Highly efficient and durable solar absorber coating based on a hierarchical architecture

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A solar absorber coating is a key technology in concentrating solar power (CSP) because it converts concentrated sunlight into heat. The coating should be highly efficient and durable at elevated temperatures to improve the profitability and reliability of CSP. A 1% drop in absorptance of coating results in a 1% reduction in receiver efficiency. Pyromark 2500, a coating widely considered to be the current state of-the-art in CSP, exhibits 96–97% solar absorptance in pristine conditions but its solar absorptance significantly decreases after a few years of operation [1]. Poor durability leads to an increased levelized cost of electricity because of costs associated with repainting the entire receiver several times during their service lifetime.

To address this issue, a collaboration between Nano Frontier Technology (Japan), Shinshu University (Japan) and the Australian National University (Australia) developed and tested a coral-structured coating that exhibits outstanding solar absorptance and optical stability [2]. A unique hierarchical architecture yields a 98.2% solar absorptance in pristine condition. Importantly, the coating exhibits outstanding, stable solar absorptance of 97.75 ± 0.04% after aging at 850°C for more than 2000 hours. This coating is comprised of three layers: a base layer, an absorption layer, and a top layer, each playing a crucial role in enhancing its absorptance and durability. The base layer produces a strong adhesion to the substrate while having light-trapping properties due to its micropores. The absorption layer increases the absorptance by up to 1.1% and introduces optical resilience (optical ability to resist materials degradation) due to its coral-based macro-architecture. The top layer is a nanostructure consisting of a thin silica matrix (~8 nm) and ~120 nm silica nanospheres that enhances light absorption via forward light scattering. The absorption and top layers reduce reflection losses by almost half, from 3.5% to 1.9%, and significantly increase the light acceptance angle, defined as the angle at which the light absorption is 99% of its normal-incidence value. The coral-structured coating has an acceptance angle 28° greater than that of Pyromark 2500. Details of this new coating were recently published in *Energy & Environmental Science* [2] and featured on the cover of this prestigious journal.

More recently, the coating has been subjected to a range of accelerated aging tests to study optical and mechanical stability. Results of this testing demonstrate that the coral-structured coating has a higher absorptance and superior optical and mechanical durability compared to Pyromark 2500. For example, after 5000 cycles of thermal cycling testing, the coral-structured coating showed a 2.3% higher absorptance than Pyromark 2500. Significant optical and materials degradation were observed in Pyromark 2500, while the coral-structured coating remained relatively stable, showing no signs of failure for the same testing regime.

Nano Frontier Technology and Shinshu University led the coating design, materials development, and manufacturing method for this new coating. The Australian National University led the accelerated aging testing, light-trapping modelling, material and optical characterisation and assisted with the design of the hierarchical architecture.

[1] C. K. Ho, A. R. Mahoney, A. Ambrosini, M. Bencomo, A. Hall, and T. N. Lambert, “Characterization of Pyromark 2500 paint for high-temperature solar receivers,” in *Proceedings of the ASME 2012 6th International Conference on Energy Sustainability*, San Diego, USA, 2012, p. 91374.

[2] J. F. Torres*, K.* Tsuda, Y. Murakami, Y. Guo, S. Hosseini, C.A. Asselineau, M. Taheri, K. Drewes, A.Tricoli, W, Lipiński, J. Coventry , “Highly efficient and durable solar thermal energy harvesting via scalable hierarchical coatings inspired by stony corals,” *Energy & Environmental Science*, 2022.