

OpenAPI를 사용한 ChatGPT 활용 실습

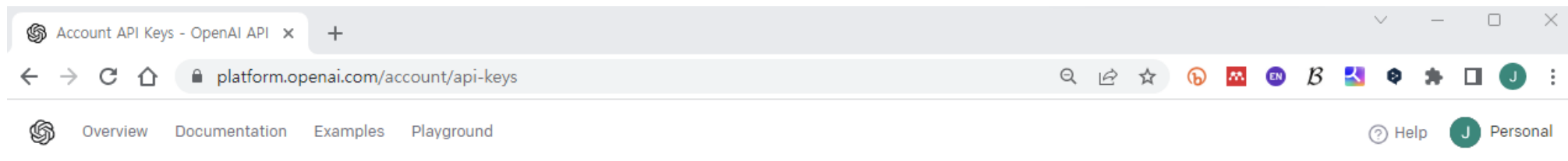
2023.04.19.

한국에너지기술연구원 계산과학연구실

이제현

OpenAI API Key 만들기

<https://bit.ly/42aPAlS>



ORGANIZATION

Personal ⓘ

Settings

Usage

Members

Billing

USER

API Keys

API keys

Your secret API keys are listed below. Please note that we do not display your secret API keys again after you generate them.

Do not share your API key with others, or expose it in the browser or other client-side code. In order to protect the security of your account, OpenAI may also automatically rotate any API key that we've found has leaked publicly.

SECRET KEY	CREATED	LAST USED	
sk-...Ds4r	2023년 3월 10 일	2023년 3월 15 일	🗑️

+ Create new secret key

Default organization

If you belong to multiple organizations, this setting controls which organization is used by default when making requests with the API keys above.

Personal ▼

Note: You can also specify which organization to use for each API request. See [Authentication](#) to learn more.



Google Colab

<https://bit.ly/3mHZriT>

230419_KSES.ipynb ☆
파일 수정 보기 삽입 런타임 도구 도움말 오후 12:00에 마지막으로 저장됨

목차

라이브러리 설치

- 단위 기능 구현
 - 논문 검색 (semantic scholar)
 - 초록 받기 (semantic scholar)
 - 초록 요약 (ChatGPT)
 - 한글 번역 (Google Translator)
 - 일괄 초록 요약 번역 (python: for)
 - 명사 추출, 기본형 변환 (ChatGPT)
 - 데이터 취합, 엑셀 파일 저장 (pandas)
 - 워드 클라우드 작성 (WordCloud)

섹션

+ 코드 + 텍스트

라이브러리 설치

```
[ ] 1 # OpenAI
    2 !pip install openai
    3
    4 # Google Translation
    5 !pip install googletrans==4.0.0-rc1
    6
    7 # Word Cloud
    8 !pip install wordcloud
```

단위 기능 구현

1. 논문 검색 (semantic scholar)

<https://www.semanticscholar.org/product/api>
https://api.semanticscholar.org/api-docs/graph#tag/Paper-Data/operation/get_graph_get_paper_search

```
[ ] 1 # example: perovskite solar cell
    2
    3 import requests
    4
    5 query = "https://api.semanticscholar.org/graph/v1/paper/search?query=photovoltaic&machine&learning&limit=30"
    6 s = requests.get(query)
```

```
[ ] 1 # 첫번째 논문
```



Settings and user profile icons (gear, 'J' in a circle) are visible in the top right corner of the interface.

