Nanocrystalline silicon optomechanical cavities

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Cavity optomechanics and opto-mechanical circuits in general have gained popularity and are now used as a versatile framework in which to observe various classical and quantum phenomena involving both light and mechanical vibrations. Many studies focus on non-linear applications due to potentially huge impact of features such as phonon lasing, chaos and high sensitivity readout. Ultra-high quality factor optomechanical cavities have be created with a large number of shapes, such has micro-toroids, spheres, high-finesse Fabry-Perot cavities. Recently, cavities created in planar semiconductor films from specifically engineered one or two-dimensional periodic patterns gained popularity. Similarly, a large number of crystalline and polycrystalline materials were used to create these structures, such as silicon nitride (Si3N4), gallium arsenide (GaAs), aluminium nitride (AlN), diamond, and, of particular importance, crystalline silicon (Si) [1]. Si, in particular via the Silicon-on-Insulator platform that is already widely used in photonics, is especially promising for on-chip applications, due to both its low loss at telecom wavelength and CMOS compatible fabrication process. So far, the focus has been put on high quality crystalline silicon. However, the role of crystallinity is not as straightforward for non-linear applications as for linear ones. Furthermore, crystalline silicon presents two main drawbacks, namely the relatively high cost of the wafers and the limitation to a single thin layer of crystalline silicon.

To remedy to these issues, we have investigated the use of nanocrystalline silicon to create optomechanical devices. We demonstrate that this platform can be used to fabricate optomechanical cavities that display similar features to the crystalline platform, namely optical and mechanical properties that enable thermos-optic/free-carrier dispersion self-pulsing, phonon lasing [2] and chaos [3]. All of these effects occur at low input laser power and we even observed an extremely large tuning of the optical resonance, going as far as 30 nm, which occur due to the lower thermal dissipation rate in this material. Moreover, the self-pulsing induced phonon lasing appear at frequencies as high as 0.3 GHz, which is a factor of 5 higher than its crystalline silicon counterpart. We attribute this improvement to the shorter free carrier relaxation lifetimes.

References

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Figures

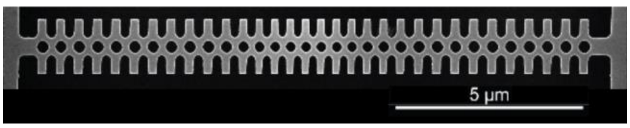

Figure 1: SEM image of the nanocrystalline silicon optomechanical cavity.