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Programmable Mechanical Resonances in MEMS by Localized Joule Heating of Phase Change Materials

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Dynamical control of mechanical resonance in MEMS and NEMS is a challenging task, usually achieved by external electrical fields or by modulating internal stress by thermal expansion. However, these solutions show some drawbacks and in particular they lack of memory effects . We report a material-based approach exploiting the phase transition of VO_2. Above 68°C VO_2 shows a sharp drop of resistivity by more than four orders of magnitude, accompanied by a monoclinic to rutile crystallographic phase change. This phase transition is hysteretic, showing a width of about 4°C and can be tuned by chemical doping or growth conditions.

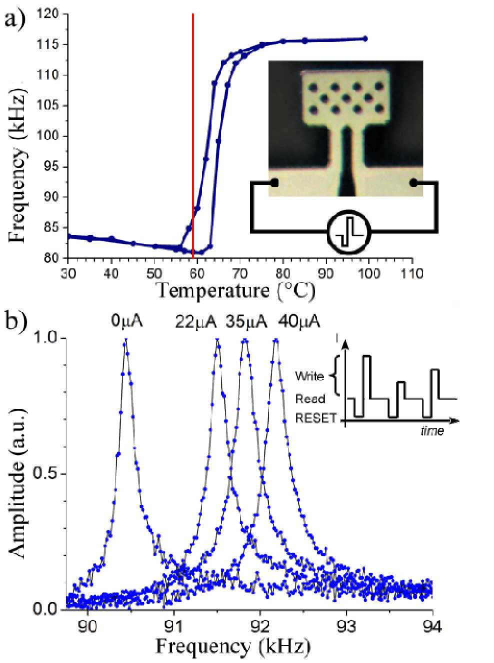

Fig.: a) Temperature dependence of the first flexural mode of the (unbiased) VO_2 microcantilever. b) Mechanical resonances of the microcantilever measured within the hysteretic windows (59 °C) and 15 μA constant read current bias upon a series of erase (0 μA)/write (22-35-40 μA) pulses (inset).

In thin films this phase transition is characterized by percolation between nanoscale-size domains, allowing the selection of intermediate physical states. Applying a current bias to a VO_2/TiO_2 free-standing mechanical microresonator we are able to control the formation of metallic (rutile) nanodomains by localized Joule heating. The local phase change modifies the interfacial stress between the two layers with a consequent shift of the mechanical resonance frequency proportional to the number of the rutile (metallic) domains. We are able to drive the monoclinic/rutile domains ratio by current pulses, thus selecting the resonance frequency of the microcantilever. The number of rutile domains is determined by the amplitude of the electrical pulse. A constant current bias maintains the "written" state after the pulse end, while the state is simply erased by a current pulse of zero amplitude. The key point of this approach is the mixing between VO_2 peculiar properties, low thermal coupling of free-standing devices and current biasing, which allows stable and reproducible selection of the different mechanical states.