

# ON THE LEAP TOWARDS GREEN CHEMISTRY

Among his many talents, it took a while for Majd Al-Naji to discover his current passion for chemistry. He is currently searching for solid catalysts for the production of fuels and other chemical products from plant waste or plastic at the Max Planck Institute of Colloids and Interfaces in Potsdam, and he can already look back on his extraordinary career.

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TEXT: KLAUS JACOB

Al-Naji speaks several languages, is interested in art and culture and has been a theater actor as well as a professional show jumper. After graduating from high school, he developed a passion for many and varied subjects – but not for chemistry. But that is what he has now become: a chemist, who has been leading a team at the Max Planck Institute of Colloids and Interfaces in Potsdam, developing catalysts for sustainable chemistry since 2018. His journey to becoming a Max Planck researcher was anything but preordained, both in terms of his choice of discipline and his background story, as his future prospects seemed to be anything but promising when he was born. But, spurred on by his optimism to which his frequent bursts of laughter attest, he refused to be deterred. He is convinced that: “You need luck in life, and I have been very lucky.” Essentially, Al-Naji was born stateless. He could be considered to be Syrian, because his parents lived in Syria for a long

time, or Saudi, because he was born in Saudi Arabia. He has traveled extensively around the world, but he has no homeland where his family is rooted. His grandparents fled from Palestine to Syria in 1948. Many of his relatives still live there but are still refugees to this day. His family members were only given travel documents rather than passports. A Palestinian, as he soon learned, is at home throughout the world – or nowhere. But he has been lucky. Just what this means can be seen in a small Polaroid photo pinned on the bulletin board in his office, which shows him standing between two friends, Baris Kumru and Paolo Giusto, clutching an official document in his hand: his Certificate of Naturalization. “Having German citizenship makes my life easier,” he says. The 17<sup>th</sup> of August 2020, the day he became a German, is a date that he can recall with ease. But the journey that led to his citizenship was beset with obstacles and required tenacity, fortunately a trait that Al-Naji has demonstrated on many occasions.

His first career is a case in point. At the age of four, his father sat him on a horse. His father, a horse lover himself, was working in Saudi Arabia, where Majd spent much of his childhood and youth. Not a day went by on which he did not clear obstacles mounted on a horse. The rhythm of his days was set by his school and stable timetable. What began as a hobby soon became a profession and, as a professional show jumper, Majd trained ten hours a day, from 6 to 11 in the morning and 4 to 9 in the evening. “I was nuts,” he says looking back. At the age of ten, he was already earning prize money at show jumping competitions and was also working as a trainer. He traveled through many Arabic countries, going from one tournament to the next and competing with adults. Of course, the occasional fall came with the territory: at the age of 13,

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# VISIT TO

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MAJD  
AL-NAJI



PHOTO: DAVID AUSSERHOFER FOR MPG

A focus on renewable materials: Majd Al-Naji has developed a catalyst that converts lignin extracted from sawdust into the raw materials for biofuel and other chemical products.

he fell onto a metal fence and woke up in hospital, where doctors diagnosed a kidney hemorrhage. After that, his father came close to banning him from show jumping, but his son's successes made him change his mind. So Majd Al-Naji kept at it – and successfully: he competed in the qualification for the Olympics in 2008, by which time he was already studying at university. Ultimately, however, he was unable to compete in the Games due to lack of funding.

His attitude towards equestrian sports changed when he moved to Germany. Instead of pursuing prizes and success, he rode for pleasure, preferring to ride in the countryside rather than in the arena. Nevertheless, he bought himself a young show jumper in Leipzig, his first point of call in Germany. Only when work came to dominate his schedule did he finally close that chapter. However, he still has not completely given up on the sport and hopes to buy another horse at some point in the coming years. Show jumping in Germany opened up a completely new path for him. During his time in Leipzig, he worked for a number of years as a commentator on international tourna-

in my first semester.” Only after his father had had a serious talk with him did he pull himself together and finally start to enjoy the subject. Practical laboratory work, in particular, was something he developed a passion for. So, he decided to continue his studies after earning his bachelor's degree in Damascus in 2009. That would have been all but impossible in Syria, where only a fraction of the many students had the chance to take a master's degree. Research was also all but out of the question, at least not at the cutting edge, due to the lack of equipment. So, Al-Naji applied for a master's degree in Germany via the German Academic Exchange Service (DAAD). He is deeply grateful for the opportunity, he says. But here, too, luck was required. “Obtaining a visa was a difficult and lengthy process.” The only people who were granted a visa were those who could demonstrate that they could finance their own studies. His cousin, Bassel El Nagi, who had been living in Germany since the 1980s, guaranteed his monthly fees. It was also fortunate for Al-Naji that the civil war had not yet erupted and that it was easier for Syrian students to come to Germany than it currently is.

