

Chemical route for the recovery of different components in silicon based solar panel module

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ABSTRACT

As solar photovoltaic (PV) technology continues to expand in the global energy market, it is imperative to comprehend end-of-life management of solar panels. The recovery and recycling of materials from waste solar modules are essential for the sustainable development of the PV sector. In this work, back-sheet, glass, and other components including copper, silica were recovered using a solitary thermal method. The panels had to be heated to 250°C in order to remove the aluminium frames, and then they had to be heated to 600°C for 15 to 20 min in order to separate the layers of EVA encapsulant. The effective recovery of materials like aluminium frames and EVA layers was made possible by the thermal approach. Furthermore, nitric acid, phosphoric acid, and potassium hydroxide were used to recover copper and silica, yielding a 90% recovery rate for both materials. The suggested approach offers a viable means of recovering and reusing valuable materials in the photovoltaic industry while also demonstrating economic viability for the sustainable management of waste solar modules.

KEYWORDS: Solar panels; Silicon; EVA; Chemical route.

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1. Introduction

The world population is growing at an accelerated rate, which has led to a huge demand for electricity and a severe strain on the world's non-renewable energy resources. Several serious environmental problems, including greenhouse gas emissions and global warming, have been brought on by the careless use of these non-renewable resources. In order to address these environmental issues

and reduce carbon emissions during the power generation process, renewable energy sources are vital. To tackle climate change, the European Union has taken the lead in promoting a 20% cut in carbon emissions by 2020, highlighting the significance of switching to renewable energy sources [1]. The Indian government has established ambitious objectives to greatly increase the nation's capacity for renewable

energy, especially in the solar photovoltaic (PV) industry. India plans to install 100 GW of solar PV capacity by 2022 under the updated Jawaharlal Nehru National Solar Mission. This indicates the government's dedication to changing the nation's energy mix to include more clean and sustainable energy sources. On the other hand, solar PV systems' long-term dependability and performance are important factors to consider. Average lifespan of solar modulus is 25 to 30 years, but under normal environmental and operating conditions, this can be impacted by the deterioration of a number of components, including the encapsulant polymer material, active layers, back-sheet, contacts, and wires [2]. In order to meet the dedicated renewable energy targets, set by the Indian government and to guarantee the best possible performance and lifespan of the installed solar PV systems, it is imperative that these material and design issues are resolved. Over the course of their 25-year lifespan, solar photovoltaic (PV) modules typically see a 10% reduction in efficiency during the first 10–12 years of operation and a 20% drop. The design and warranties of solar photovoltaic systems anticipate and account for this gradual deterioration in performance [3]. In addition to damage sustained during manufacture, handling, and installation, the main causes of this deterioration are the long-term impacts of environmental elements like hail, storms, and corrosive environments. These environmental factors have the potential to cause early solar PV module failure, which would generate waste and necessitate premature replacement. Enhancing materials, manufacturing techniques, and installation procedures to address these degradation mechanisms is essential to prolonging the useful life of solar PV systems and reducing waste production [4,5]. It is predicted that when solar modules reach the end of their operational lives, there will be a corresponding increase in electronic waste (E-waste) [6]. It is projected that 8 million tons of EOL solar module waste will be produced in India as a result of the expansion of photovoltaic (PV) installation capacity to 100 GW [7]. 90% of installations are made up of mono- and polycrystalline silicon solar cells, which make up the majority of PV modules on the market [8,9]. As a result, silicon-based photovoltaic systems are anticipated to be the main source of waste. **Fig. 1** shows the various layers that make up a typical crystalline silicon solar module.

