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ENERGETIC CHARACTERISTICS OF NANOPOROUS SILICON IMPREGNATED WITH DIFFERENT OXIDIZERS

Abstract

Nanoporous silicon is an inert material that can be fabricated by anodization of silicon in a highly concentrated hydrofluoric acid solution. The inert nanoporous silicon structure can be transformed into an energetic material by impregnation of a dissolved oxidizer into the nanopores. The process creates a mixture of a fuel (silicon) and an oxidizer in an almost molecular level, due to the unique nanoporous structure of the silicon. The fabrication process of the nanoporous silicon based energetic material is compatible with micro electro mechanical systems (MEMS) fabrication techniques, enabling manufacturing of the energetic material as an integral element of a MEMS system. This type of energetic material has specific advantages for multiple possible applications, e.g., actuation and propulsion of MEMS components, integrated micro pyrotechnic circuits, and micro igniters. This research presents a study on nanoporous silicon fabrication using the DOE (Design Of Experiments) method, which enables to determine the trends of influence of electrochemical etching process parameters on the porous silicon layer properties. DOE results were implemented to an empirical model that predicts the stability of the porous layer following the anodization process and enables to define the process window for fabrication of nanoporous silicon. Following the preparation of different nanoporous silicon samples, the energetic characteristics of nanoporous silicon combined with different oxidizers were investigated. Selected nanoporous silicon samples were impregnated with different perchlorate oxidizers dissolved in methanol. All samples were tested in a differential scanning calorimeter (DSC) at temperatures up to 600C, showing unique exothermic reaction peaks corresponding with the energetic reaction of silicon with the oxidizer. The heat of reaction for different compositions varied considerably, contradicting thermochemical calculations that predicted similar heat of reaction for all compositions. In practice, the heat of reaction of nanoporous silicon with oxidizers having higher oxygen content (e.g., calcium perchlorate versus sodium perchlorate), was found to be higher, exhibiting the behavior of a fuel rich reaction. Further feasibility proof for an energetic reaction was demonstrated by rapid heating ignition using a-priori heated hot plate to temperatures above 300C as well as by a semi-conductor-bridge igniter.