6 CONCLUSION AND OUTLOOK

In this work we set out to investigate the transfer of triplet excitons and demonstrate a singlet fission solar cell. Since the transfer of triplet excitons remains the main unaddressed challenge in the realization of singlet fission solar cells, any progress in this area is of great technological importance.

In Chapter 2 we saw quantum dots can be used to transfer triplet energy, but the requirement is a very close distance between quantum dots and a silicon surface. This distance requirement might be challenging if silicon is passivated by a thick passivation layer. The quantum dot itself can also have passivation shells that are thicker than the oleic acid groups we used. However, a main advantage of FRET compared to photon transfer is that we do not have to engineer any photon collection scheme in the singlet fission layer, potentially saving costs. It would be interesting to see an experimental demonstration of the predicted r^{-3} distance dependency. This has been attempted in the Master Thesis of Stefan Tabernig but the data was unfortunately not sufficiently clear to distinguish different distance functions.

The different transfer schemes in Chapter 3 lead to different solar cell efficiencies. It will be interesting to see whether this calculation increases the efforts to search for singlet fission materials with lower exciton energy and high entropy gain, to be used in a charge transfer singlet fission-solar cell. The requirements for a singlet fission material that can be used to manufacture an efficient singlet fission-silicon solar cell are numerous. The absorption has to be strong and broadband at the right absorption onset, the singlet fission process has to be efficient, the entropy gain should be high, and the triplet and hole transport has to be efficient.

Different schemes have less strict requirements for each of these, but the challenge remains. Once a solar cell has been produced it should also be stable for 25 years, since this is the lifetime of the base silicon cell. It might therefore be wise to focus first on the easiest singlet fission-silicon solar cell implementations.

Another problem we discussed is the detection of triplet transfer in Chapter 4. It is often difficult to immediately produce a complete solar cell stack with a singlet fission layer for each idea of how to facilitate triplet transfer. Even if the triplet exciton is transferred it can still be lost subsequently due to poor charge collection. One might therefore discard interlayers or other harvesting schemes because the solar cell is inefficient. This is only exacerbated for small singlet fission injection currents that only slightly change the overall cell current. Our method addresses some of these issues since a whole solar cell is not required, which can speed up sample preparation and throughput. We compare the triplet quenching of many different tetracene islands on the same sample with the same deposition and measurement conditions. It is however necessary to collect light from the recombining triplets, which is not possible for singlet fission materials with ultrafast singlet fission, such as pentacene.

During our demonstration of a singlet fission-silicon solar cell in Chapter 5 we saw that the polymorphism of tetracene can facilitate triplet transfer into silicon. In future work it will be very interesting to see whether one can deliberately deposit one or the other polymorph to control the transfer efficiency. The orientation of molecules at the buried interface is not yet measured, which would give further insight into the transfer mechanism. To increase our theoretical understanding of triplet exciton transfer it will be worthwhile to develop a theoretical framework of molecule orbital overlap with the tetracene wavefunctions and the silicon bandstructure, which could be used to investigate the effects of different interlayers and orientations on the Dexter transfer efficiency.

At last, we have to ask whether singlet fission-silicon solar cells can be on the market fast enough to compete with perovskite tandems and contribute to the green energy transition. There has been good progress recently, but fundamental challenges remain and the focus of the organic solar cell community has shifted towards perovskite solar cells in the last years. The author hopes that the successful realizations of singlet fission-silicon solar cells lead to increased research interest.