An aluminium frame encasing each of the solar module's layers makes up the top layer. Beneath this, the module's mechanical strength and shock resistance are provided by the second layer of optically transparent tempered glass. The plastic film called ethylene vinyl acetate (EVA), which holds the glass and solar cells together, comes right after the glass layer. The back of the module is covered with a second EVA layer that houses the solar cells, and the end of the module is laminated with PET, PVDF, and PVF polymers. Lastly, a junction box for electrical connections is attached to the solar module's back [10–17]. At the moment, the early loss scenario is the main way that end-of-life (EOL) solar modules end their operational life. But between 2030

and 2040, there will likely be a significant rise in the number of EOL PV modules—for both regular and early loss scenarios—which will call for recycling and disposal strategies. This change suggests that a greater proportion of solar modules are reaching the end of their useful lives, necessitating the development of effective management plans to deal with the growing waste from EOL PV modules [6]. Metallurgical operations can be used to extract the remaining semiconducting and metallic materials, while thermal treatment processes can be used to recover the glass and aluminium components, respectively.

To reduce waste and allow for the reuse of these resources in the production of new goods, it is imperative that the materials used in solar panels be recovered and recycled [18,19]. It is important to note that recovering silica, copper, glass, and aluminium is essential because it leads to the efficient use of resources and lessens the need for mining virgin materials. This is in line with the circular economy's tenets, which emphasize resource reuse and waste reduction.

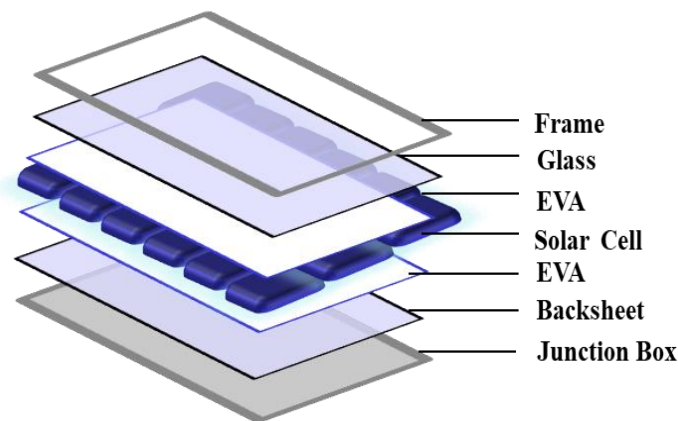


Fig. 1. Schematic of various layers of Photovoltaic module.

2. Experimental

2.1. Recovering glass and aluminium frames from solar panels

One important step in separating the various layers of solar panels is thermal treatment. The cost of recycling solar panels is largely dependent on the silicon wafers, so it is important to carefully optimize the heating conditions to prevent damage to these wafers.

Two stages of heat treatment are used in the recycling process for solar panels to separate the various components. The aluminium frames are removed from the panels by first heating them to 250°C.

2.2. Extraction of EVA

The ethylene-vinyl acetate (EVA) encapsulant layers are then separated by heating the panels to 600°C for 15-20 mins. The efficient recovery of the different materials, such as the aluminium frames and the EVA layers, is made possible by this stepwise thermal approach, which also prevents damage to the silicon wafers underneath. Solvents such as chloroform, toluene, and trichloroethylene dissolve EVA.

Toluene was selected as the material recovery solvent out of the three because it is less toxic and volatile than other organic solvents [20]. After that, the extracted EVA is heated to 60 degrees and submerged in toluene to achieve full dissolution. EVA completely dissolves in toluene in 10 to 15 minutes as mentioned in **Fig. 2(a)**. We have now put this solution in a petri dish and allowed it to dry overnight (**Fig. 2b**). We prepare an EVA film, which allows us to recover 95% of the EVA (**Fig. 2c**).