연구 및 행정 활용 시도구 모음

<https://jehyunlee.github.io/2023/04/15/Python-General-22-Altools/>

tool	주소	용도	장점	유의점
 ChatGPT	https://chat.openai.com/ https://ai.com/	<ul style="list-style-type: none"> • 문서 초안 작성 • 문서 교열, 번역, 요약 • 어조 변경 (ex. 전문적, 대중적) • 문서 처리 (ex. 키워드 추출) 	<ul style="list-style-type: none"> • 대량 학습 • 대부분의 질문에 답변 • 코딩 활용시 매우 좋음 • “나에게 ~질문해줘” 가능 : self-discussion • 향후 GPT-4 이미지 입력, Plugin 활용 검색, MS Office Copilot 등 공개 예정 	<ul style="list-style-type: none"> • 보안 이슈 존재 • 외부 데이터 검색 기능 없음 (논문, 특허, 규정 등 신뢰 불가) • 허위 답변도 능숙 • Fact check 필수 • GPT-4 활용 추천 (성능 이슈)
 아속업 AskUp	http://pf.kakao.com/_BhXkWxj	<ul style="list-style-type: none"> • 카카오톡에서 실행 • 그림 생성 beta test 중 (ex. ~ 그려줘, draw ~) 	<ul style="list-style-type: none"> • ChatGPT의 모든 기능 사용 가능 • 이미지 입력 및 글자 인식 • ? 로 시작시 검색 후 답변 : 실시간 정보 가능 • ! 로 시작시 GPT-4 버전 사용 (1일 10회 제한) 	<ul style="list-style-type: none"> • ChatGPT에 비해 답변 길이 제한 • ChatGPT 단점 포함
 perplexity	https://perplexity.ai	<ul style="list-style-type: none"> • 참고문헌 검색 	<ul style="list-style-type: none"> • 일상 언어로 질문 • Internet, news, academic, wikipedia 등 신뢰하는 데이터를 검색, 정리해서 제공 • iphone App 제공 	<ul style="list-style-type: none"> • 한번에 찾는 논문 수가 제한됨 • Scopus 데이터를 검색하지 않음 • 질문이 구체적일수록 답이 틀림 (ex. 피인용수 10건 이상 논문 검색)
 elicit	https://elicit.org/	<ul style="list-style-type: none"> • 참고문헌 검색 	<ul style="list-style-type: none"> • 일상 언어로 질문 • 저널 데이터를 전문적으로 검색, 정리해서 제공 • 초록 요약, 주요 결과물 요약 제공 • 검색결과 중 Top 3~5 논문을 요약, 문단 제공 (품질은 검토 및 수정 필요) 	<ul style="list-style-type: none"> • 최신 정보가 없지는 않으나 취약 • Scopus 데이터를 검색하지 않음 • 질문이 구체적일수록 답이 틀림 (ex. 피인용수 10건 이상 논문 검색)
 ChatPDF	https://www.chatpdf.com/	<ul style="list-style-type: none"> • 입력한 PDF에 대한 질의 	<ul style="list-style-type: none"> • 논문에 한정되지 않음 (규정집 등 행정문서도 가능) • 성능이 빠름 • 다국어 지원 (일어 문서 입력, 한글 질의 가능) 	<ul style="list-style-type: none"> • 보안 이슈 존재 : 민감 문서 사용 자제

