different IR sources and detectors.

Then, a novel ATR spectrometer is presented. The ATR sampling method is based on multiple reflections of light inside a high refractive index internal reflection element (IRE) allowing evanescent field to penetrate through the sample, which is in direct contact to the IRE. The transmittance is modelled for different types of excitations and compared to experimental results for different liquid samples. Finally, an integrated ATR spectrometer is proposed, where the IRE is micromachined on a silicon chip using deep-reactive-ion-etching (DRIE). Micro IREs are fabricated and characterized showing the ability of the proposed design for performing spectroscopic measurements. The device is compatible with microfluidics, where liquids flow inside micro-sized channels beside ATR IREs. The effect of sidewall roughness on the obtained ATR spectrum is theoretically modelled using ray-matrix method and compared to experimental results.

Keywords: Mid-Infrared, Micro-Electro-Mechanical-System, Silicon, Gas sensing, Food analysis, Attenuated Total Reflection, Evanescent field, Deep-Reactive-Ion-Etching, Microfluidics, Ray matrix method.

SUMMARY

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Thesis Title: **"Wide Spectral Range MEMS FTIR Spectrometer"**
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Development of miniaturized spectrometers for molecular analysis has gained great interest in the late few years for the sake of performing material identification and quantification everywhere and by everyone. Although many miniaturized spectrometers are reported either in the literature or in the market, most of them have a limited spectral response in the visible or near-infrared (NIR) ranges. At the same time, most of the materials have their fundamental absorption peaks in the mid-infrared (MIR) range which are much stronger than their overtones in the NIR range. Among different spectroscopic methods, Fourier transform infrared (FTIR) spectroscopy has proved to be the most promising technique having no limit on the spectral range of operation.

This work is based on bulk micro-machined free-space MEMS FTIR spectrometer. Michelson interferometer with one moving mirror, the core engine of a Fourier transform spectrometer, is micro-fabricated on a single silicon chip using deep reactive ion etching (DRIE) technology. Optical coupling to MEMS chip is based on free-space coupling instead of optical fibers. A study on silicon absorption in MIR range is performed showing the limitations on the MEMS spectrometer range that may not occur in discrete bulk spectrometers. Different spectroscopic measurements are done validating the wide spectral range of MEMS spectrometer and its application in gas sensing with the different available sources and detectors.