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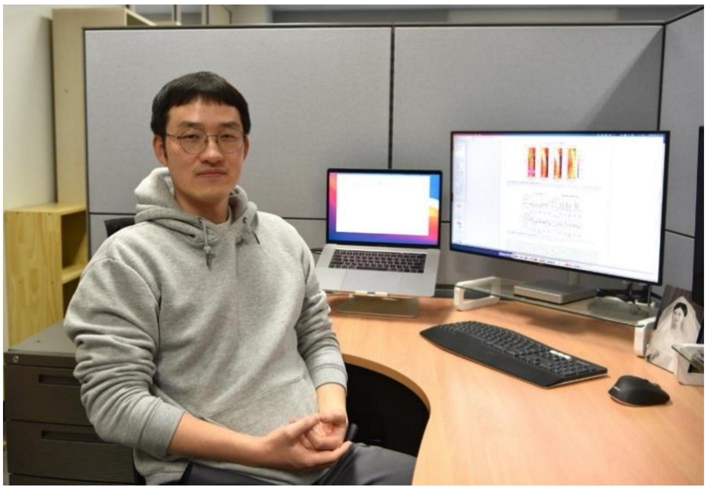
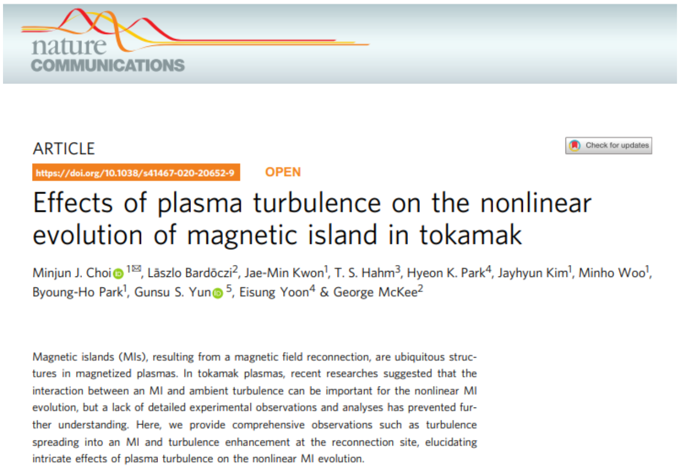
Recent Research

A clue for a fusion conundrum: Defining the interaction between magnetic islands and plasma turbulence





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ARTICLE

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Effects of plasma turbulence on the nonlinear evolution of magnetic island in tokamak

Minjun J. Choi [1✉], Lāszlo Bardōczi[2], Jae-Min Kwon[1], T. S. Hahm[3], Hyeon K. Park[4], Jayhyun Kim[1], Minho Woo[1], Byoung-Ho Park[1], Gunsu S. Yun [5], Eisung Yoon[4] & George McKee[2]

Magnetic islands (MIs), resulting from a magnetic field reconnection, are ubiquitous structures in magnetized plasmas. In tokamak plasmas, recent researches suggested that the interaction between an MI and ambient turbulence can be important for the nonlinear MI evolution, but a lack of detailed experimental observations and analyses has prevented further understanding. Here, we provide comprehensive observations such as turbulence spreading into an MI and turbulence enhancement at the reconnection site, elucidating intricate effects of plasma turbulence on the nonlinear MI evolution.

Dr. Minjun J Choi and his article in Nature Communication

Dr. Minjun J Choi of the KSTAR Research Center of KFE has successfully proven the direct effects of plasma turbulence on magnetic islands. The findings, from a collaborative investigation involving researchers from Korea and the United States, were published in Nature Communications in January.

“This research is the reverse of a previous study that revealed the effect of magnetic islands on the distribution and development of background turbulence. This time, we analyzed how background turbulence affects the evolution of magnetic islands. Based on this work, we expect to be able to weaken or redistribute the turbulence near magnetic islands, to prevent or alleviate plasma disruption," explained Dr. Choi, who was first author of the paper.