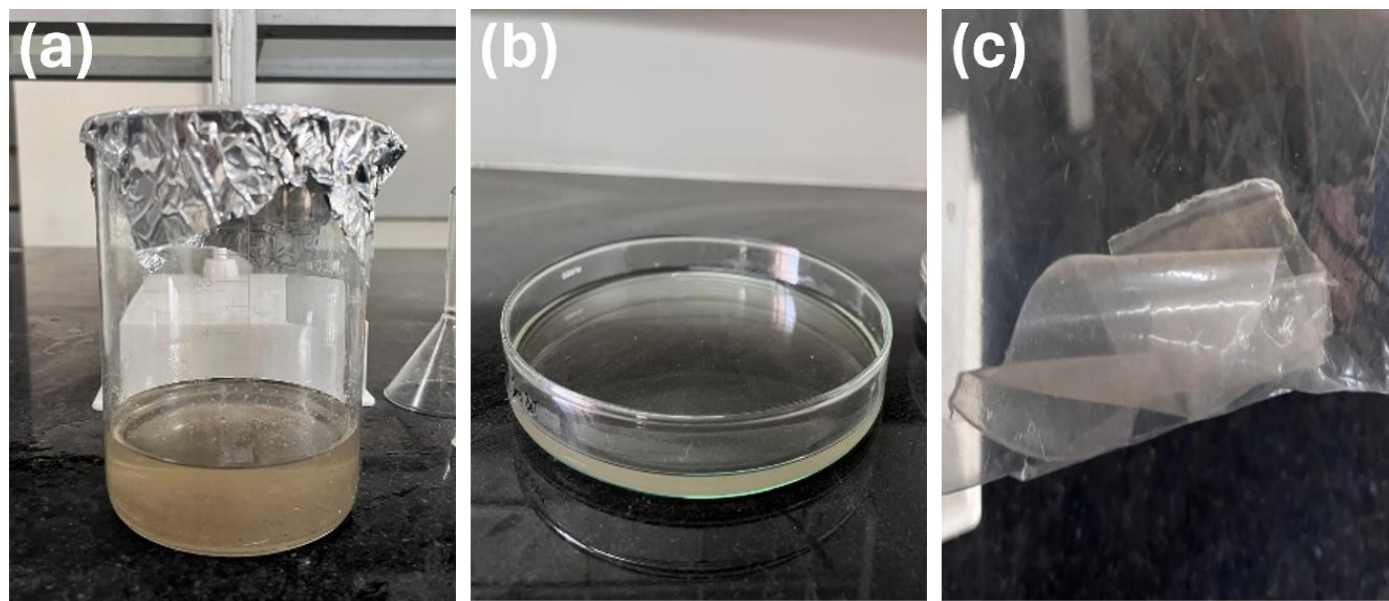


Fig. 2 (a) EVA dissolved in toluene, (b) Preparation of film of EVA and (c) Recovery by EVA film.

2.3. Recovery of Glass and Copper (Cu)

Damage-free glass was recovered after the heat treatment, and copper wires and the remaining solar cells were collected by manual sorting as illustrated in **Fig. 3**. This methodical recovery procedure protects priceless items like unbroken glass and makes it easier to gather recyclables like copper wires and solar cells for further recycling processes.

2.4. Recovery of Si and Cu

We need to take 1N HNO₃ for an hour without disturbing anything. The solution is now filtered using Whatman paper 44 after an hour has passed. Following filtering, the materials are submerged in 90% H₃PO₄ solution at 160°C for an hour, and then they are once more filtered. Next, for a full day at room temperature, the filtrate is once more submerged in

45% KOH solution. These procedures result in the recovery of pure silica and Cu wires (**Fig. 4**).

3. Results and Discussion

In the current experiment, easy approach is applied by using lesser amount of chemicals for solar panel components recovery including glass, copper wires, silica wafers, aluminium frames, and back-sheet. Al frame and back-sheet are 100% recovered as a result of this process. Si and Cu wire recovery has been reported to be 90%, while EVA recovery is 95% (**Fig. 5**). This technique makes efficient component recovery possible, making it a very cost-effective and large-scale process. The thermal method has a high separation efficiency and a quick separation rate.