tool	주소	용도	장점	유의점
 TLDRThis	https://tldrthis.com/	<ul style="list-style-type: none"> 영문 요약 	<ul style="list-style-type: none"> 웹문서 URL 직접 입력 및 텍스트 입력 가능 추출요약/생성요약(글 새로 쓰기) 선택 가능 전체요약/섹션별요약 선택 가능 뉴스, 성명 등 논문 外 문헌 요약에 유리 	<ul style="list-style-type: none"> 요약문 분량 조정 어려움 한국어 요약 불가
 DeepL	https://www.deepl.com/	<ul style="list-style-type: none"> 다국어 번역 	<ul style="list-style-type: none"> (체감상) 구글 번역기보다 매끄러움 외국어 → 한국어 번역시 경어/평어 섞임 적음 스마트폰 앱 활용시 사진 촬영 입력 가능 개인별 용어집 활용 전문용어 번역이 용이 docx, pptx, PDF 파일 전체 번역 가능 	<ul style="list-style-type: none"> 국내 신용카드 API 결제 불가 → RapidAPI 활용시 우회 가능 설명 : https://bit.ly/3UxF8B7 PDF 파일 번역시 보안 이슈 존재 (Adobe社를 경유해 PDF 해석)
 connected papers	https://www.connectedpapers.com/	<ul style="list-style-type: none"> 인용 네트워크 작성 	<ul style="list-style-type: none"> 인용-피인용 관계를 보며 중요 레퍼런스 탐색 피인용수를 직관적으로 알 수 있음 선택 논문의 초록까지 접근 가능 	<ul style="list-style-type: none"> 일부 논문 초록이 보이지 않음 (semantic scholar)
 paper digest	https://www.paper-digest.com/	<ul style="list-style-type: none"> 논문 요약 	<ul style="list-style-type: none"> PDF 파일 업로드 가능 본문 내용을 성격에 따라 정리 What this paper is about vs What you can learn 	<ul style="list-style-type: none"> Open Access 논문에 한해 동작
 scispace	https://typeset.io/	<ul style="list-style-type: none"> Research Copilot을 표방 용어 설명 관련 문헌 검색 	<ul style="list-style-type: none"> PDF 파일을 업로드하고 안에서 질의 관련 문헌을 검색하며 가지치기 가능 일부 논문은 요약본 제공 (semantic scholar) Google Chrome Extension 존재 	<ul style="list-style-type: none"> Open Access 논문에 한해 동작 (추정) 서지 정보

J 다음은 어떤 논문의 초록이야. 이 논문을 읽을 때 스스로에게 던져야 할 질문들을 초록 기준으로 3개 뽑아줘.

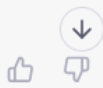
A comprehensive review is presented on the chemical reactions of perovskite films under different environmental conditions and with charge transfer materials and metal electrodes in perovskite solar cells. The influence of chemical reactions on device stability is elucidated. Effective strategies for suppressing the degradation reactions are specified. © 2023, The Author(s).

Lead halide perovskite solar cells (PSCs) have become a promising next-generation photovoltaic technology due to their skyrocketed power conversion efficiency. However, the device stability issues may restrict their commercial applications, which are dominated by various chemical reactions of perovskite layers. Hence, a comprehensive

...

 이 논문을 읽을 때 스스로에게 던져야 할 질문들:


1. 페로브스카이트 필름이 다양한 환경 조건(예: 습기, 산소, 빛)에서 어떤 화학 반응을 일으키며, 그 반응들이 기기 안정성에 어떻게 영향을 미치는지 설명되어 있는가?
2. 페로브스카이트 태양전지의 화학적 안정성을 향상시키기 위한 전략 중 어떤 것들이 효과적으로 분해 반응을 억제하는지 그 방법들이 어떻게 작용하는지 이해할 수 있는가?
3. 이 리뷰 논문에서 제안된 결론 및 전망을 바탕으로 페로브스카이트 태양전지의 미래 발전에 대한 시사점과 기대를 도출할 수 있는가?



Send a message...  

J science, nature, ACS nano에서 출판되는 photovoltaic 관련 논문을 매주 월요일 오전 9시에 검색, 요약, 번역하는 파이썬 코드를 짜줘



 아래 코드는 Python과 BeautifulSoup, requests 라이브러리를 사용하여 Science, Nature, ACS Nano에서 photovoltaic 관련 논문을 검색, 요약 및 번역하는 예제입니다. 코드 실행을 위해 `bs4`, `requests`, `googletrans==4.0.0-rc1` 패키지를 설치해야 합니다. 월요일 오전 9시마다 실행하도록 설정하려면, 코드를 실행하려는 컴퓨터의 작업 스케줄러 또는 cron 작업을 설정하세요.

```
python
import requests
from bs4 import BeautifulSoup
```

...

```
while True:
    schedule.run_pending()
    time.sleep(60)
```



Send a message...  

AskUp

It didn't amount to much at first.