A magnetic island is an island-like magnetic structure that is created in a plasma by a magnetic field reconnection, due to plasma instabilities. It can degrade tokamak performance by interfering with its magnetic confinement or can even cause plasma disruption. Understanding its effect and behavior has been one of the most difficult conundrums to solve in fusion research, and doing so is essential to realizing fusion energy.

Several projects were being carried out on multiple fusion devices to address the problem. Dr. Choi focused his efforts on the interactions between magnetic islands and background plasma turbulence.

The collaborative research team successfully proved by experiments on KSTAR that turbulence directly influenced magnetic islands to evolve by turbulence spreading or magnetic reconnection acceleration. Contributing researchers include Dr. Laszlo Bardoczi (General Atomics, US), Dr. George McKee (General Atomics, US), Professor T. S. Hahm (SNU, Korea), Professor Hyeon K. Park (UNIST, Korea), Professor Eisung Yoon (UNIST, Korea), and Professor Gunsu S. Yun (POSTECH, Korea).

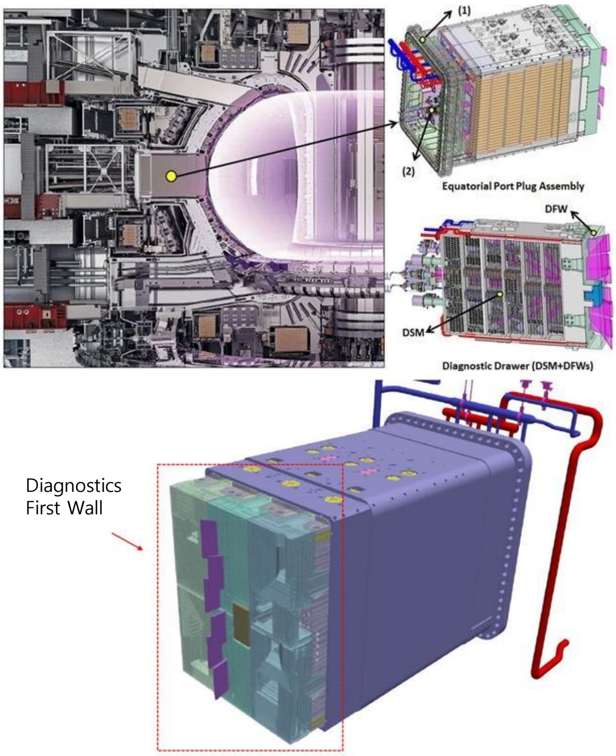
Multiple physics models have emerged to explain how plasma turbulence affects the evolution of magnetic islands, though few have been supported by actual experiments. Recent studies have suspected that turbulence spreading was suppressing the magnetic islands, but verifying it experimentally was difficult. The advanced diagnostics of KSTAR allowed the team to observe the turbulence as it spread from the outside of the magnetic islands to the inside. They were also able to witness turbulence enhancement at the reconnection site in the event of a fast collapse of a magnetic island.

The findings provide a solid explanation of the main plasma phenomena necessary to realize fusion power. The researchers expect to contribute to future fusion reactor operations by advising how to suppress the magnetic islands causing plasma disruption.

Related publication: Effects of plasma turbulence on the nonlinear evolution of magnetic island in tokamak

Issue & Focus

A Korean company wins ITER diagnostics first protection wall contract



The location of the diagnostics port plug inside ITER, where the diagnostics first wall is to be installed

A Korean company, Vitzro Tech, announced in December that it earned ITER's diagnostics first wall manufacturing contract. This contract is worth approximately 9.8 million euros.

ITER will be equipped with a number of diagnostics to measure plasma temperature, density, radiation properties, etc. The diagnostics first wall will protect these devices inside the reactor from the super-hot plasma temperature, neutrons, and strong magnetic fields.

