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Fundamental Research Insights

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IS SILICON GOING INDOORS?

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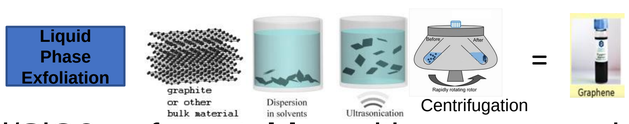
INTRODUCTION

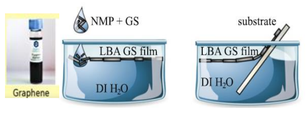
Recent developments in the field of photovoltaics and their prospective role in the internet of things (IoT) applications indicate a clear need to leverage on their ability to operate indoors. Low-light harvesters are particularly interesting, as they can provide a driving source for low-power sensor nodes used in various IoT systems [1,2]. In this work, we propose a facile, low-cost solar cell fabrication approach towards efficient indoor light harvesters based on graphene/n-Si Schottky-junction. The cells exhibit the efficiency of 6% and only 0.2% in indoor and outdoor conditions, respectively; demonstrating a 30 times increase in efficiency indoors [3]. With Raman spectroscopy and thermovision we validate the operational stability of such devices over a period of 48 months and identify critical structural points responsible for performance degradation during the ageing process [4]. The high efficiency under indoor light is caused by large shunt (parallel) and serial resistances. As we used high quality c-Si which is very stable over many years and graphene that becomes more stable with time, we can conclude that the Ag contact degradation mostly impacts the cell performance. The cells are produced from liquid phase exfoliated graphene made by Langmuir-Schaefer assembly [5]. In addition, cells were annealed (A cells) and then functionalized for 5 min by UV/ozone (AO cells). We found that AO cells exhibit a better performance than A cells. We assume that our cells are better in dark than light conditions because of intense recombination owing to the highly doped Si. A good performance at low light intensities and low cost solution production process of the graphene films could significantly extend the usage of Si solar cells in indoor light conditions.

PRODUCTION OF GRAPHENE FILMS AND SOLAR CELLS

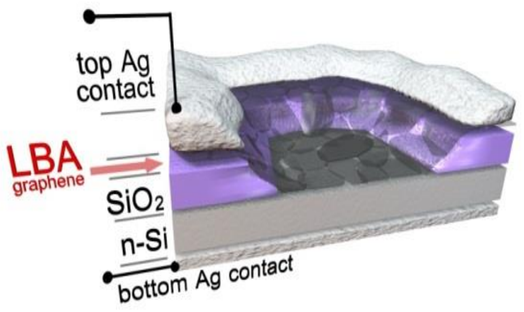
1. Graphene films fabrication by **LPE method**



2. Si/SiO2 wafers **etching** with concentrated HF of the SiO2 on front and back
3. **Depositing** graphene films on prepared wafers (Gr/Si junction)



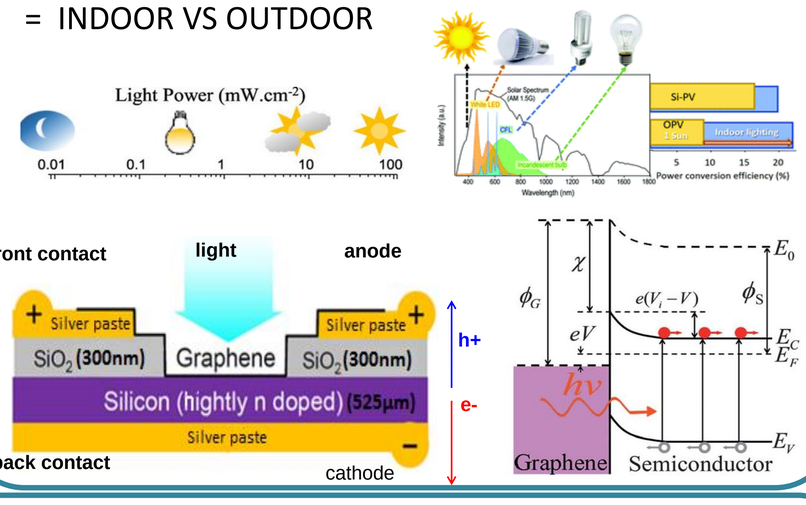
4. **Treatment** of graphene films: **Annealing** (300^0C ,2h in Ar)+**O_3** (50^0C air/100^0C plate,5min)
   - To remove residual solvent and to reduce sheet resistance
5. **Silver paste front and back contacts**



