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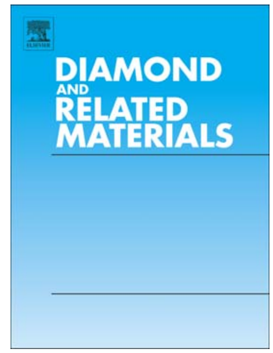

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Piezoelectrically Actuated Diamond Cantilevers for High-frequency Applications

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Abstract

In this work, we present a proof-of-concept for the modulation of field emission currents from boron doped nano-diamond based micro-electro-mechanical cantilevers. This modulation was achieved by variations in anode-cathode spacing using mechanical oscillations of the field emitting tips by means of piezoelectric actuation of an aluminum nitride layer. In these devices, the nano-diamond layers serve as a multifunctional material as they are used as field emitter, elastic layer in a unimorph layer stack and as electrode for piezo-actuation. The cantilevers are processed using conventional micro-fabrication technology and are enhanced by focused ion beam milling, introducing nano-scale features. In addition, it is shown that a stress compensating geometry is efficient to counteract the large thermally induced strain in the nano-materials used.

Introduction

In recent years, radio frequency micromechanical systems (RF MEMS) based on compound semiconductors and diamond have enabled breakthroughs in numerous application fields. Telecommunication technologies may profit directly from this development. In particular, by combining conventional MEMS technologies with the unique mechanical and electrical properties of thin nano-diamond films, one can obtain advantageous devices capable of operating at high temperature and in a radiation environment [1-3]. As nano-crystalline diamond (NCD) thin films [4] inherit most of the unique characteristics of bulk diamond, using NCD components fits perfectly to the RF MEMS concept, as NCD films can be highly p-doped [5] and also show superior mechanical properties and chemical stability along with high thermal conductivity[6].

Electrical switches based on such RF MEMS are especially suitable for front-end technology due to their potential advantages, e.g. low on-state insertion loss (0.2– 0.5 dB), high off-state isolation (> 45 dB), low power consumption (~ 1 μW) and high linearity over a large bandwidth [7]. However, fast mechanical and electrical degradation of switches that should realize billions of contacts per second remains a challenge [8]. Only by achieving a non-contact electro-mechanical switching functionality, conventional solutions such as transistors and pin-diodes can be replaced in emerging RF devices such as tunable low noise power amplifiers. Many groups have developed capacitive non-contact switches, however, these are prone to other failure mechanisms such as unwanted charging through e.g. electron field emission (FE) [9]. So, one prospective approach to prevent the mechanical contact in micro-