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Efficiency Improvement of Silicon Nanowire Arrays (NWAs) Thermoelectric Power Generation (TEG) by Spin on Doping (SOD)

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Thermoelectricity offers an excellent clean energy generation opportunity because of its robustness and energy scavenging capabilities. Recently, it was shown that the replacement of bulk semiconductor materials by nanowires can boost the thermoelectric (TE) performance [1]. Since Si is ubiquitous, its use for integrated TEGs is attractive. However, Si bulk is a poor TE material. Single Si nanowires (NWs) have been reported to exhibit a 60 times higher figure-of-merit than Si bulk [2]. We have demonstrated that Si NWA-based thin film TEGs exhibit a 4× higher efficiency than silicon bulk [3]. However, their efficiency is still very low, limited by thermal and electrical interface resistances. In the current work we present a method to boost the output power of the TEG via post NWA-definition SOD.

Si NWAs are fabricated using metal-assisted electrochemical etching [4]. In order to have small interface resistances, the doping concentration at the contact-semiconductor interface needs to be high. This high doping concentration degrades the quality of the NWA, thus decreasing their TEG performance. Our strategy is to first etch the NWA and then apply SOD and anneal to overcome this problem (Fig. 1). In this research we have optimised the anneal process to minimise the Ohmic contact resistance and maximise the output power. The bulk side of the Si wafer has also been treated with SOD to decrease contact resistance. It is found that the efficiency improvement of the NWA-based TEG is depending on the SOD annealing time. Optimising the anneal time increases the maximum power output by 88500%. We attribute this increase to different factors: 1. the decrease of the electrical contact resistance, 2. the high quality NWA etched in less heavily doped Si, and 3. the surface passivating effect of the SOD that impedes surface depletion effects of the NWs.

We will present different measurements and simulations to explain the origin of the performance improvement. These include measurements of resistivity, contact resistance, Seebeck coefficient and output power (Fig.2). Simulations illustrate the doping diffusion process and the impact of the thermal and electrical contact resistance.

References:

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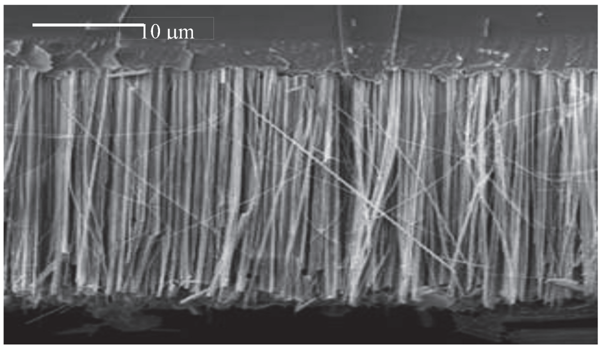

Fig. 1: Si NWA with SOD after been under pressure.

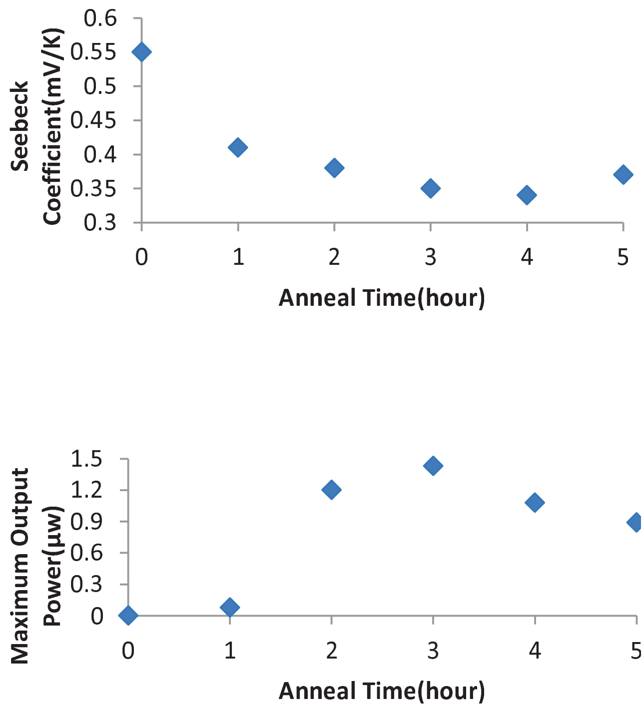

Fig. 2: The Seebeck coefficient and the maximum output power as a function of anneal time.