Thermal Response of Encapsulants for Photovoltaic Applications

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INTRODUCTION: Glass, polymeric encapsulant, solar cells, backsheet and aluminum frames conform traditional photovoltaic (PV) panels. During operation, they are exposed to environmental conditions and ultraviolet (UV) radiation. The encapsulant can suffer degradation due to the high energy photons and thermal stress [1-2]. Thus, we are interested in describing the thermal response of the encapsulant material, when inserted in a glass-encapsulant-glass (G-E-G) structure and in a small-factor (uPV) module (Figure 1), under indoor conditions using a lamp for accelerated aging.

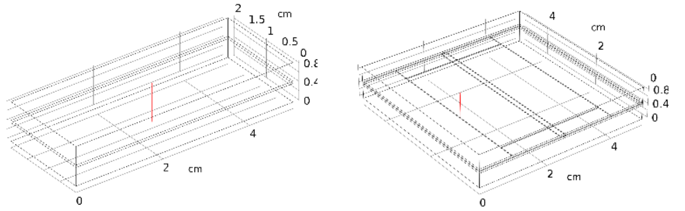

Figure 1. Glass-encapsulant-glass structure (left). Small-factor module (right).

COMPUTATIONAL METHODS

Governing equations

- The heat equation (Eq.1), where T is the temperature and ρ, C_p and k are the material density, heat capacity and thermal diffusivity.
- The Fourier's law of thermal conduction $\boldsymbol{q} = -k\nabla T$
- The external heat source Q due to light absorption (Eq.2), where I and α_b are the light intensity and broadband absorption coefficient.
- The Joule effect for the PV device, $Q_{el} = \boldsymbol{J} \cdot \boldsymbol{E}$, where $\boldsymbol{J}$ is the current density and $\boldsymbol{E}$ the electric field.

$$\rho C_p \frac{\partial T}{\partial t} - \nabla \cdot \boldsymbol{q} = Q \qquad (1)$$

$$\frac{\partial I}{\partial z} = \alpha_b \, I(z) = Q \qquad (2)$$

Boundary conditions (BC)

- Dirichlet BC for a lamp irradiance of 1480 Wm^{-2} at: the glass-encapsulant interface for the G-E-G structure and the encapsulant-cell interface for the uPV module.
- Heat convection at surfaces, $q_{conv} = h(T_{ext} - T)$, where h is the heat transfer coefficient, T_{ext} = 20 ºC.
- Surface-to-Ambient Radiation at front/rear surfaces, $q_{rad} = \varepsilon\sigma({T_{ext}}^4 - T^4)$, where ε is the emissivity of glass and σ the Stefan-Boltzmann's constant.

Input parameters: Table 1 shows the parameters of the PV materials [3]. The λ-dependent absorption coefficient [4-6] is used to compute the broadband α to insert in Eq. 2 as $\alpha_b = \int \alpha(\lambda) G(\lambda) d\lambda / \int G(\lambda) d\lambda$, with G the lamp's spectral irradiance in the $0.28 < \lambda < 2.2$ µm range.

Table 1. Thermal parameters for the PV materials, extracted from [3].

	k (W/(mK))	ρ (kg/m^3)	C_p (J/KgK)	ε
Glass	1.8	2700	750	0.9
EVA	0.32	960	2090	
Si solar cell	149	2330	838	
Silver	419	10500	239	
Aluminum	237	2700	900	

RESULTS: Stationary studies are shown in Figures 2-3.

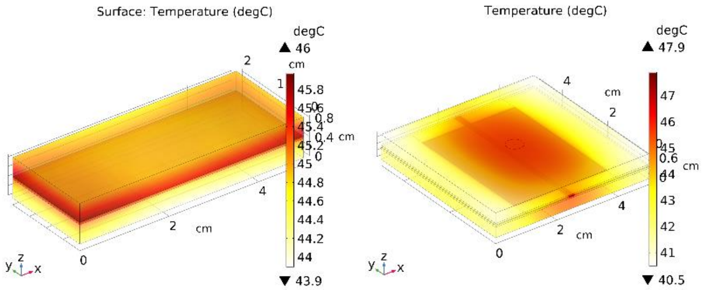

Figure 2. Temperature distribution for the G-E-G structure (left) and for the uPV module (right).

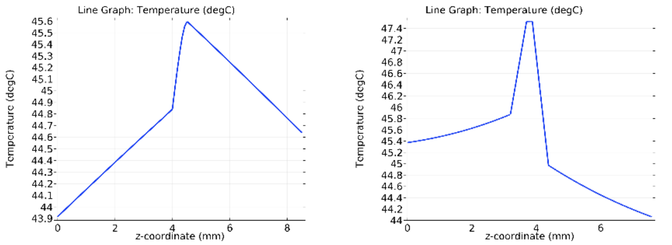

Figure 3. Temperature profile as function of z coordinate for the G-E-G structure (left) and uPV module (right). The temperature is specified along the vertical red lines in Figure 1.

CONCLUSIONS

The model reproduces experimental measurements of the surface temperature for the G-E-G structure, reaching ~50ºC in the stationary study. In addition, the temperature distribution of the uPV module agrees with the thermal response of PV modules operating under illumination.

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ACKNOWLEDGEMENTS

The authors acknowledge ANID/FONDECYT/11190289, ANID/FONDAP/15110019 "SERC-Chile" and CORFO with contract Nº 17PTECES-75830 "AtaMoS TeC" project.

Excerpt from the Proceedings of the 2020 COMSOL Conference