Launched into orbit aboard the space shuttle *Discovery* on April 24, 1990, amid flurries of hope and hype, the Hubble Space Telescope promptly faltered. Rather than remaining locked on its celestial targets, it trembled and shook, quaking like a photophobic vampire whenever sunlight struck its solar panels. Opening its protective front door to let starlight in perturbed the telescope so badly that it fell into an electronic coma. Worst of all, Hubble turned out to be myopic. Its primary light-gathering mirror, eight feet in diameter and said to be the smoothest large object ever fashioned by humans, had been figured perfectly wrong. Its design was already a compromise. The astronomers had wanted a bigger telescope in

오전 10:00

AskUp

이미지 에서 767 글자를 읽었습니다.

오전 10:00

오전 10:00

내용을 번역해줘

AskUp

AskUp

먼저 별다른 의미가 없었다. 1990년 4월 24일 스페이스 셔틀 디스커버리로 발사된 허블 우주 망원경은 많은 기대와 희망 속에서 발사되었지만, 그것은 처음에는 별다른 결과를 가져오지 않았다. 천체를 추적할 때에도 불구하고, 태양광이 태양 전지에 비춰질 때 뱅파이 어처럼 떨리면서, 흔들리면서, 떨리며 흔들리기 시작했다. 별빛을 받기 위해 보호 문을 열 때마다, 망원경은 심각한 상태로 빠졌다. 최악의 경우, 허블은 근시안이었다. 그것의 주받음 거울은 인간이 만든 가장 매끄러운 대형 물체 중 하나로 꼽혔지만, 완벽하게 제작되었다고 여겨졌던 거울의 크기가 잘못되었다. 그것의 디자인은 이미 타협이 있었다. 천문학자들은 더 큰 망원경을 원했다.

오전 10:00

오전 10:01

허블망원경을 쏘아올린 날짜는 언제야?

AskUp

AskUp

허블 우주 망원경이 발사된 날짜는 1990년 4월 24일입니다.

오전 10:01

2023년 3월 21일 화요일

오전 12:16

연구원들과 행정원들은 어떻게 달라?

AskUp

연구원들과 행정원들은 보통 다른 역할을 수행합니다. 연구원들은 주로 연구 및 개발 작업을 수행하며, 새로운 아이디어를 창출하고 실험을 설계하고 분석합니다. 반면, 행정원들은 조직의 운영과 관리에 중점을 둡니다. 예를 들어, 예산 관리, 인적 자원 관리, 일정 관리, 문서 작성과 보관, 회의 조직 등을 수행합니다. 둘 다 조직 내에서 중요한 역할을 수행하지만 그 역할과 책임은 서로 다

what is the world record of photovoltaic efficiency?

PERPLEXITY

There are multiple world records for photovoltaic efficiency, depending on the type of technology used. As of the available search results, the highest efficiency value ever reported for an organic photovoltaic module is 12.6% on a module area of 26 cm² and 11.7% on a module area of 204 cm² ¹. For thermophotovoltaic conversion efficiency, a world record of over 30% has been demonstrated in two materials systems operating at two different thermal emitter temperatures ². For polymer-based organic photovoltaic solar cells, a new record with a certified efficiency of 9.2% has been achieved ³. For Cu(In, Ga)(Se, S)₂ thin film solar cells, a world record efficiency of 22.3% has been achieved ⁴.

- 1 Organic photovoltaic...
- 2 World record demo...
- 3 Inverted polymer so...
- 4 New world record C...



RELATED

- what is the current world record for photovoltaic efficiency +
- what materials are used in the world record photovoltaic efficiency +
- what are the potential commercial applications for the world record photovoltaic efficiency +

Ask follow-up...



what is the world record of photovoltaic efficiency? ←

SUMMARY OF TOP 4 PAPERS BETA

The papers report on different types of photovoltaic efficiency records. [Narayan 2020](#) reports on the world record for thermophotovoltaic conversion efficiency, with a GaAs-based PV device achieving 31% efficiency and an In0.53Ga0.47As-based PV device achieving 30% efficiency. [Distler 2020](#) and [Distler 2021](#) report on new world record efficiencies for organic photovoltaic modules, with the former achieving 12.6% efficiency on a module area...

