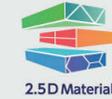


Chapter Two: CVD for Redemption



令和3(2021)年度学術変革領域研究(A)

2.5次元物質科学：
社会変革に向けた物質科学のパラダイムシフト

NEWS
LETTER

Welcome to the 2.5 D Laboratory

© もんでんひでこ

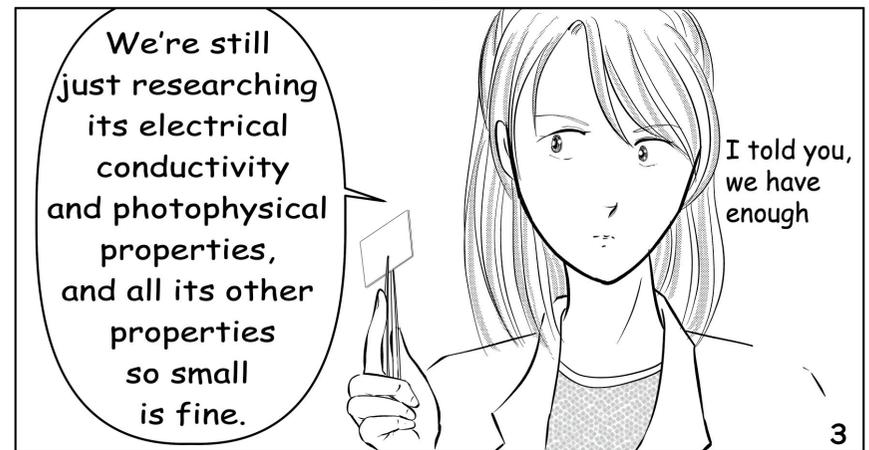
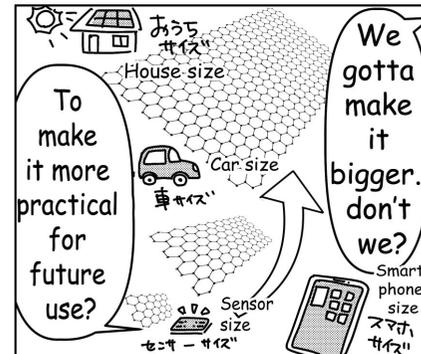
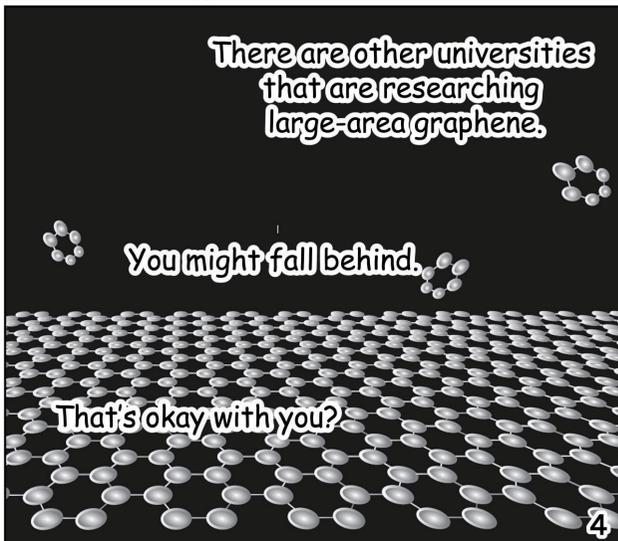
Previously in the series

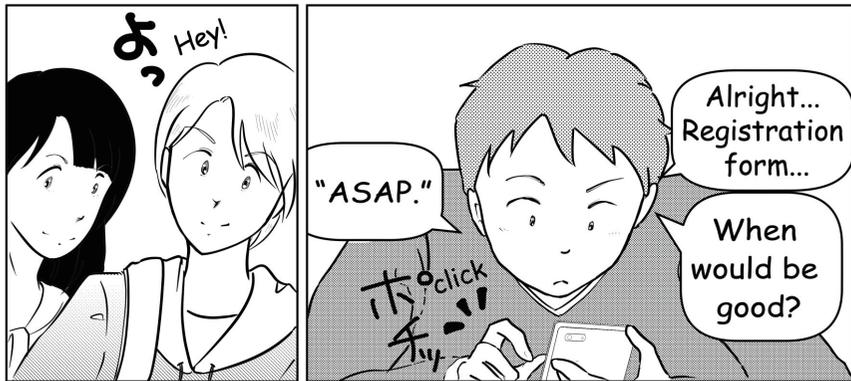
Koji Ota, freshly a senior at university, requests an assignment to the Ando Research Lab, drawn to the idea of being able to do cutting-edge science.

It turns out, however, that this is a deeply unpopular lab, with zero applicants over the past few years, and the only student a very strange graduate student.

