Chapter 1: Introduction

The demand for inexpensive infrared systems has grown for both civilian and military application for use as night vision systems, and in target acquisition, aerial navigation, commercial aircraft landing, and for smoke penetration.

For these applications, the atmospheric windows at 8-14 μm and 3-5 μm are particularly important, especially for the location/identification of warm objects, since peak emission for a 300 K object occurs in the former spectral region [1]. In general, IR detectors may be classified as either thermal or photon detectors. In photon detectors, the absorption process results in some specific quantum event such as photoelectric emission of electrons from a surface or electron-hole generation within the bulk, which is then counted by the detection system. Such photon processes require a certain minimum photon energy to initiate them. Photon detectors have a long wavelength cut off when the energy of a single photon, given by $E = hn = hc/\ l$, falls below this minimum required energy. For example, indium gallium arsenide exhibits a 1.7 μm cutoff wavelength. In addition, conventional silicon photon detector cannot be used for wavelengths greater than ~1.1 μm.

For longer wavelength detection, the performance of photon detectors is generally limited by the noise associated with dark current. This is particularly significant when the involved photon energies become comparable with the average thermal energies ($\approx kT$) of atoms in the detector itself. A relatively large number of quantum events may then be generated by thermal excitation rather than by light absorption, thus constituting a significant source of noise. To reduce this noise and thereby achieve high detectivity, the detector is usually cooled to 77K or lower temperature for operation in the infrared.

In contrast to photon detectors, which are sensitive only to wavelengths shorter than the cutoff, thermal detectors such as a conventional bolometer are, in principle, sensitive to all wavelengths. The absorption of light raises the temperature of the device and this in turn results in changes in a temperature-dependent parameter such as electrical conductivity. As a consequence, the output of a conventional bolometer is usually proportional to the amount of energy absorbed per unit time by the detector and, provided the absorption efficiency is same for the all wavelengths, is independent of the wavelength of the light. In addition, dark current does not limit thermal detectors. Therefore, they can be operated inexpensively at room temperature. For a number of important IR applications, it would be desirable to create sensor arrays that are capable of responding to infrared wavelengths. The development of a multi-spectral capability with functionality in the infrared region would have a profound influence on a number of military/civilian applications

In this dissertation, micromachined wavelength selective microbolometers operating at room temperature are fabricated, characterized and modeled using a transmission line equivalent circuit. The amount of power absorbed by the device is adjusted using interference effects, resulting in a device with wavelength dependent response characteristics. Using surface and bulk micromachining techniques, significant improvement in thermal performance is achieved by removing the substrate from the bolometer, supporting it with long and narrow suspension legs to increase the thermal impedance. Constructive interference produced by a mirror placed a quarter wavelength of the incoming infrared signal behind the microbolometers is used to enhance the absorption of the microbolometer are also briefly reviewed.

Chapter 2 reviews the basics of microbolometer theory. The operation theory of a microbolometer and the figures of merit of microbolometer detectors are discussed in detail, as well as their performance limitations. The common features of micromachining techniques that are used to realize better performance of microbolometers are briefly reviewed.

Chapter 3 presents the modeling of absorbed power coupling efficiency using a transmission line equivalent model and proposes a microbolometer structure capable of wavelength selectivity. The model demonstrates that the amount of absorbed power by the device can be adjusted by interference effects, and this modulation results in a device with wavelength dependence. Finally, the results of simulation using the model are given for several different structures, and a possible method of resolving multi-wavelength ambiguities is presented.

Chapter 4 describes the fabrication procedures used for the construction of the conventional, resonant dielectric cavity enhanced, and a resonant air cavity enhanced microbolomter. Several issues of fabrication processes are presented. In addition, mechanical stability and stiction, which are some of the most challenging problems in MEMS fabrication, are discussed, and a method of preventing those difficulties is introduced.

Chapter 5 shows the measurement results from the microbolometers. Several characteristics of microbolometers are evaluated such as thermal impedance, TCR, resistance versus dissipated power, and responsivity. Optical and electrical measurement setups are described, followed by the measured optical response of resonant dielectric cavity enhanced microbolometer. A comparison between the modeled and measured optical response is performed to establish the validity of the measured optical response. Finally, dc NEP is calculated by measuring the noise voltage under operating bias current.

Chapter 6 concludes the dissertation with a summary of the achievements of this research and presents ideas for future work in this area.