Add information about all papers

- Abstract summary ✓
- Intervention
- Outcomes measured ✓

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Paper title	Abstract summary	Outcomes measured
<p>★ World record demonstration of > 30% thermophotovoltaic conversion efficiency</p> <p>🔗 T. Narayan, L. Kuritzky, Dustin P. Nizamian, Benjami...</p> <p>📄 <i>Photovoltaic Specialists Conference</i></p> <p>2020 10 Citations DOI</p>	<p>A GaAs-based PV device under a 2330°C thermal emitter produced an efficiency of (31.2)%.</p>	<ul style="list-style-type: none"> •Thermophotovoltaic (Tpv) Conversion Efficiency •Electrical Output Power Density
<p>★ Organic photovoltaic modules with new world record efficiencies</p> <p>🔗 A. Distler, C. Brabec, H. Egelhaaf</p> <p>📄 <i>Progress in Photovoltaics</i></p> <p>2020 48 Citations DOI</p>	<p>The power conversion efficiency of solution-processed organic photovoltaics to nowadays record values above 17% on small lab cells.</p>	<ul style="list-style-type: none"> •Power Conversion Efficiency
<p>★ New efficiency world record for organic solar modules</p> <p>🔗 Dr. Andreas Distler</p> <p>2021 0 Citations</p>	<p>The highest efficiency value ever reported for an organic photovoltaic module was confirmed by a certified calibrated measurement under standard testing conditions by the independent certification laboratory of Fraunhofer ISE (Freiburg) in September 2019.</p>	<ul style="list-style-type: none"> •Efficiency Value
<p>★ Inverted polymer solar cell efficiency sets world record</p>	<p>The new design is expected to catalyze</p>	<ul style="list-style-type: none"> •Efficiency Of Polymer Based

+ New Chat
Drop PDF here

s40820-023-01046-0.pdf

Chat with s40820-023-01046-0.pdf



improving device stability?

what is the world record efficiency?

According to page 26 of this PDF file, Chinese perovskite tech firm Wuxi Utmost Light claims to have achieved a "world record" efficiency of 20.5% for a perovskite solar mini module, which has been certified by Japan's JET.

what is the world record efficiency except for perovskite?

I'm sorry, but the information provided in this PDF file does not include the world record efficiency for any other type of solar cell technology.

논문에 서술된 최대 효율 소자의 세부 내역을 설명해줘

안녕하세요! 이 PDF 파일에서 언급된 최대 효율 소자의 세부 내역에 대한 정보는 제공되지 않습니다. 이 파일에서는 주로 납 할라이드 페로브스카이트 태양전지의 안정성과 화학적 반응에 대한 내용이 다루어졌습니다. 다른 질문이 있으시면 언제든지 물어보세요!

Figure 1이 의미하는 바를 설명해줘

Figure 1은 납 할라이드 페로브스카이트 태양전지의 화학적 안정성과 관련된 다양한 실험 결과를 시각적으로 보여주는 그림입니다. 이 그림에서는 다양한 환경 조건에서 페로브스카이트 필름의 안정성을 평가한 결과, 필름 내부에서 발생하는 화학 반응과 이에 따른 전하 이동 속도 변화 등이 나타나 있습니다. 또한, 그림에서는 이러한 반응을 억제하기 위해 사용되는 다양한 전극 및 전하 수송재료의 종류와 역할에 대한 정보도 제공됩니다.

Ask any question...



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Home > News > The Renewable Energy Financing Mechanism sees first tender established

NEWS ANNOUNCEMENT | 14 April 2023 | Directorate-General for Energy

The Renewable Energy Financing Mechanism sees first tender established

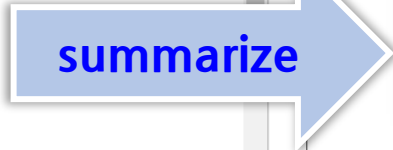


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The first-ever cross-border tender to support renewable energy in the EU has been adopted by the Commission today. The tender is organised in the framework of the [renewable energy financing mechanism](#) (RENEWFM) and builds on the [commitments by Luxembourg and Finland](#) to cooperate under this new instrument. Luxembourg is contributing with a voluntary payment of €40 million and Finland hosts the projects which will compete for the support.