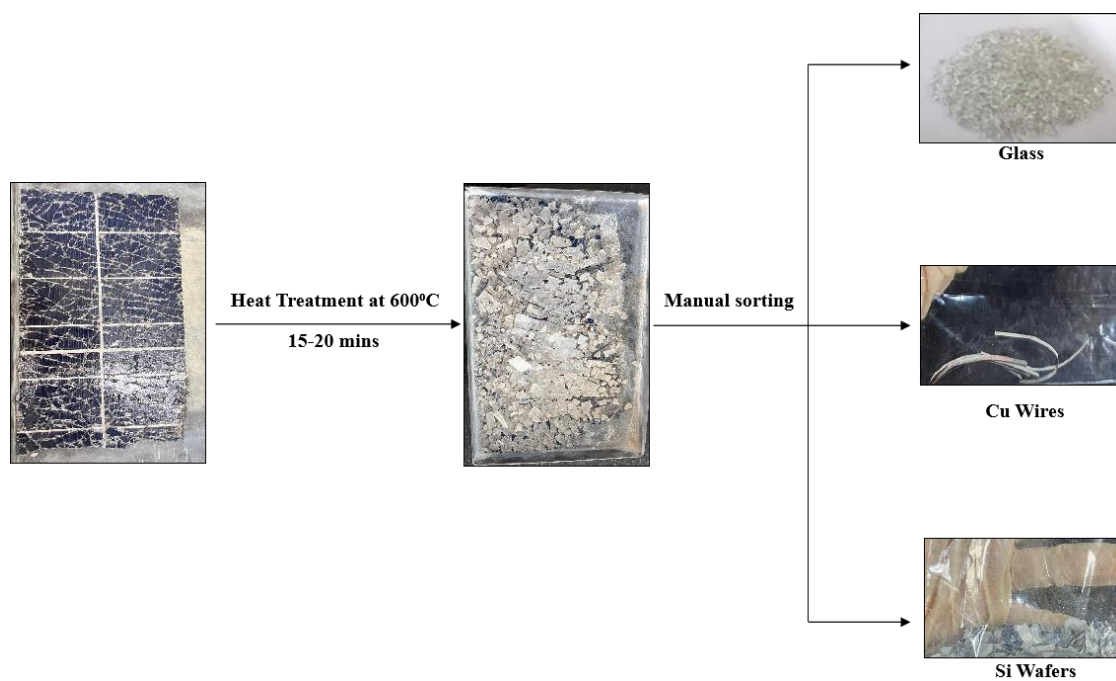


Fig. 3. Extraction of Glass, Cu wires and Silica wafers.