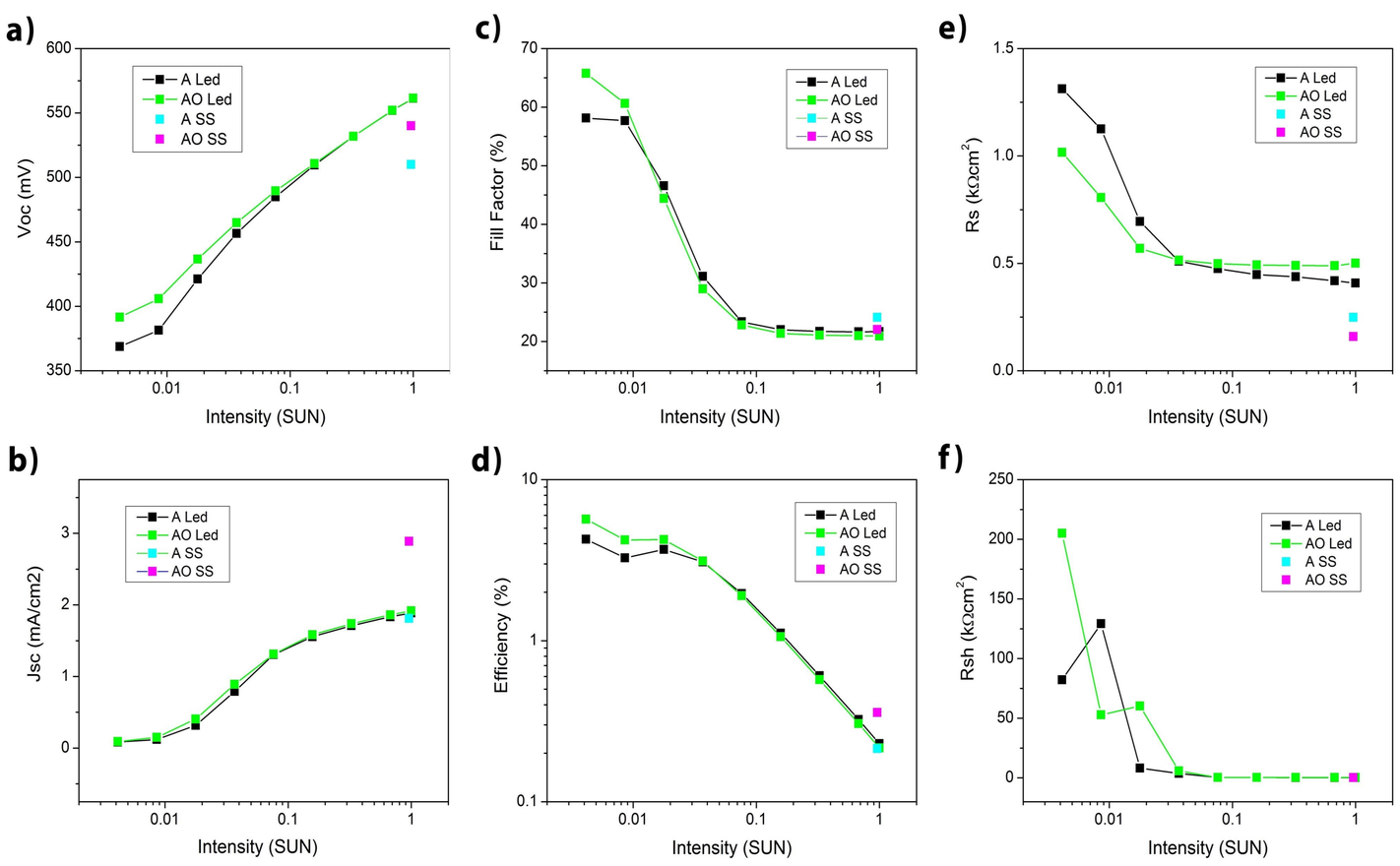
BACKGROUND PHYSICS

Low (indoor) VS normal (outdoor) light

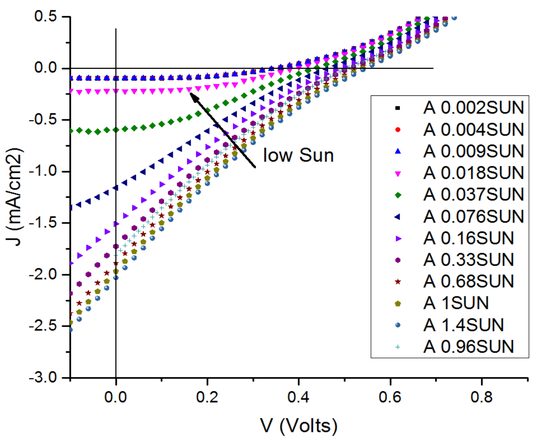
- 1-10W/m2 (0.1-1mW/cm2) low (indoor) VS 100-1000W/m2 (10-100mW/cm2) normal (outdoor) light conditions
  = INDOOR VS OUTDOOR



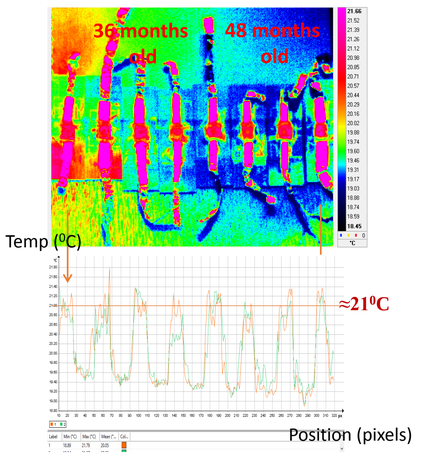
RESULTS

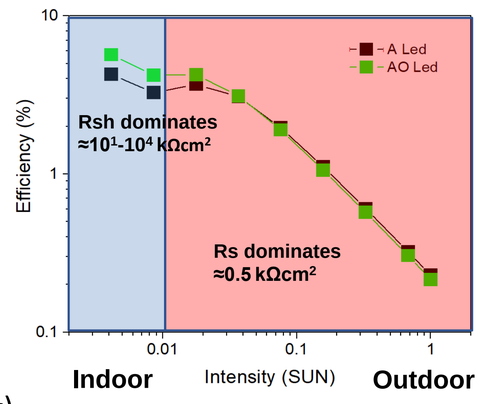


Solar cell parameters of pristine A and AO cells for different light intensities (indoor to outdoor) from LED (4200K, 0.004-1Sun) and Solar Simulator AM 1.5G (0.96Sun) light sources.



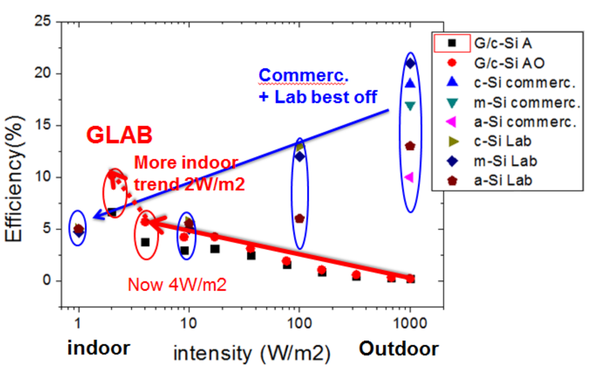
J-V characteristics of SC for diff. light intensities and sources





Rs and Rsh impact on Eff.

SC Stability (Thermovision map)



Glab VS Commercial Si

CONCLUSIONS

- We got **highest up to now Efficiency** for **Schottky junction SC made by LBA graphene films on Si**: **6% for AO** SC in low light 0.004 Sun conditions.
- The **efficiency is comparable to Si commercial and Lab solar cells in low light regime** (for less then 0.004Sun=4W/m2)
- **G/Si are better for Indoor** because of intense recombination + high Rsh and less impact of Rs
- **More then 500 days stability with Eff of 6% and more then 1000 days without significant defects**.
- Contact Ag degradation mostly impacts on cell performances.

CONTACT PERSON

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