The tender takes the form of a call for proposals, implemented by the [European Climate Infrastructure and Environment Executive Agency \(CINEA\)](#). The call will be open for submission as from 18 April in the [funding and tender portal](#). It will disburse grants to project developers for setting up new renewable energy projects using solar photovoltaic technology. Eligible participants in the call are companies which will build a new solar PV installation with a capacity between 5 and 100 MW and comply with the [rules of the tender](#), designed in close cooperation with Luxembourg and Finland.

The call for proposals is the first cross-border tender between EU countries. It marks a new stage of cooperation in the area of renewables and fulfils the objectives of the European Green Deal and



The Renewable Energy Financing Mechanism sees first tender established

Apr 14, 2023 | Time Saved: 1 mins

- Tender
- Renewable Energy
- Luxembourg
- Open
- Finland

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용어집

The first-ever cross-border tender to support renewable energy in the EU has been adopted by the Commission today. The tender is organised in the framework of the renewable energy financing mechanism (RENEWFM) and builds on the commitments by Luxembourg and Finland to cooperate under this new instrument. The call will be open for submission as from 18 April in the funding and tender portal.



유럽연합의 재생 에너지를 지원하기 위한 최초의 국경 간 입찰이 오늘 집행위원회에서 채택되었습니다. 이 입찰은 재생 에너지 금융 메커니즘(RENEWFM)의 프레임워크에 따라 조직되었으며, 룩셈부르크와 핀란드가 이 새로운 기구에 협력하기로 한 약속을 기반으로 합니다. 입찰은 4월 18일부터 자금 조달 및 입찰 포털에서 신청서를 제출할 수 있습니다.



