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Edge Enhancement of Photocurrent in Si Stripes Measured by Multimode SPM

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A variety of semiconductor devices such as solar cells and photo-detectors exploit photo-carrier generation. As the size of modern devices decreases, the role of structural elements such as edges and corners in carrier accumulation has been increasing. Previously, we have demonstrated photocurrent enhancement near edges of wide Si stripes due to photocarrier generation at top and side surfaces under tilted illumination by multimode scanning probe microscopy (SPM).[1] Here, we investigated variations in edge enhancement of SPM photocurrent for STI-separated Si stripes (Si(001), Sb, ~1E17 cm^{-3}) under tilted optical excitation with 364 nm laser light, and compared it with FDTD simulations.

In our setup [Fig.1(a)] arrays of Si stripes were exposed to modulated laser light at ~40° angle, resulting in homogeneous excitation of top and left side of narrow stripes. While SPM topographs were acquired in a noncontact AFM mode,[Fig.1(b)] amplitude of SPM photocurrent (PC), i.e. tunneling current between the metal probe tip and the sample, was measured by a lock-in technique at a sample bias voltage of V_S =-0.8 V. Si surfaces with low density of surface states were obtained by passivation with ultrathin oxide layer.[2]

In narrow stripes, the PC amplitude was large in regions with straight edges, while PC was low near curvy edges such as indicated by circles in Fig.1(b,c). In wide stripes the peak-to-interior PC ratio was between 2 and 5 in Fig.1(d), which is larger than expected value of 2 for algebraic sum of top and side light intensity. Simulations of light intensity for our geometry and sharp edge of a Si bar in Fig.1(e) gives the PC ratio of ~4 for light polarization along the edge. Coherent laser light led to constructive interference in Si near sharp edges, thus, increasing photocarrier generation and consequently the SPM photocurrent. In contrast, interference of light is suppressed near rounded edges, resulting in small PC value. The results show significance of geometrical edges in effective carrier photo-generation in nanoscale semiconductors.

[1] L.Bolotov, et al., JJAP **51**, 088005 (2012);　[2] L.Bolotov et al., JVSJ **54**, 412 (2011)

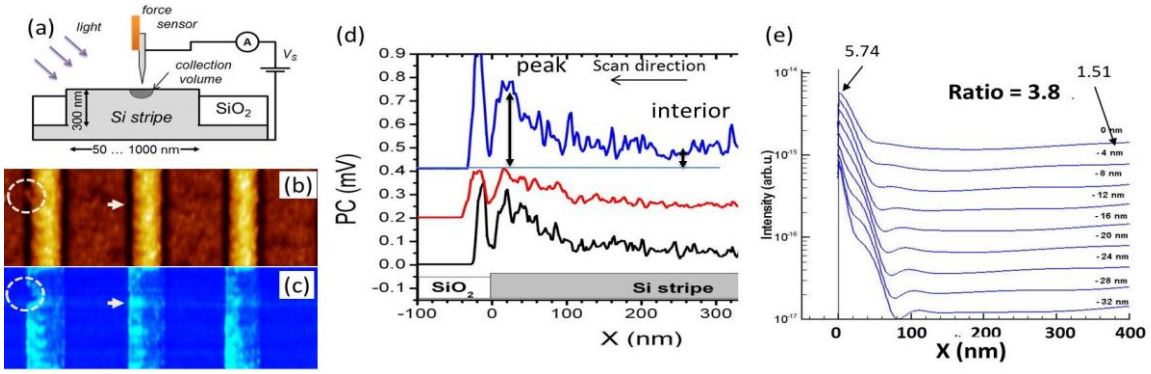

Fig.1 (a) Measurement setup. (b) SPM topograph and (c) corresponding PC map of 200-nm-wide Si stripes, V_S=-0.8V. Circles and arrows mark rounded and sharp edges, respectively. (d) PC profiles for different stripes. Profiles are shifted vertical for sake of clarity. (e) Simulated light intensity profiles.