## Majd Al-Naji hopes to end our dependence on oil – and above all, to combat climate change: “That’s the future.”

ments for Arabic television stations. He would interview the riders in English or German and moderate in Arabic.

Picking up a microphone was no coincidence. He had always felt drawn to journalism. After graduating from high school, he initially flirted with the idea of media studies. “I wanted to study anything except chemistry,” he says. Of all the subjects he took in high school, chemistry was the one for which he received his worst grade. Maybe he was trying to emancipate himself from his family and was mentally resisting their expectations. His two uncles Mahmoud and Omar Al-Naji were chemistry professors, one having studied in Russia and the other in France. In the end, they convinced him to study chemistry, but his first steps at university did not go as planned at all: “I didn’t pass a single module

His move from Damascus to Leipzig, where he studied for his master's degree, was a leap into the unknown, because he spoke no German. Cosmopolitan by nature, Al-Naji finds learning languages easy. This talent helped him through his subsequent career: for example, he spent one academic year at the University of Cordoba in Spain and later, after completing his doctorate with Roger Gläser at the University of Leipzig, he spent a year conducting research in Belgium, where he learned French. He now speaks five languages: Arabic, English, German, Spanish, and French. He came upon his current research focus – green chemistry – while studying for his master's thesis. He now heads the “Biorefinery and Sustainable Chemistry” working group at the Max Planck Institute. With enthusiasm and creativity, Al-Naji explains what this involves. In fact, it is illustrated on his of-



fice wall, which is strewn with framed graphics that once appeared in periodicals. He sketched them himself and had them completed in detail by artists who are his friends. One depicts a piece of wood that is transformed into a plastic object. “Art is the best tool for conveying knowledge,” says the scientist.

Al-Naji wants to make fuels and other chemical industry products from plant-based materials, thus ending our dependence on oil, specifically with a view on combating climate change: “That’s the future,” he says. As such he has set himself a highly ambitious goal, as oil has shaped many aspects of our daily lives for over a century and employs an entire sector of industry – the petrochemical sector. Sophisticated technology has emerged during

this extended period of time to facilitate the production of a wide range of products. Petrochemicals have an enormous lead over green chemistry. For the most part, fuels are made of crude oil, which powers cars, airplanes, and ships in the form of gasoline, kerosene and diesel. However, oil can also be found in many everyday products where one would hardly suspect its presence, such as chewing gum, candles, cleaning agents, and in many cosmetic products including body lotions and shower gels. The synthetic fibers found in many garments are also products of the petrochemical industry. The majority of plastics in particular are also derived from crude oil – and are now infamous, among other things, for the harm they cause to the environment. Plastics accumulate in the oceans in horrific quantities as they are

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Fearless of obstacles: as a show jumper, Majd Al-Naji in the Olympic Games Qualification. He also had to overcome a number of obstacles to become a research group leader in Germany.



PHOTO: RABIH MOGHRABI/APP VIA GETTY IMAGES



Chemical recycling: Qisong Hu, Francesco Brandi, Majd Al-Naji, and Jose Chacon (from left) are searching for ways to extract useful substances from plant waste such as sawdust, straw and from plastic waste.

all but non-degradable and when it does degrade it disintegrates into ever smaller pieces that have been contaminating the entire ecosystem for many years in the form of microplastics.

Al-Naji is looking for ways to make such products from natural materials – entirely oil free. To minimize harm to the environment, he has set his sights even higher. In stark contrast to currently available biofuels, one of his precepts is that the raw materials should not originate from crops that could be used to feed people or that are grown specifically to produce fuels or fodder, because food is already in short supply in many countries, as is land that could be used for agriculture. Al-Naji is focusing exclusively on waste that would otherwise end up in incinerators or as compost, such as sawdust or kitchen scraps, which is why he has been gathering bark in the forest and collecting grass trimmings from the soccer field, where he plays with colleagues. And that is not all: he always bears the question of costs in mind and avoids using expensive materials. Everything he needs in addition to organic waste products is cheap and abundant in nature – that is his second precept.

One can view his raw materials and the way he processes them when one accompanies him through his laboratory. The lab contains equipment that you might expect to find in a kitchen rather than a

chemistry lab: a pasta machine, a pizza oven, and a blender. Likewise, many of the chemicals he employs are natural substances, just like the ingredients found in a kitchen – albeit in different containers and labeled differently: olive oil, salt, palm oil, vitamin C and amino acids. Chemists, it is said, are good cooks. Al-Naji and his colleague Francesco Brandi take this literally and employ a “kitchen laboratory” founded by Markus Antonietti.

