Low temperature hermitic laser-assisted glass frit encapsulation; a safe bet toward stable perovskite solar cells

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Perovskite solar cell (PSC) are one the most fast growing photovoltaic technologies. The power conversion efficiency (PCE) of these emerging cells increased from 3.8 % to 22.1 % in 8 years[1, 2]. While PSCs displayed high PCE, their stability remains a major challenge. PSCs are known to be highly sensitive to many external environmental factors such as humidity and photo- and thermal exposure[3]. Stability issues such as photo- and thermal are mainly related to the components of the cell. However, the humidity can cause decomposition of the perovskite structure leading to a large PCE decrease[4]. Even though application of protective layers on top of the device can improve the humidity related issues, the commercialization of PSCs requires more advanced encapsulation methods.

The most common encapsulation methods for sealing PSCs are epoxy resins[5-7]. However, epoxies are not hermetic and therefore not long-time stable. According to MIL-STD-883 standard of microcircuits a sealing should display < 5×10^{-8} atm cm^3 s^{-1} of helium leak rate for being considered as hermetic[8]. Glass frit sealing is compatible to this hermeticity standard but the conventional bonding processes requires temperatures higher than 380 °C. Alternatively, a selective local bonding *via* laser beam can lower the process temperature to extend the hermetic encapsulation for a wide range of applications[9].

The present work, discloses a laser-assisted method for sealing glass substrates at process temperature of *ca*. 120 °C.

1. A. Kojima, K. Teshima, Y. Shirai and T. Miyasaka, *Journal of the American Chemical Society*, 2009, **131**, 6050-6051.
2. NREl, *Research Cell Efficiency Records*, 2017.
3. H.-S. Kim, J.-Y. Seo and N.-G. Park, *ChemSusChem*, 2016, **9**, 2528-2540.
4. D. Wang, M. Wright, N. K. Elumalai and A. Uddin, *Solar Energy Materials and Solar Cells*, 2016, **147**, 255-275.
5. F. Matteocci, L. Cinà, E. Lamanna, S. Cacovich, G. Divitini, P. A. Midgley, C. Ducati and A. Di Carlo, *Nano Energy*, 2016, **30**, 162-172.
6. Q. Dong, F. Liu, M. K. Wong, H. W. Tam, A. B. Djurišić, A. Ng, C. Surya, W. K. Chan and A. M. C. Ng, *ChemSusChem*, 2016, **9**, 2597-2603.
7. H. C. Weerasinghe, Y. Dkhissi, A. D. Scully, R. A. Caruso and Y.-B. Cheng, *Nano Energy*, 2015, **18**, 118-125.
8. MIL-STD-883H, *United States Department of Defense*, 2010.
9. S. Emami, J. Martins, L. Andrade, J. Mendes and A. Mendes, *Optics and Lasers in Engineering*, 2017, **96**, 107-116.