Development and Testing of a Micro-Cantilever Based Nano-Calorimeter for Explosives Detection

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ABSTRACT

Micro-cantilever sensors are considered to be attractive sensing platforms for chemical and biological detection. In this study we report the development of a nano-calorimeter based on a thermal bi-morph structure consisting of an array of 8 silicon nitride (SiN) micro-cantilevers with a gold (Au) coating that is integrated with a micro-heater at the base of each cantilever structure. The thickness of the SiN layer is 600 nm and the thickness of the Au layer is 400 nm. Each cantilever is heated to a different temperature by controlling the power (i.e., "actuation current") supplied to each micro-heater. The bending response of the micro-cantilevers is monitored using a laser source and a detector. The nano-calorimeter was tested by performing experiments using liquid and solid explosives such as Alcohol, Acetone, Ammonium Nitrate and TNT (Tri-Nitro-Toluene) as the vapor sources. The experiments were performed in a testing chamber developed for this study. In presence of the explosives vapors the bending response of the micro-cantilevers in the nano-calorimeter array is found to be different - depending on the ignition temperature and the vapor pressure of the analyte. Numerical models were developed using Computational Fluid Dynamics (CFD) and Finite Element Methods (FEM) to simulate the performance of the nano-calorimeter platform for the nano-scale combustion and heat generation/ heat loss from the gold coated cantilevers (where the 400 nm thick gold coated layer serves as a catalyst for the nano-scale combustion processes). Experimental validation of the numerical models for the thermal performance of the nano-calorimeter were performed using high speed digital image acquisition apparatus. Additional experiments are in progress using Picric Acid, Picramic Acid, PETN, Guanidine Nitrate, RDX, and Ethylene Glycol Di-Nitrate (EGDN). The aim of these studies is to detect Improvised Explosives Devices (IED) for a variety of explosives materials by developing a robust field deployable portable nano-calorimeter sensor ("electronic dog" or "nano-nose").