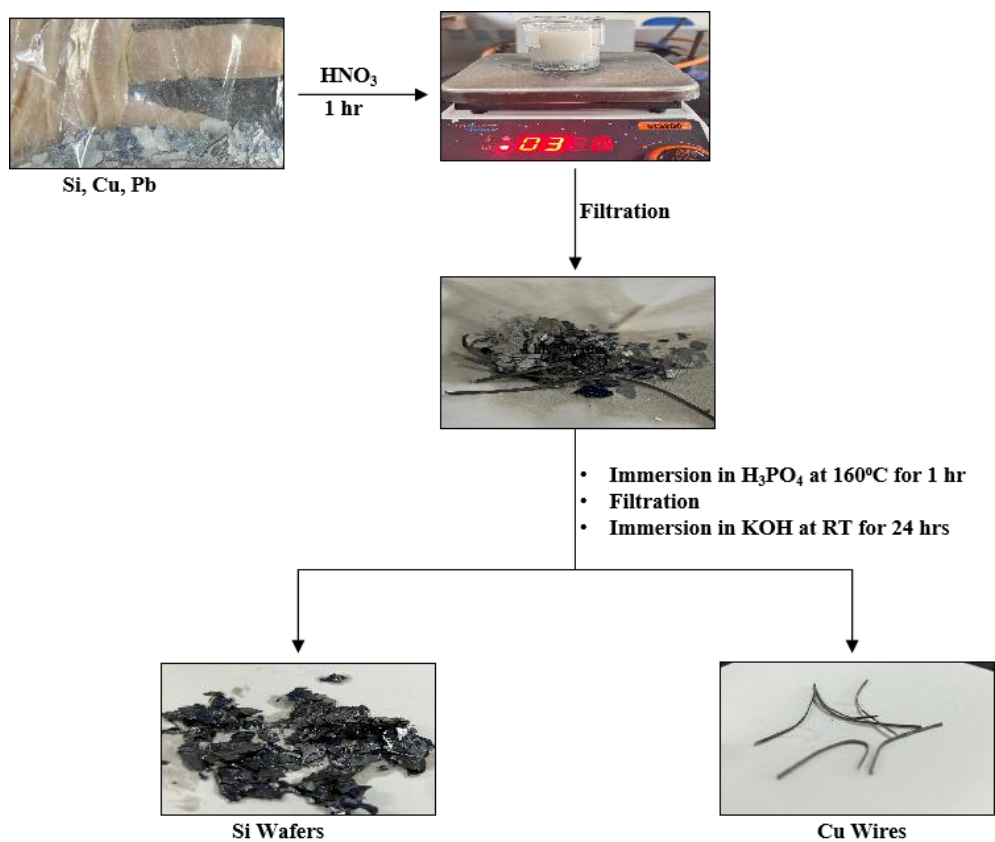


Fig. 4. Process of recovery of Pure Si wafers and Cu wires.

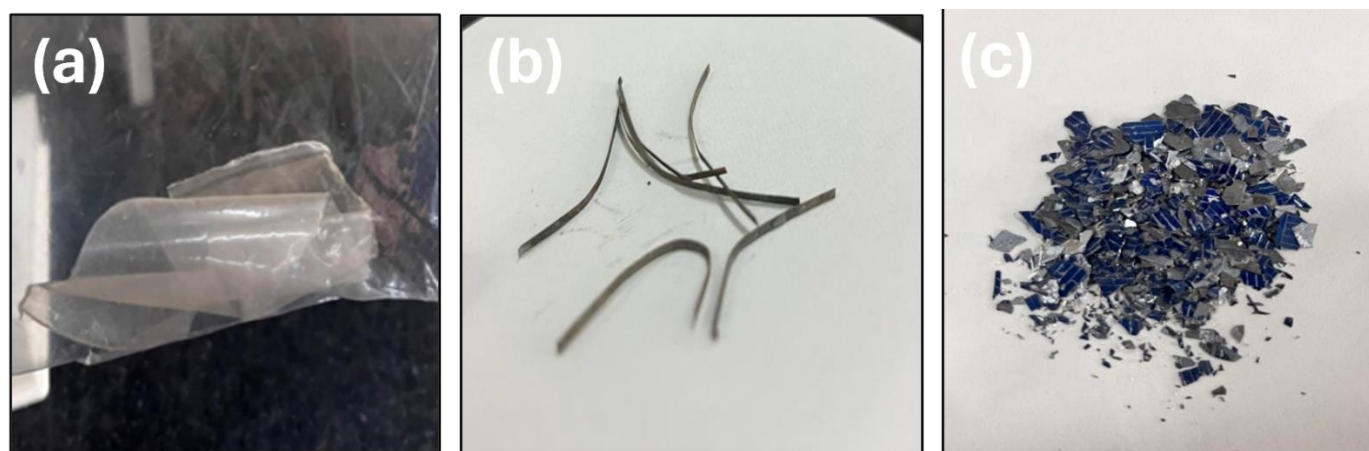


Fig. 5. Recovered (a) EVA, (b) Cu wires, and (c) Si wafers.

4. Conclusions

In the current work, an easy approach for removing copper, glass, silica, and aluminium frames from a photovoltaic module is reported using a thermal method. The process adopted led to the efficient recovery of 90% of silica and copper and 100% recovery of back-sheet, glass and junction box. The preheat treatment led to Al frame recovery and then second heat treatment resulted in the separation of different layers of EVA. EVA can be further extracted by dissolving it in toluene that made 95% of EVA recovery. It is now possible to fabricate a new solar modulus using the recovered polymeric materials. For the management of used solar modules, the proposed approach will be financially feasible.

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Disclosure statement

The authors declare no relevant financial or non-financial interests.

Data availability

Raw data of the research article is available with the authors and will be provided as per a request from the journal.

Ethical approval

Not applicable.

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