Vitzro Tech also won another ITER contract in October 2018, the ITER IVC Busbar. The company's accomplishments originate with its participation in Korean fusion research at ITER Korea and KSTAR, where it has been able to accumulate fusion know-how. It has participated in manufacturing the KSTAR Motor Generator and the NBI (Neutral Beam Injection) systems, which prepared it for such opportunities.

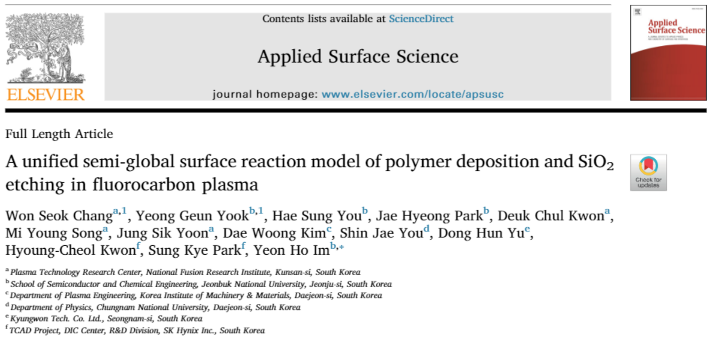
Director-General of ITER Korea, Dr. Kijung Jung commented, "ITER is not only a crucial project for fusion energy research and development but also a huge opportunity for domestic industry to enter the global market to build the huge, state-of-the-art research facility. ITER Korea will do its best to support Korean companies with excellent fusion-related technologies to earn contracts from ITER and other partner countries."

KFE People

2020 KFE Paper Awards

Every January, KFE celebrates the authors of the most notable papers published the previous year with The Grand Paper Award, the Excellence Paper Award, and the Rookie Award. The Grand Paper Award goes to the author whose article recorded the highest SCI IF (Science Citation Index Impact Factor) and the Excellence Paper Award goes to the author of the second-highest article. The Rookie Award is for the young author with the highest IF among his or her peers who joined KFE within the last three years and earned their doctorate within the last five years.
Here we have the three award winners with the most frequently cited papers of 2020.

- The Grand Paper Award / Senior Researcher Won-Seok Chang



Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

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Full Length Article

A unified semi-global surface reaction model of polymer deposition and SiO_2 etching in fluorocarbon plasma

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Senior Researcher Won-Seok Chang published a paper titled 'A unified semi-global surface reaction model of polymer deposition and SiO2 etching in fluorocarbon plasma' in Applied Surface Science in 2020. It describes how silicon-based surfaces react to fluorocarbon plasma etching, based on modeling derived from measurements and diagnostics.

It achieved the highest impact among all KFE papers released in 2020, by suggesting a realistic model of plasma surface reactions based on an analysis of reaction mechanisms with plasma diagnostics.

The physical and chemical properties of plasma used in semiconductor processing are known to change depending on various factors, such as process gas, temperature, pressure, source, etc. This complexity, resulting from ions and radicals in the plasma, had to date been beyond the understanding of scientists and engineers, and semiconductor processing has been managed by hands-on experience.

Chang's research was a game-changer by providing a predictive model. He firstly conducted quantitative measurements of radical species that affect the deposition and ion incidence towards silicon oxide from plasma. Then he employed the results for modeling. He was able to attain more precise etching properties by analyzing the polymer layer produced by the etching and deposition of plasma particles. In particular, he included the property of the polymer layer as a factor, which researchers had always considered to be a mere byproduct of the etching process, and this significantly increased precision.

