The joy of working together

Cooperation can help transform small ideas into a complete workable system, says Hyunjae Lee.

My interest in material sciences began when I was an undergraduate at Seoul National University. I was intrigued that materials can possess new and distinctive properties when scaled down from their bulk counterparts. This fascination led me to work on various projects. I started by learning how to synthesize semiconductor nanoparticles, studying their properties, and finding ways to manipulate them. During this period, I spent most of my time working alone and sometimes I found interpersonal relationships difficult. Whenever conflicts with colleagues arose, I struggled to resolve them. In late 2011, I joined Dae-Hyeong Kim's group and began working on flexible and stretchable electronic devices for biomedical applications. I remember being a little apprehensive because I knew little about biomedical materials, devices, and clinical medicine. Reflecting on this now, I realize that I have acquired lots of technical knowledge by working closely with researchers from different fields. Importantly, however, the experience has taught me the true value of teamwork.

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The aim of my original research project was to find an application for graphene grown by chemical vapour deposition. I was looking to capitalize on the unique properties of graphene to create a meaningful device system. Graphene is interesting because depending on the application, its characteristics can be easily modified by varying the synthesis conditions and post-synthesis treatments. From these basic ideas and knowledge, I developed a graphene-based transparent sensor and actuator that can be integrated with a surgical endoscope for tumour sensing and feedback ablation therapy (*Nature Commun.* **6**, 10059; 2015). The most challenging part of this work was

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to find a way to modify the graphene surface without sacrificing transparency. Through trial and error, my colleagues and I found that simple solution-based gold doping could effectively enhance the electrodeposition of iridium oxide on the surface of graphene. The electroplated iridium oxide had low impedance and was pH sensitive. This allowed impedance- and pH-based tumour sensing, and controlled radiofrequency tumour ablation. When this graphene-based transparent device was placed onto an endoscope tip, it became possible to characterize and treat colon cancer. This was exciting because the integrated device worked and it offered new possibilities to current surgical procedures. And I realized that to create breakthroughs in an interdisciplinary project, working with others in different fields is critical and can be very effective.

Very quickly, I found myself developing more graphene-based electrochemical sensors and actuators. My second project involved the integration of glucose, pH, temperature, humidity, and strain sensors, as well as drug-containing microneedles with embedded thermal actuators onto a single wearable patch for sweat-based non-invasive blood glucose monitoring

and transdermal drug delivery (*Nature Nanotech.* **11**, 566–572; 2016). Among the various obstacles in this project, I struggled with the quantitative characterization of the graphene/solution interface and the fabrication of a stable glucose sensor. However, through various discussions with colleagues and, in particular, a chat with Taek Dong Chung (a specialist in electrochemistry), I realized that I had overlooked the basic principles of electrochemistry and the working mechanism of the glucose sensor. With Chung's help, I was able to resolve the issues of accuracy and sensitivity of the glucose sensor. The benefits of building good relationships with others and learning to ask for help when needed became apparent.

The various devices that we designed are more valuable when combined with other devices. In many ways, my research journey resembles this system-level integration. Working alone, I often took longer to overcome obstacles and was able to achieve less than when I cooperated with others.

As a leader of a small sub-group in our research group, I have designed and managed several research projects with my colleagues. I have found that intimate working relationships based on mutual respect and a shared desire for growth and success are more important than the number of people that make up a group or team. For me, having three to four members in a group has been most enjoyable and productive. Through this experience, I have grown to appreciate group work and am happy that I have changed from being a lone worker to a good team player and leader. Importantly, I have learned that small ideas can become something big if we can work together effectively.

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