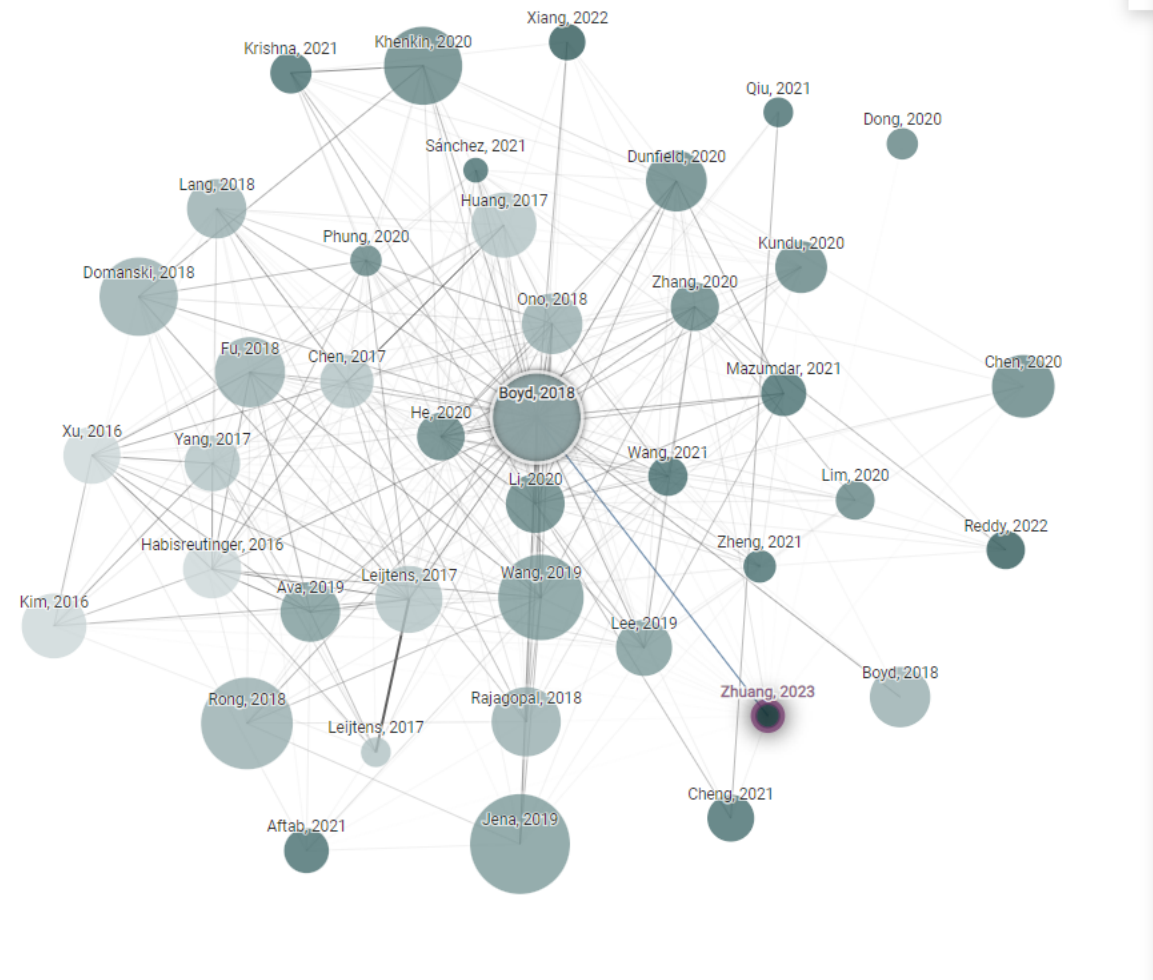
사전

해당 언어 쌍에는 사전을 사용할 수 없습니다.

Review on Chemical Stability of Lead Halide Perovskite Solar Cells

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- Origin paper**
Review on Chemical Stability of Lead Halide Perovskite Solar Cells
Jing Zhuang, Jizheng Wang, Feng Yan 2023
- Barrier Designs in Perovskite Solar Cells for Long-Term Stability
Shasha Zhang, Zonghao Liu, Wenjun Zhang, Zhaoyi Jiang, ... 2020
- Pushing commercialization of perovskite solar cells by improving their intrinsic stability
Yuanhang Cheng, Liming Ding 2021
- Understanding Degradation Mechanisms and Improving Stability of Perovskite Photovoltaics.
Caleb C. Boyd, Rongrong Cheacharoen, T. Leijtens, Michael D. ... 2018
- Recent progress in stabilizing hybrid perovskites for solar cell applications
Jian-qing Chen, Xin Cai, Donghui Yang, D. Song, Jiajia Wang, ... 2017
- Decomposition and Cell Failure Mechanisms in Lead Halide Perovskite Solar Cells.
Jinli Yang, T. Kelly 2017
- A critical review of materials innovation and interface stabilization for efficient and stable perovskite...
Yousheng Wang, Gowri Manohari Arumugam, T. Mahmoudi, Y. ... 2021
- Toward Perovskite Solar Cell Commercialization: A Perspective and Research Roadmap Based on Interfacial...
A. Rajagopal, Kai Yao, A. Jen 2018
- Materials and Methods for Interface Engineering toward Stable and Efficient Perovskite Solar Cells



Understanding Degradation Mechanisms and Improving Stability of Perovskite Photovoltaics.

Caleb C. Boyd + 2 authors Michael D. McGehee

2018, Chemical Reviews

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This review article examines the current state of understanding in how metal halide perovskite solar cells can degrade when exposed to moisture, oxygen, heat, light, mechanical stress, and reverse bias. It also highlights strategies for improving stability, such as tuning the composition of the perovskite, introducing hydrophobic coatings, replacing metal electrodes with carbon or transparent conducting oxides, and packaging. The article concludes with recommendations on how accelerated testing should be performed to rapidly develop solar cells that are both extraordinarily efficient and stable.