Results from an industry-academia consortium

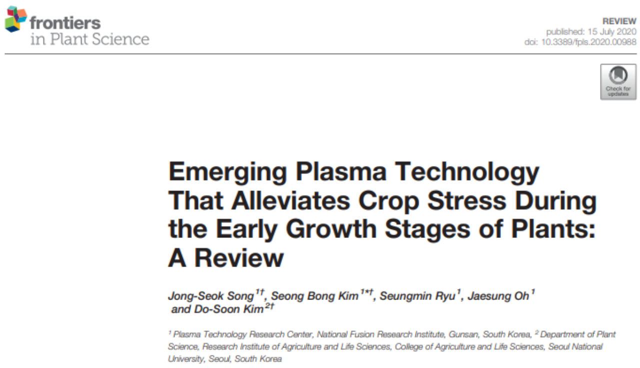
The cutting-edge research, now attracting the interest of the semiconductor industry, was begun ten years ago. In 2009, a consortium of five institutions emerged to develop semiconductor process simulations: Jeonbuk National University, KW Tech, KRISS(Korea Research Institute of Standards and Science), Pusan National University, and KFE. When KFE started to develop plasma surface reaction modeling, Chang took charge of measuring and diagnosing plasma properties. The results laid the groundwork for the paper published in 2020.

"In the beginning, I assumed my work would be over soon. However, plasma processing has kept getting more diverse, with semiconductor manufacturing evolving significantly. There is still a lot to know, and I want to know more than to stop."

He gave the consortium credit for his award. According to him, the semiconductor technology was developed because of contributions in three areas: industry experience, simulation technology, and analysis techniques.

"Plasma is an original technology leading manufacturing competitiveness. Plasma research is empowered by collaboration and fusion between sectors. Industry and academia should work together to achieve results. Just as we did ten years ago, I hope for closer cooperation between industry and academia," added Chang.

- The Excellence Paper Award / Doctor Jong Seok Song



frontiers in Plant Science

REVIEW
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Emerging Plasma Technology That Alleviates Crop Stress During the Early Growth Stages of Plants: A Review

Jong-Seok Song[1†], Seong Bong Kim[1†], Seungmin Ryu[1], Jaesung Oh[1] and Do-Soon Kim[2†]*

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Dr. Jong-Seok Song has published work in Frontiers in Plant Science showing that plasma technology can help plants survive in stressful environments such as drought or against harmful microorganisms. The title of the article is 'Emerging plasma technology that alleviates crop stress during the early growth stages of plants.'

"Seeds treated with plasma in gas or water gain the strength to survive stressful environments, as if it were vaccinated. Plasma can also sterilize microorganisms on the surface of seeds. In addition, it helps thick seeds to more easily germinate in extreme conditions such as drought by inflicting shock on their surface to absorb moisture," explained Dr. Song.

The best part of this plasma technology is that it is environment-friendly. The agriculture industry has developed many chemical products to aid the sterilization and vitalization of seeds, but they have sometimes ended up threatening the environment and human health. In contrast, plasma technology only uses harmless air, water, and electricity to make fertilizer water. It can even degrade the chemical pesticides remaining in crops.

Another reason his paper is worth attention is that it provides standard parameters for plasma treatment, such as the amount of electric power and exposure time.

“Water, which is indispensable for plant growth, may also kill the plant if it is too abundant, by rotting the root. The same goes for plasma. Plasma treatment levels should differ depending on the type of crop, as they have different optimal growth conditions."

Dr. Song made an effort to find the optimal conditions to enhance the seeds’ ability to sprout and thrive concerning seed sterilization and scarification. It also induces the plant to produce secondary metabolites, which are beneficial ingredients for people, by allowing it to develop a defense system against stressful environments. For example, plasma can enhance the level of ginsenoside in ginseng sprouts.

To build a platform from cross-cutting research

In 2016, Dr. Song attended an interdisciplinary symposium in university where he learned how plasma technology could lead to agricultural innovation. Then he joined the Plasma Bio Convergence division of Plasma Technology Institute in KFE, where researchers from various fields such as agriculture and life sciences, chemistry, and plasma science are conducting convergence projects outside of the box.

“Other laboratories are also carrying out bio research using plasma technology. However, they only have limited access to conventional plasma devices that merely show beneficial effects based on manuals. On the other hand, here in KFE, we can customize our own plasma machines and develop processing techniques to find the best conditions,” commented Dr. Song.