As if this weren't enough, Ota also fails to pass the entrance test for the lab—making graphene using the exfoliation method—and finds himself at a crossroads.







Hey!

ASAP.

click

Alright... Registration form...

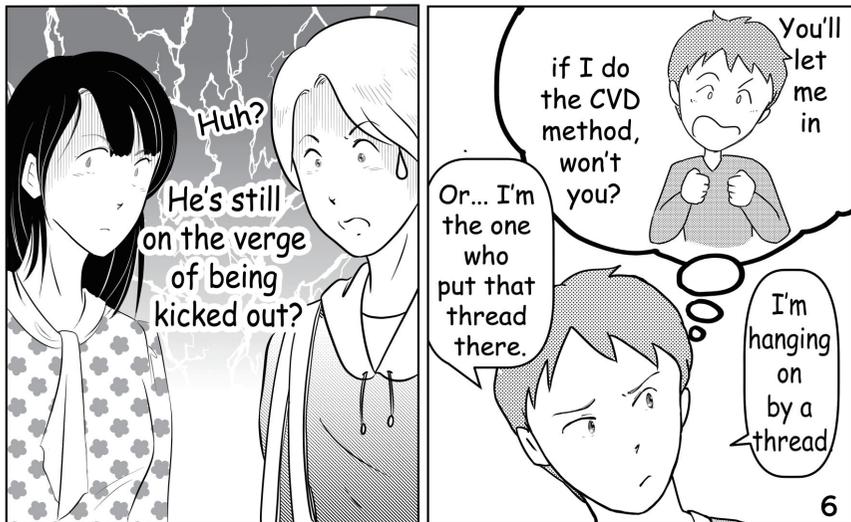
When would be good?



Oh, shut up.

Don't be mean. Lab.

How was it? The cram school entrance exam.



Huh?

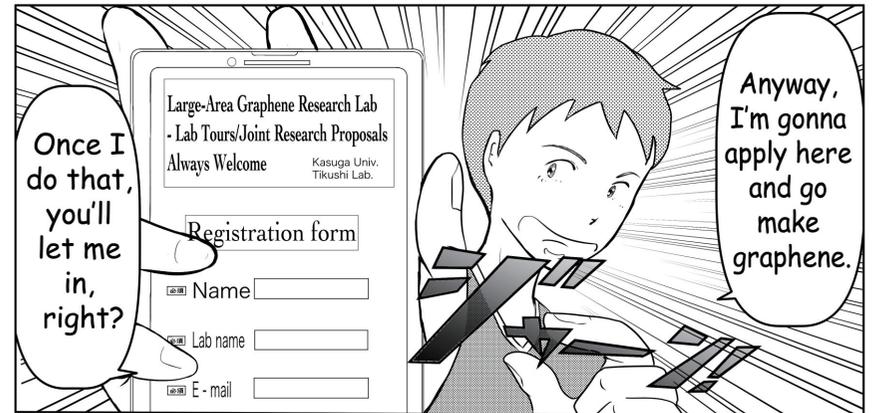
He's still on the verge of being kicked out?

if I do the CVD method, won't you?

You'll let me in

Or... I'm the one who put that thread there.

I'm hanging on by a thread



Once I do that, you'll let me in, right?

Large-Area Graphene Research Lab
- Lab Tours/Joint Research Proposals
Always Welcome

Kasuga Univ.
Tikushi Lab.

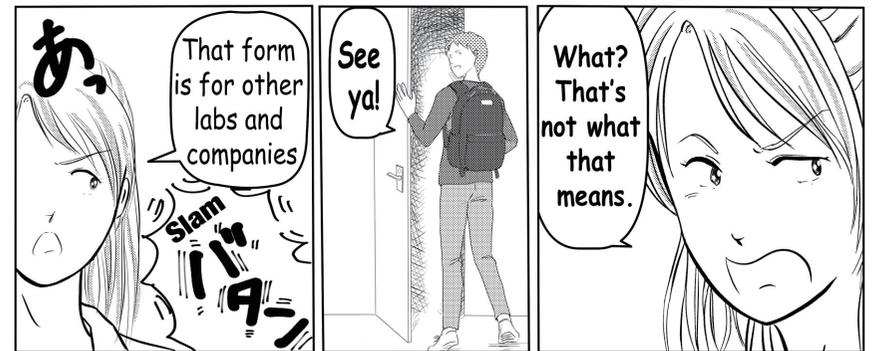
Registration form

Name

Lab name

E-mail

Anyway, I'm gonna apply here and go make graphene.



