Towards organic agrivoltaics: OPV-like optical filters and their impact on crop growth

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In a scenario where world population is projected to reach 9.4 to 10 billion in 2050 [1], its food and energy needs will grow accordingly. Agrivoltaics (or agriPV) represents an elegant solution to circumvent any land competition between food and energy production. It consists in deploying photovoltaic (PV) panels on top of crops or animals for a dual usage of the same plot [2]. While crystalline silicon (c-Si) has taken over this new application quite naturally, it might not be the best suited PV technology, particularly for crops.

In order to grow, plants draw H_2O, CO_2 and light from their environment to produce carbohydrates and O_2 via the complex process of photosynthesis. Out of the entire solar spectrum, plants utilize the 400 to 700 nm range, known as Photosynthetically Active Radiations (PAR), for this two-step reaction. Over this spectral window, c-Si absorbs over 80% of the light, hindering photosynthesis and many key photomorphogenetic processes in plants. Organic photovoltaics (OPV) offers the advantage of tailoring the material absorption in perfect synergy with the crop needs to obtain the ultimate agrivoltaic system.

In this study, optical filters integrating various OPV materials were deployed on top of crops in greenhouse structures and compared to a control condition. Amongst the investigated materials stand green-absorbing donor polymers PTQ10 and PM6 and NIR-absorbing non-fullerene acceptors Y11 and IEICO-4F variously combined into blends. Inside each greenhouse structure sensors were implemented to monitor the temperature, relative humidity and solar irradiance. Growth dynamic was compared between the different conditions, monitoring the germination rate, 3rd leaf stage as well as survival rate. Upon harvest, biomass was characterized in a variety of ways from length and weight of the whole plant and its hypocotyl alone to the number and area of leaves. Stability of the different materials and encapsulation solutions to the greenhouse environment was assessed by absorption spectroscopy. Organic solar cells integrating these same blends were also fabricated and their initial performances as well as their stability over time were evaluated.

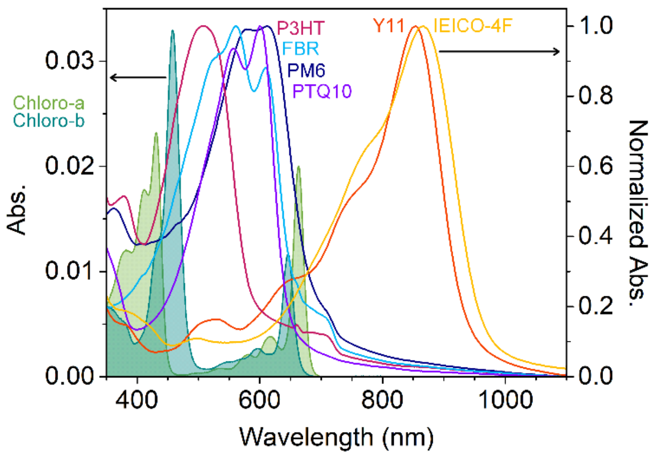

Figure 1: Absorption spectra of chlorophylls a and b (filled areas under curve, left Y-scale) and of various organic thin films: P3HT, FBR, PM6, PTQ10, Y11, IEICO-4F (lines, right Y-scale).

References

[1] United Nations "*World Population Prospects 2022: Summary of Results*" report, p. 27
[2] Goetzberger and Zastrow, "*On the Coexistence of Solar-Energy Conversion and Plant Cultivation*" International Journal of Solar Energy, Volume 1, 1982 - Issue 1