Nonlinear-optical anisotropy of silicon nanowire arrays

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Nowadays, arrays of silicon nanowires (SiNW) of about 100 nm attract great interest due to their unique optical properties such as extremely high light absorption, enhanced spontaneous Raman scattering, third-harmonic generation, and infrared interband photoluminescence, which are often connected with the light trapping in SiNW arrays.

The SiNW sample was fabricated by means of metal-assisted chemical etching process [1] at (110) crystalline silicon (c-Si) wafer. The formed SiNWs are strongly prolate parallelepipeds of about 100 nm in diameter tilted to the surface at the angle of 45° with projection oriented along $(1\bar{1}0)$ direction (Fig. 1a). The SiNW arrays demonstrate effective light scattering, therefore linear reflectance measurements evidence no effect of the SiNW orientation. However, nonlinear-optical processes, e. g. third-harmonic generation and coherent anti-Stokes Raman (CARS) scattering, which strongly depend on the local fields could demonstrate their anisotropy. The broadband CARS signal was generated at the frequency $2\omega_1 - \omega_2$, where ω_1 and ω_2 were the frequencies of Nd:YVO_4 laser (1064 nm, 10 ps) radiation and continuum radiation generated in optical fiber, correspondingly. The third-harmonic generation was carried out with the help of Cr: forsterite laser (1250 nm, 80 fs). In all cases polarization dependences of the signals were obtained.

In contrast to spontaneous Raman, the SiNW arrays exhibit pronounced polarization dependences of the CARS signal. The resonant CARS signal in SiNW ensemble is an order of magnitude less than in c-Si in the case when pumping radiation propagates perpendicular to the SiNWs and the CARS signal is collected in the direction along SiNWs and two orders of magnitude less than in c-Si in another case. Although third-harmonic signal for SiNW array exhibits less expressed orientation dependence then for c-Si, it exceeds the latter one the case of the fundamental radiation incident perpendicular, whereas in the case of incident wave propagation along the SiNWs it falls several time in comparison with c-Si (Fig. 1b). Thus, found in experiments anisotropy of the nonlinear-optical signals evidences the sensitivity of the these techniques to the orientation of SiNWs in their highly scattering arrays.

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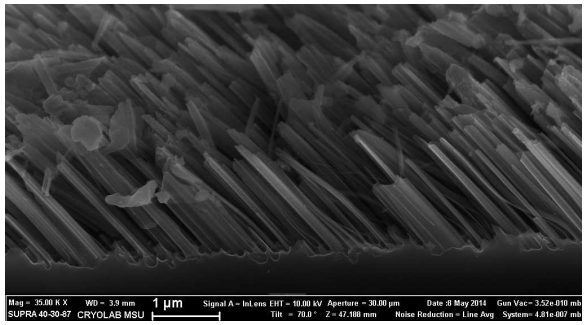
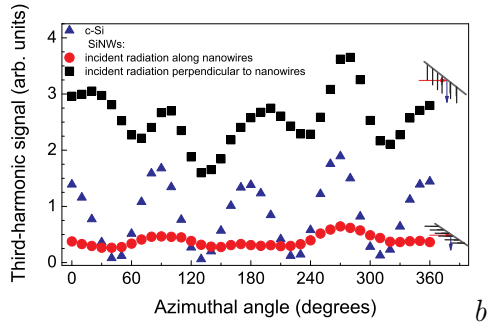


a



b

Fig. 1: (a) The SiNW sample cross-section in (100) plane. (b) Orientation dependence of the third-harmonic signals for c-Si and SiNW array in cases of fundamental radiation incident along and perpendicular to the nanowires.

References

[1] V. A. Sivakov *et al.*, *J. Phys. Chem. C*, **114**, 3798–3803 (2010).