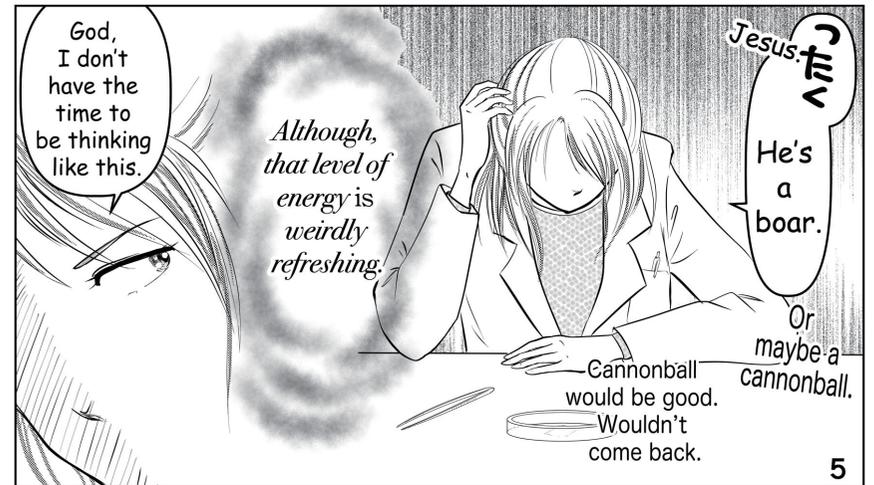
あ

That form is for other labs and companies

Slam

See ya!

What? That's not what that means.



God, I don't have the time to be thinking like this.

Although, that level of energy is weirdly refreshing.

Jesus-
He's a boar.
Or maybe a cannonball.

Cannonball would be good. Wouldn't come back.



I don't think he's even in the lab.



What's he like?

You met the professor didn't you?



The grad student you were talking about was talking to someone.

I assumed it was the professor.

It's becoming seriously annoying.



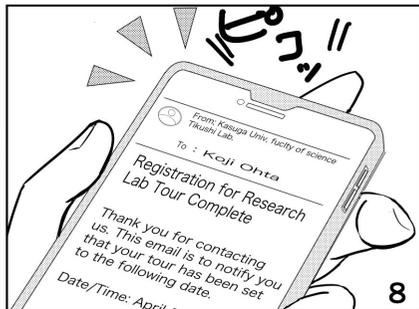
庵渡研究室
Ando Research Lab.

That's weird. The other day I heard voices in the Ando Research Lab.

No, he still hasn't given up.



Oh! An email already.



From: Katsuga Univ., faculty of science
Tikashi Lab.
To: Koji Ohta
Registration for Research Lab Tour Complete
Thank you for contacting us. This email is to notify you that your tour has been set to the following date.
Date/Time: April 8



I can't make graphene if it means I have to look at it through a microscope.

Just listen! I. Am. Clumsy.



Hey! It got on me too!

Ah! Shaking your separatory funnel too hard and spraying the liquid everywhere...

Ups! It ended up having to do the experiment for the Meissner effect on a sample.

And during that superconductivity experiment, when you scattered the powder for the disk all over the place...



True. Your clumsiness is pretty legendary.

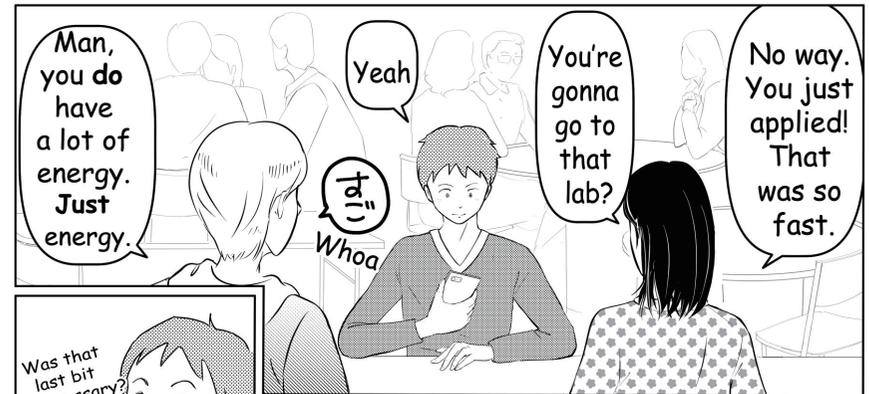
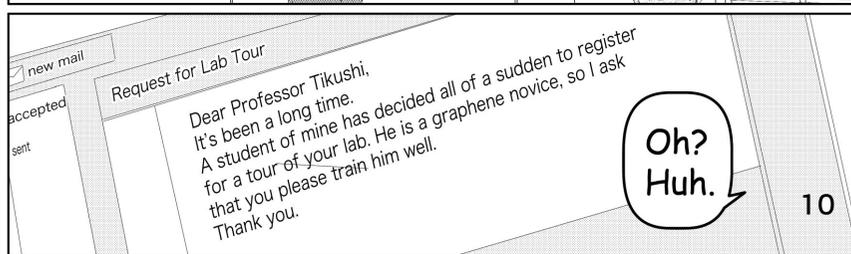
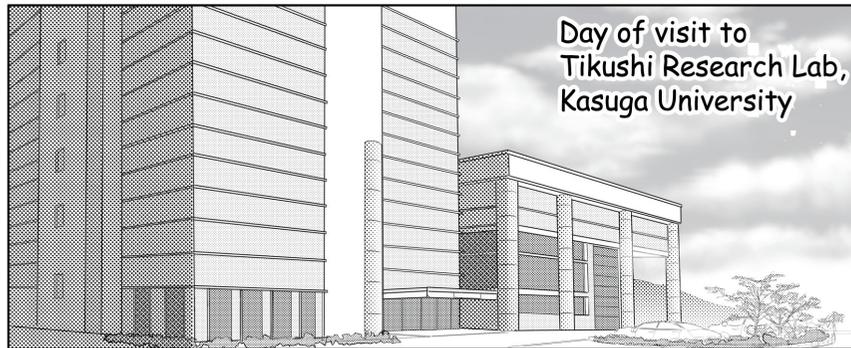
俺も被災した
I've been a victim to it