Regarding his ultimate goal, he said: "My final goal is to build a platform, which is open for both academia and industry, by applying plasma technology to various crops, converging plasma technology and crop production, and databasing the research results."

- The Rookie Award / Doctor Jisung Kang

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Role of fast-ion transport manipulating safety factor profile in KSTAR early diverting discharges

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In 2020 Dr. Jisung Kang published ‘Role of fast-ion transport manipulating safety factor profile in KSTAR early diverting discharges’ based on his 2018 KSTAR experiments.

“Several pillars sustain the hot plasma shape like a doughnut. A safety factor can indicate whether one of these pillars is collapsing, causing plasma instability. From the KSTAR experiment data, I was able to learn that fast-ions significantly manipulate the safety factor,” explained Dr. Kang.

When fast-ion transport speeds up in unstable plasma, it affects the plasma safety factor. In this sense, fast-ions would seem to have a negative impact on fusion. However, according to him, it is not necessarily a bad thing.

“Fusion plasma must reach the self-heating status, where the energy from the fusion reactions themselves can heat the plasma up without any assistance from an external heating device. Fast-ion research is crucial because if we can understand the impact of fast-ions on plasma, we can get a clue about how to get to the stable self-heating status.”

It is necessary to understand such a phenomenon in experimental devices like KSTAR, because DEMO reactors will produce much more fast-ions.

The uniqueness of this research also lies in how it derives the safety factor. A safety factor profile needs to be based on multiple diagnostics, meaning it draws on all of the state-of-the-art technologies of KSTAR. That is why many researchers are paying attention to his work.

“KSTAR's distinctive features helped me to draw a meaningful conclusion from experiments. Conventional fusion devices produce fast-ions only for a short period and have difficulty attaining continuous, steady-state data. KSTAR, in contrast, can carry out a stable operation with high-performance plasma thanks to its superconducting magnet, which enabled me to continuously observe and analyze them,” Dr. Kang added.

KSTAR's first plasma in 2008 ignited another dream in a young physicist's heart

Dr. Kang's dream of fusion began ten years before he joined KFE. In 2008, KSTAR ignited its first plasma, a watershed in Korean fusion research history. And he was there, a young physicist visiting KFE to write his undergraduate thesis. KSTAR's first plasma started another fire in him to become a fusion researcher.

Later in June of 2017, he became a researcher at KFE, where his job was to connect results from the Integrated Simulation division, the division he is in, with those from other divisions.

"My research mission is roughly divided into three categories: firstly, as I have written in the paper, I am working on fast-ion physics. Secondly, I carry out simulations to build a future fusion reactor. Lastly, I am a sort of a translator between experimental data and the supercomputer, as we need to standardize KSTAR experiment data before the supercomputer can process and figure out certain physics phenomena," he commented.

His research on fast-ions has been progressing since he began in 2018. His major interest is to solve the relations between plasma transport and fast-ions, which is one of the key challenges that need addressing to realize fusion power. He has focused on finding the associations between fast-ions and the fast frequency bands that happen in plasma instabilities. Now, he will take a step further, to draw a safety factor from relations between fast-ions and slow frequency bands.

NEWS Brief

KFE hosted PSI-24 on-line in January 2021

KFE hosted the 24th International Plasma Conference on Plasma Surface Interactions in Controlled Fusion Devices(PSI-24) in January. In the original planning, the PSI-24 was supposed to be held in May of 2020. However, COVID-19 postponed it, to five days in January from the 25th to the 29th. The conference location also changed from Jeju in South Korea to an online webinar.

286 PSI experts from 22 countries participated in PSI-24 to address issues regarding divertor heat flux and lifetime. Participants exchanged recent results and technical information on fusion reactor divertor and inner walls, which will enable divertor-related technologies and contribute to future reactor manufacturing and operations.

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