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Dielectric Tunability of DNA Biopolymer Films with Varying Amounts of Hexadecyltrimethylammonium Chloride

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Deoxyribonucleic acid (DNA) biopolymer films are fabricated with varying amounts of hexadecyltrimethylammonium chloride (CTMA), which is a surfactant necessary to produce a DNA complex that is soluble in organic solvents. The dielectric constant (κ) of these films at microwave frequencies as a function of applied static electric field (E_{DC}) is investigated. Results show that the dependence of κ on E_{DC}, which is referred to as the dielectric tunability, is influenced by the amount of CTMA in the complex. Dielectric tunability is suppressed when the amount of CTMA is insufficient and improved when more CTMA is added. However, excessive amounts of CTMA also result in a very rough film surface that causes shorting problems when used in a capacitive structure. A varactor employing a 1-μm-thick DNA biopolymer film as the dielectric is demonstrated. Under 5 V DC bias, which generates E_{DC} = 5 V/μm, its capacitance at 15 GHz changes by 0.04 pF. This change corresponds to a relative dielectric tunability of 6.6%. A simple application of this varactor for modulation of the power transmitted through a microwave transmission line is also demonstrated.

Key words: DNA biopolymer, varactor, dielectric tunability, microwave

INTRODUCTION

Over the past decade there has been tremendous progress in flexible electronic devices, and interest in this arena continues to grow. One apparent demand of such devices is for wearable applications. A couple of examples that have already been demonstrated are wearable sensors[1] and antennas.[2] There are numerous device applications such as optoelectronics, photonics, and radio frequency (RF) electronics where there is a growing demand for mechanical flexibility. To meet this demand, new flexible materials have to be explored. Biopolymers are appealing candidates because they are inherently deformable and biodegradable. With the rapid changes in technology, accumulation of electronic waste has become a concern, and thus the idea of biodegradable devices is attracting much attention.[3]

A specific class of biopolymers worth exploring is DNA-based biopolymers derived from waste products of the salmon fishing industry. In addition to being a low-cost material, it has already demonstrated properties that are appropriate for device applications; For example, DNA biopolymers provide higher electrical conductivity and lower optical loss than some cladding materials such as UV15 when used in polymer-based optical modulators. This results in higher poling efficiency.[4] The dielectric constant (κ) of DNA biopolymers at microwave frequencies responds to a static electric field (E_{DC}), which is generated by applying a DC bias voltage.[5] This property, which is referred to as dielectric tunability, can be exploited for tunable microwave devices; For example, materials exhibiting dielectric tunability can be used to form a variable capacitor, also called a varactor. Varactors are used in chip

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