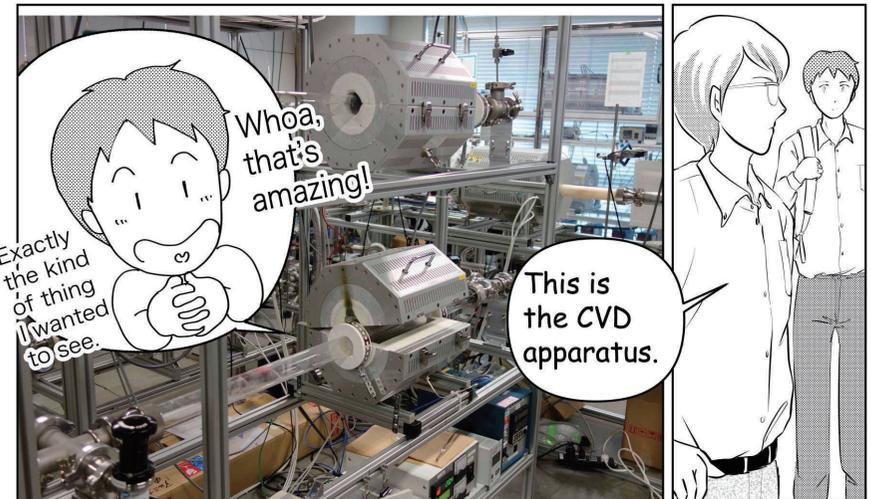
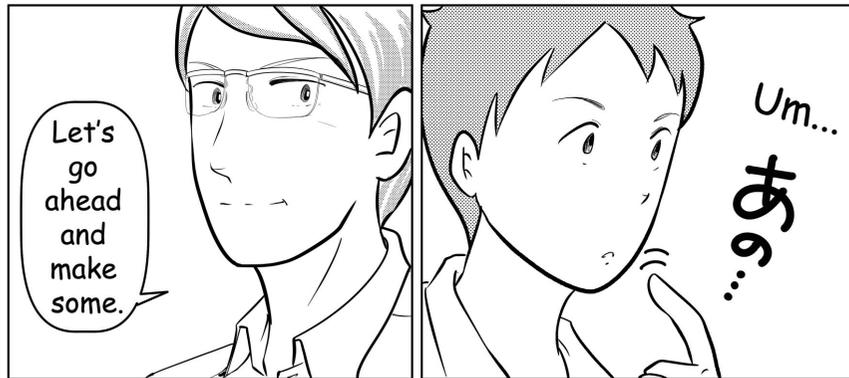


So that's why your lab isn't decided yet...
Oh!



That's why I want to redeem myself using this CVD thing. Something where I'm less likely to fail.





So the CVD method is a method that involves synthesizing thin films and fine particles under atmospheric or vacuum conditions.

The raw materials here are sent into this tube-as-a-gas.

Heat and other energies are used to promote chemical reactions that then create a film on the surface of this substrate.

For graphene

メタンガス (CH₄) CH₄ gas 水素ガス (H₂) H₂ gas

Send with hydrogen, argon gas, etc.

The H₂ floats away

The C remains

Cu acts as catalyst → Cu Substrate

単層グラフェン Single layer graphene

The C assembles together to form graphene

11



I mean, there's graphene out there that's in the range of 100 meters.

If we wanted to make it larger though, we could.

This one will be about 1.5 x 1.5 cm.



I see!