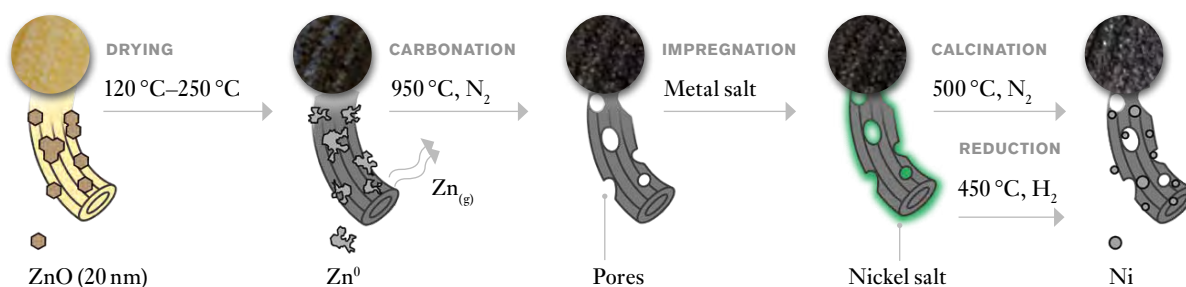
Al-Naji’s team produces catalysts in the so-called KitchenLab. Most chemical reactions require these solid catalysts to get going, but the catalysts used in the petrochemical industry are ill suited to green chemistry. Others are too expensive because they contain precious metals such as platinum and gold or are not sufficiently stable. Among other things, Al-Naji is working on catalysts that can depolymerize the lignin contained in wood, in other words break it down into smaller, chemically usable units. Together with his colleagues, he has developed a simple recipe to achieve this: take eight parts of protein-rich waste and two parts of zinc oxide, mix everything in a blender with glucose from waste wood and a dash of urea to form a homogeneous mixture, before adding water to make a spreadable paste. Feed this into a pasta machine to form thick strands of spaghetti. Put these in a pizza oven for a day at 120–250 °C until the water evaporates. Finally, place the hardened strands

of spaghetti in a high-temperature furnace, roasting the flour at 950 °C to form carbon. The process causes the zinc oxide to evaporate, leaving behind countless tiny pores. The finished spaghetti is now placed in a nickel solution for another six hours – and the catalyst is ready.

The beauty of this method is that it requires much less nickel than conventional catalysts of this type. This is because the pores created when the zinc oxide evaporates are extremely small, which provides the metal, the actual catalytic substance, with a very large surface area. His spaghetti catalysts are not

oil – from fuels to plastics. Such biorefineries could also operate on a small, mobile scale unlike petrochemical plants.

For example, Al-Naji hopes to use the technology to enable farmers to process straw and other lignocellulose-containing waste into a useful product. He is also currently developing catalysts that convert plastic waste into the raw materials for a variety of chemical products, such as fuels and plastics. It is conceivable that such facilities will be installed on ships collecting plastic waste from the world's oceans and processing it on the spot. These are no



Pasta catalyst: the researchers prepare the catalyst by roasting noodles composed of simple ingredients at 950 °C, causing the organic components to transform into porous carbon. They then load the carbon noodles with a nickel salt, before calcinating them (i.e, thermally treating them), and reducing the nickel salt to pure nickel.

just cheaper and more sustainable than competing products, they are also more efficient. However, that is not enough for Al-Naji, who has now set his sights on the entire production chain, from natural materials to the finished product. He is experimenting with small biorefineries in which the catalysts are only one component.

To make these plants work as efficiently as possible, he has developed a continuous system into which supplies are constantly fed on one side while the finished product is delivered on the other. Proven on the laboratory scale, he has also proven the technology can be successfully scaled up. A pilot project involving several companies has successfully generated 300 liters of depolymerized lignin in a single day. Al-Naji is confident that his method will enable him to produce the raw materials for many products that are currently still based on

mere pipe dreams. Al-Naji has applied for patents stemming from his work into sustainable chemistry and the biorefinery. He can envision himself launching his own start-up, but also accepting a professorship at a university where his research could allow him to make a real contribution.

Majd Al-Naji now feels at home in Germany; it has become his home. He emphasizes his gratitude to so many people for their support throughout his scientific and personal development, especially Markus Antonietti, who also believes in thinking outside the box. It was he who not only taught him how to implement a big idea from a simple experiment but also to enjoy life to the fullest. When Al-Naji and his colleagues join the Director for a glass of wine occasionally in the evening, the conversation meanders through art, politics, philosophy, sports and, of course, a little bit of chemistry.

