Versatile applications of 80 kV Electron Beam Lithography : from nanotubes to biochips

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Thales Research and Technology Laboratory has a 1600 m^2 cleanroom facility with strong involvement in nanoscale-device fabrication for a variety of applications in nanoelectronics, nano photonics and quantum devices. For the versatile fabrication of the corresponding structures, we use a novel electron beam lithography apparatus nB3 from Nanobeam Ltd[1] operating at 80 kV with 3-nm beam size. We use classical PMMA resist and also the more demanding negative inorganic resist "HSQ", suited for fine pattern feature.

We shall present at the conference results in the following areas :

- Electron source (cold cathode) for high frequency electron tube : we fabricated arrays of vertically aligned carbon nanotubes (CNTs) on planar surfaces for field-emission (FE) devices. We use the e-beam lithography to pattern Ni catalyst dots (150 to 350nm) that precisely anchor the position of individual nanotubes (Figure 1) grown by PECVD. These arrays emit a 1A/cm² current density.[2]

- RF NEMS switches based on CNTs : they may fulfil the demanding low loss and high isolation features of switches in the 1-10 GHz range while operating below 10 V for the activation voltage, below a few tens nanoseconds for the switching time and handling high power densities. It proved critical to achieve a good alignment between optical and electronic lithography steps (error < 50nm on large substrates) (Figure 2).

- Biological sensors based on silicon nanowires: analogous to the CHEMFET, silicon nanowires may sense biological species adsorbed on their surface. The nanowires can be functionalised using dedicated bioreceptors for highly selective biosensing. The fabricated wires have a width of 30nm. They are etched in ultrathin silicon layer on SoI wafer (figure 3). For this process, we use a negative resist HSQ process.

- Photonic Crystal (PhC) technology on GaAs-based membranes : GaAs PhCs are 2D periodic pattern of holes etched through a thin (~250 nm) membrane, suspended in air, allowing various resonant nanophotonic structures. We study, e.g. the replacement of microrings by such structures [3] and we benchmark the quality of PhC processing through the Q-factor of submicron nanocavities. We could recently catch up the impressive levels (Q~1,000,000) of the more mature silicon technology, demonstrating Q-factors as high as 700000, where nonlinearities arise at microwatt injection levels[4].

1. Cambridge, UK
2. Milne et al., J. Vac. Sci. Technol. B 24,,1…, Jan/Feb 2006
3. J. E. Heebner et al., Opt. Lett. v. 29, p. 769 (2004)
4. S. Combrié, A. De Rossi, Q. V. Tran, and H. Benisty, "GaAs photonic crystal cavity with ultrahigh Q: microwatt nonlinearity at 1.55 µm," Opt. Lett., vol. 33, pp. 1908-1910, 2008.

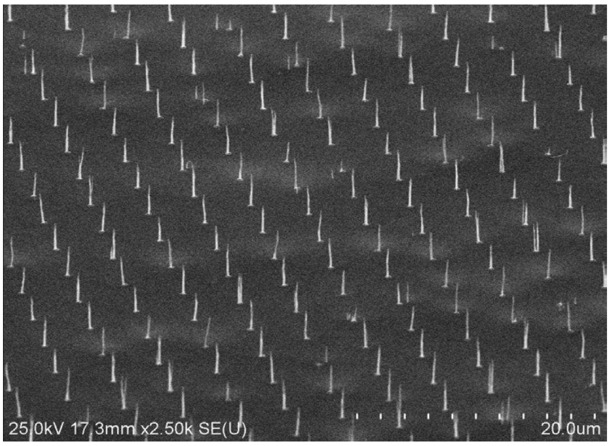

Figure 1 : arrays of vertically aligned CNTs

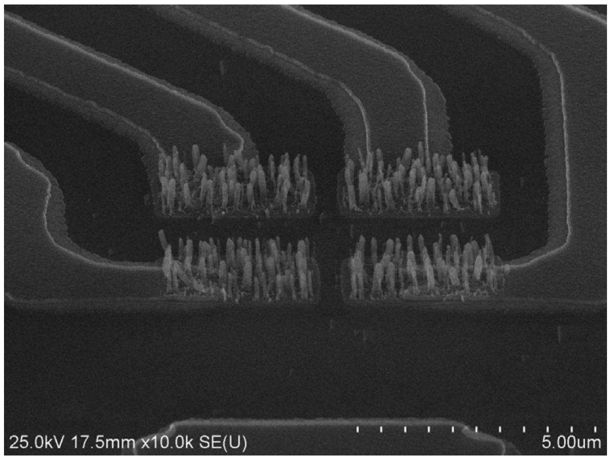

Figure 2 : RF NEMS switches based on CNTs

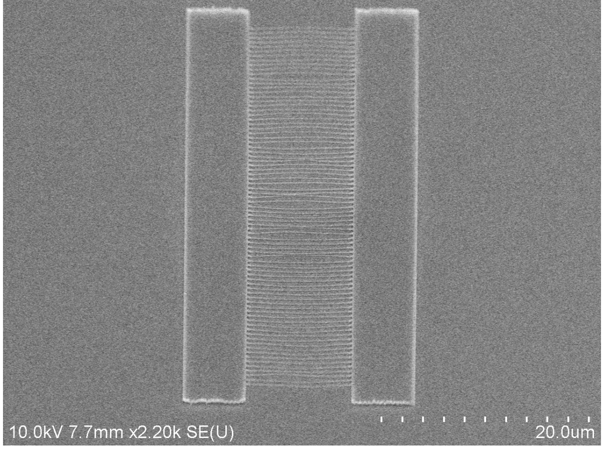

Figure 3 : Silicon nanowires for biological sensors

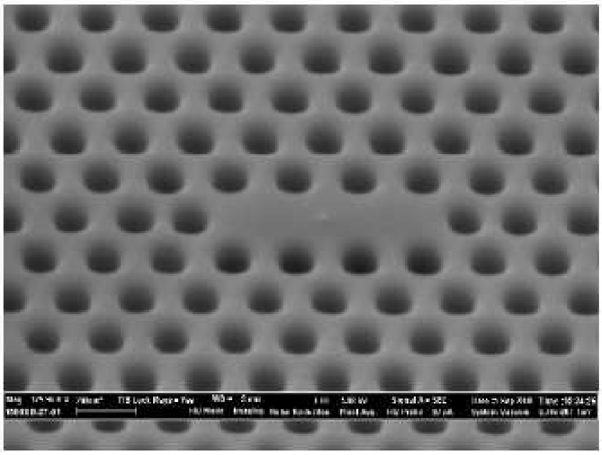

Figure 4 : Photonic Crystal on GaAs-based membranes