Of course they'll be bigger than when you use the exfoliation method.



Ah, my hands are shaking now.

Oh, and be careful not to scratch the substrate with the tweezers.

Set the substrate with the copper film on the mounting base.



Grabber?

Use this to set it in the tube.



No way, we are letting you make nice crystals!

And remember there's carbon everywhere. Don't let it contaminate the substrate.



Thank you.

Well, good luck!

In our lab, we use a sapphire substrate with an additional copper film deposited on top.

This lets us make large, high-quality graphene.

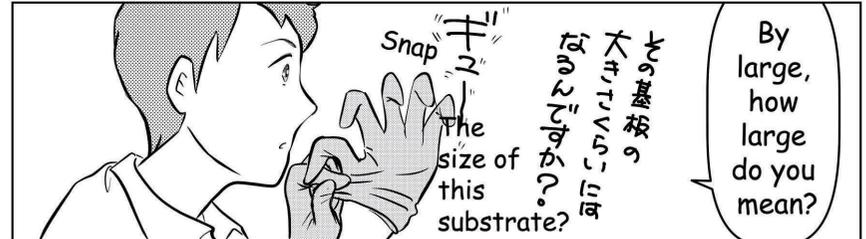
This is the copper film that will serve as the substrate.

Copper film deposited on top
上に銅を製膜しておく

Single-crystal substrate such as sapphire on the bottom
下はサファイアなどの単結晶基板

CVD

This monolayer graphene has high crystallinity with uniform thickness, and its hexagonal lattice is highly oriented.



Snap! The size of this substrate?

By large, how large do you mean?



It's just that I've only ever made microscope-sized graphene, so I was wondering how big this one would be.

No! No. That's not it.



Oh, is that not enough for you?

It's the max 1083°C that won't melt copper. 金銅の融点 Melting point of copper

So in our lab, we typically go for 1,083 degrees Celsius.

グラフェン成長 Graphene growth

See, that's why temperature adjustment is important

It's called "fake graphene" because you can't tell how terrible it is until you test it.

If the temperature is too low, on the other hand, you get terrible-quality graphene.

ちゃんと出来る ように見える Looks properly made

You have to be really careful when adjusting the amount of methane to inject.

Alright, it's finally time to send in the raw ingredient — methane.

Oh no, there's more?

Get the amount wrong, and...

16

Turn this to remove the air from the vacuum... キュッ

... which means we're removing the air in the tube.

This time, we're using the basic recipe...

Mm... Here? ん? このあたり?

Why 1,000 degrees Celsius?

It takes about an hour for the temperature to reach that level.

Lock the lid, and crank the temperature up to 1,000 degrees Celsius.

This is an image イメージ イメージ

But that might evaporate the copper, and there'd be nothing left. It does happen sometimes. 何もない be nothing left!

It could be even higher, actually.

Oh, good question.

It's because graphene crystals get bigger the higher the temperature is.