Review on Chemical Stability of Lead Halide Perovskite Solar Cells

Zhuang; Wang; Yan; Yan; Hk 0123456789

Full text link: <https://doi.org/10.1007%2Fs40820-023-01046-0>

What this paper is about

Introduction and Objective

- Wiley-VCH cells, are only used in small-area markets such as space stations, while large-area PSCs with PCE over 20.5% have been achieved, promising their large-area applications.
- The chemical reactions of lead halide perovskite have significant impacts on interfacial defects, charge transport/extraction, and thus photovoltaic performance and device stability of PSCs.
- Because of the relatively active chemical properties, perovskites may react with oxygen, water.

What you can learn

Discussion and Conclusions

- In addition, some chemical reactions at charge transport layers/perovskite interface can produce undesirable interfacial defects and reduce charge transport capacity of ETL or HTL, eventually deteriorate the chemical stability and photovoltaic performance of PSCs.
- At present, various buffer layers or additives have been employed to suppress the detrimental interfacial reactions and optimize the device performance as well as long-term stability.
- The fluorine-containing additives can improve the hydrophobic properties of lead halide perovskite films, and effectively reduce the humidity-induced degradation of PSCs.



REVIEW

<https://doi.org/10.1007/s40820-023-01046-0>

Cite as

Nano-Micro Lett.
(2023) 15:84

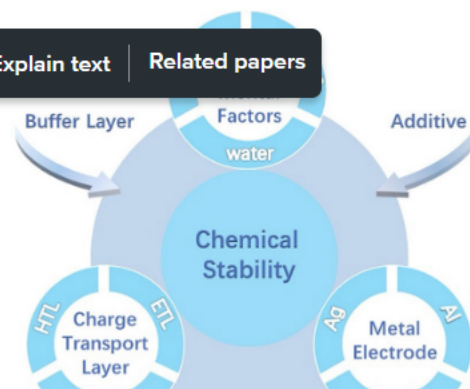
Review on Chemical Stability of Lead Halide Perovskite Solar Cells

Jing Zhuang¹, Jizheng Wang^{2,3}, Feng Yan^{1,4} Received: 19 January 2023
Accepted: 23 February 2023
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HIGHLIGHTS

- A comprehensive review is presented on the chemical reactions of perovskite films under different environmental conditions and with charge transfer materials and metaelectrodes in perovskite solar cells.
- The influence of chemical reactions on device stability is elucidated.
- Effective strategies for suppressing the degradation reactions are specified.

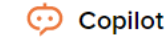
ABSTRACT Lead halide perovskite solar cells (PSCs) have become a promising next-generation photovoltaic technology due to their high conversion efficiency. However, the device stability remains a major challenge for commercial applications, which are dominated by various chemical reactions of perovskite layers. Hence, a comprehensive illustration on the stability of perovskite films in PSCs is urgently needed. In this review article, chemical reactions of perovskite films under different environmental conditions (e.g., moisture, oxygen, light) and with charge transfer materials and metal electrodes are systematically elucidated. Effective strategies for suppressing the degradation reactions of perovskites, such as buffer layer introduction and additives engineering, are specified. Finally, conclusions and outlooks for this field are proposed. The comprehensive review will provide a guideline on the material engineering and



Summarize

Explain text

Related papers



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Explain the text

halide perovskite solar cells

3:03 pm

The highlighted text "halide perovskite solar cells" refers to a type of solar cell that uses a material called halide perovskite as the light-absorbing layer. Perovskite solar cells have gained significant attention in recent years due to their high efficiency and low cost compared to traditional silicon solar cells.

Perovskite solar cells consist of several layers, including a transparent electrode, a hole transport layer, a perovskite layer, an electron transport layer, and a metal electrode. When sunlight hits the perovskite layer, it generates an electric current that can be used to power electronic devices.

However, perovskite solar cells are prone to

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