Discovery of new gigantic swelling phenomenon of layered crystal driven by water

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A research group from the National Institute for Materials Science has discovered an intriguing phenomenon in which an inorganic layered crystal expanded and contracted by 100 times its original size in a few seconds when immersed in an aqueous solution, displaying a behavior similar to a living cell.

It is known that inorganic layered crystals intercalate various types of ions and molecules between their layers to show swelling when immersed in aqueous solutions, but the degree of swelling is normally on the order of several 10%. In some limited examples, swelling of several times has been achieved when a large volume of water was absorbed, as water is a solvent. However, in such cases, the force that acts between the layers is weakened, and the crystals will split into thin fragments under even a weak external force, such as shaking of the solution. For this reason, it has been virtually impossible to maintain a stable swelling exceeding 10 times the original size, and scientific understanding in connection with the swelling reaction of lamellar crystals had been limited.

In this research, the MANA group discovered that inorganic plate-shaped crystals such as lamellar metal oxides expand in an manner similar to an accordion, reaching 100 times their original length in the layer stacking direction in 1-2 seconds, under the action of a diluted aqueous solution of an organic compound having an amino group and a

hydroxy group at its two ends. In one surprising finding, although the crystal expanded in a string-like manner, it remained stable and did not break, and it returned to its original state in several seconds when an acid was added. Although the lamellar crystal used in this research has a stacked structure comprising around 3000 layers, this means that a huge volume of water, sufficient to cause swelling of as much as 100 times, was absorbed into and then expelled from the interlayer space almost instantaneously, and in this process, the crystal behaved as a monolith without separation of the layers. This amazing phenomenon implies that the water, which is absorbed between the layers, has a special state, and theoretical calculations suggested that a strong, tough hydrogen bond network of water molecules is developed with the organic compound as the point of origin to stabilize the highly swollen structure.

These research results will contribute to advancing understanding of the synthesis process of 2-dimensional materials (graphene, nanosheets) via delamination of precursory lamellar compounds, which have been a "hot topic" in recent years, and to improving controllability of that process, and thus is expected to open the road to high yield synthesis of high grade nanosheets. This discovery is also expected to shed light on the unique behavior of water when enclosed in confined spaces, which is a key factor in biological phenomena, but is still an area where many questions remain to be answered.

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