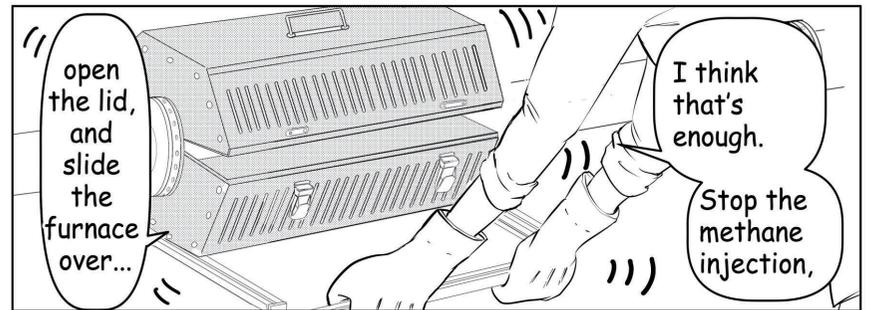
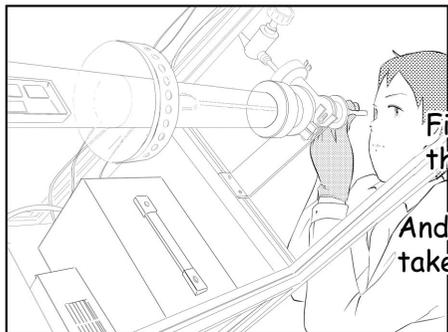
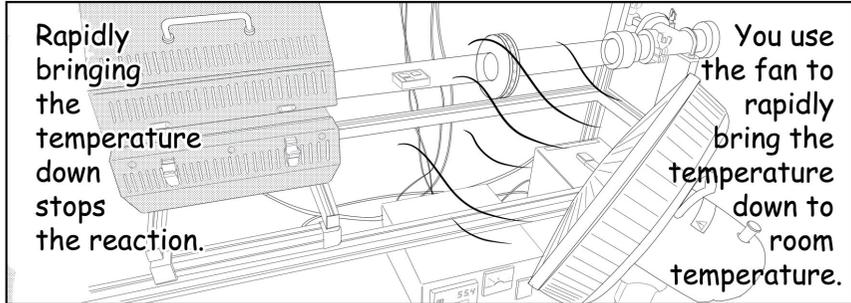
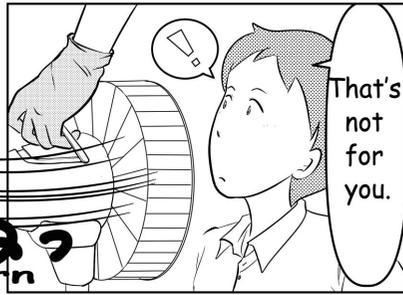
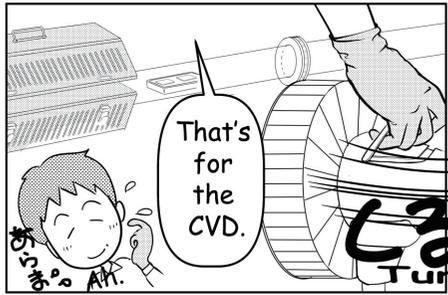
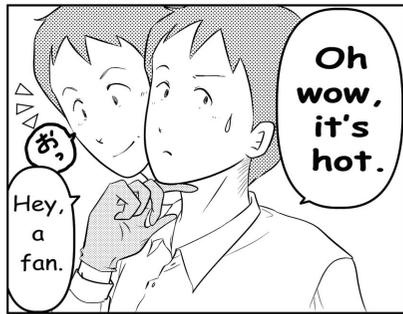
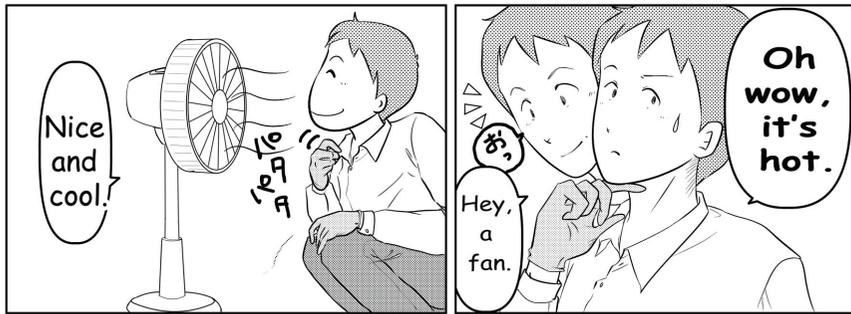
It happens a lot if the copper has poor crystallinity.

Yes

The copper evaporates?!

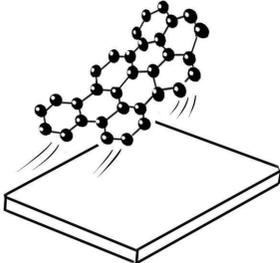
Yes

15



Whaaat? It's only an atom thick.

I can peel it off?



Alright. Next we'll be removing just the graphene.

Put it in this etchant and the copper dissolves, leaving just the graphene.



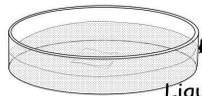
Yup, you can.

*1 liquid used to chemically remove unwanted parts
*2 Actually takes several hours for copper foil

Whoa, that's pretty. It's clear!

Scoop it up with this, and...

See that? It's floating up.



銅が溶けた液
Liquid with dissolved copper

It's so big! I don't need a microscope! I-It's amazing.

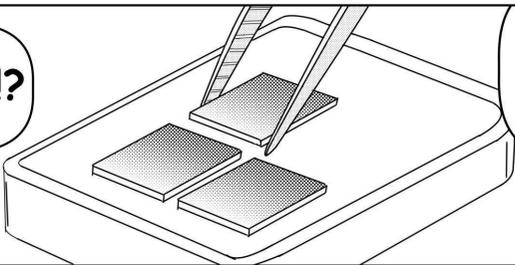
Wash it with distilled water.

残留!! I'll be able to stay!

20

What!?

It's... done?



All done.

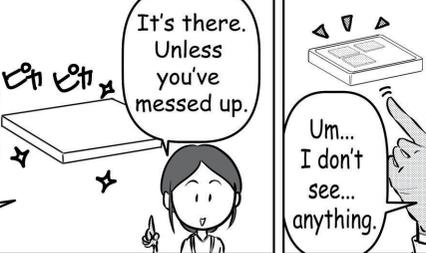
じ Stare



Graphene is transparent. It can also be hard to see when it's covering the entirety of the copper substrate.

It's there. Unless you've messed up.

Um... I don't see... anything.



That's true. I guess diamonds are transparent too.



Oh, right. I've only ever seen it through a microscope.

I guess that image was processed to make things easier to see.

This wouldn't even be usable.

And it's not even a single layer.

See Chapter One

We don't need anyone who can't make graphene!

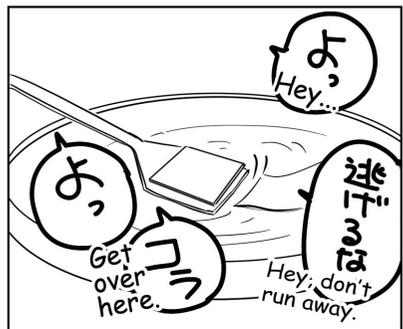
19



俺得意
You know, I'm pretty good at that game.

It's like goldfish scooping!

泳がつかないかも
And this thing isn't even swimming.



よ
Hey...

よ
Get over here.

迷子
Hey, don't run away.



はい
yup

Be careful—this is an important part of the process



来
Come on, get up there...

あ
Ah

よ
yup



You know, it's not enough that it's on the substrate.

No, that's no good.



Ah!

Got the graphene.

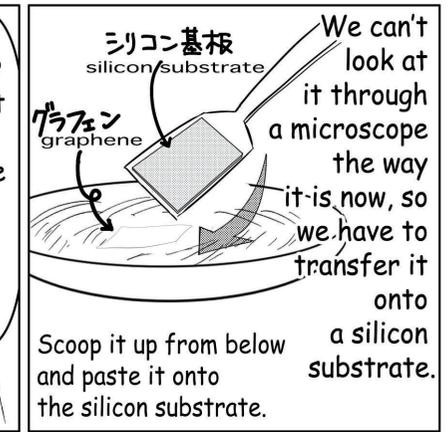
石墨烯
ゲットだぜ

I did it!



It looks perfect.

Huh? What is there to look at?

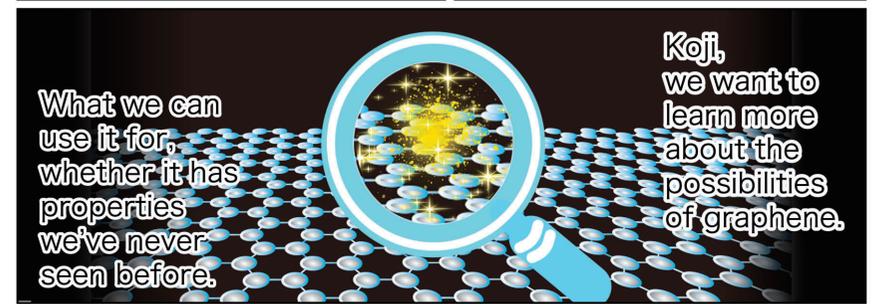


シリコン基板
silicon substrate

グラフェン
graphene

We can't look at it through a microscope the way it is now, so we have to transfer it onto a silicon substrate.

Scoop it up from below and paste it onto the silicon substrate.



What we can use it for, whether it has properties we've never seen before.

Koji, we want to learn more about the possibilities of graphene.



I... I see.

あ
...

That's research. We don't just make the graphene and then we're done.



Really ???

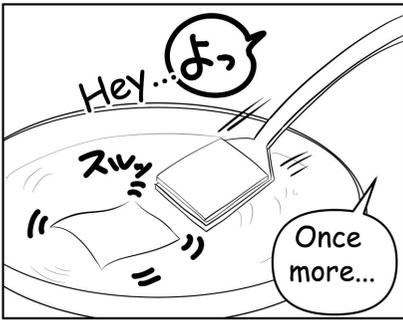
Of course



Here, try it.



Come over here. Hey!



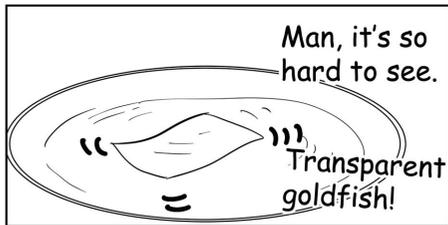
Hey... Once more...



No! It stuck to the side of the plate.



Oh! Tilt the plate a little so that it goes back in the water.



Man, it's so hard to see. Transparent goldfish!



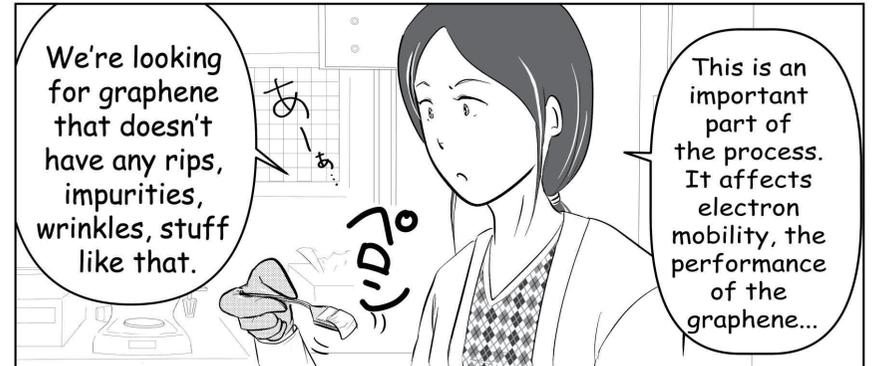
Phew



Pu!



Is it always this hard?



We're looking for graphene that doesn't have any rips, impurities, wrinkles, stuff like that.

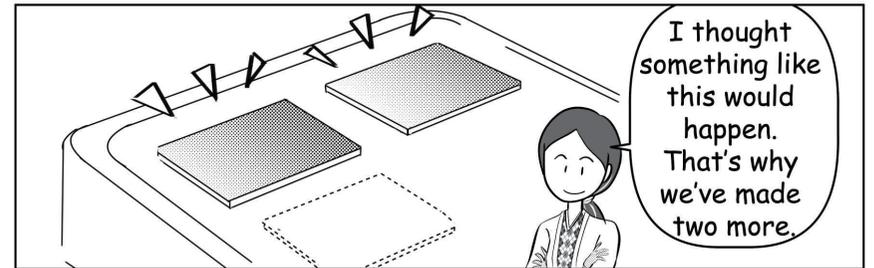
This is an important part of the process. It affects electron mobility, the performance of the graphene...



But it's alright

Ah, I've done it now!

Huh?



I thought something like this would happen. That's why we've made two more.



Thank you.

Oh, right. I'll be more careful.



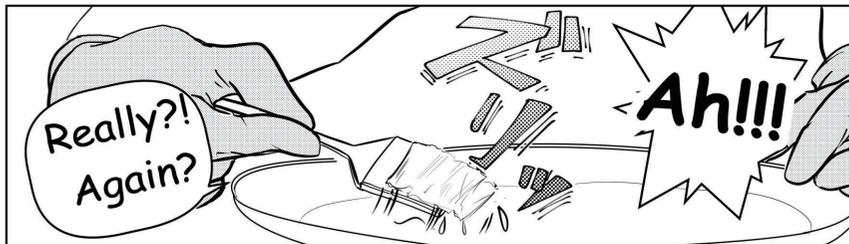
Alright, deep breath...



Now!

I'm doing it!

Oh, oh. It's working!



Really?! Again?

Ah!!!



Oh dear...

To be continue

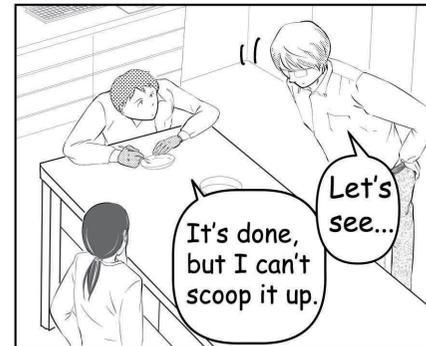


I hate this so much!

No!!

Supervised : Group A01 Hiroki Ago, Professor & Aika Uchida, Staff, Global Innovation Center, Kyushu University. For more information <https://25d-materials.jp>

© もんでんひでこ Hideko Monden Senior Lecturer, Kanagawa Institute of Technology, Science communicator



It's done, but I can't scoop it up.

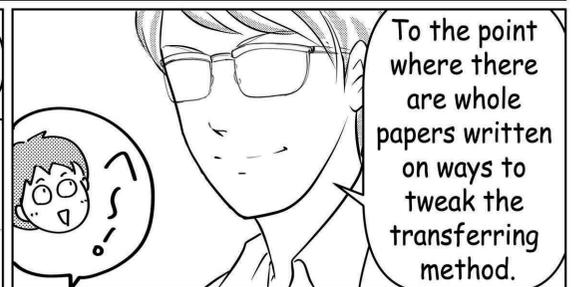
Let's see...



Hey there, how much have you been able to get done?

... and it just might be the hardest part about making graphene using the CVD method.

The process of moving it onto the silicon substrate is called transferring...



To the point where there are whole papers written on ways to tweak the transferring method.

Graphene doesn't grow on silicon.

Copper is an excellent catalyst for the growth of graphene.

Why don't people make it... on the silicon substrate to begin with?

I'm sorry if it's a stupid question, but...