Capture a galloping horse

--Catalyst surface oscillation observation--

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In 19th century there is a famous controversy about if there is a moment during a horse running that all their four legs are lifted above the ground. People holding that the horse hoovers with all legs in the air were unsupported by the opposite side. The only convincing way to figure it out is to have a camera which is faster than the galloping cycle of the running horse. The arguments last for four years until a photographer Eadweard Muybridge developed a camera with a time resolution of 2 ms, which finally proved the existence of the hoovering.

Nowadays, we have vehicles much faster than horses. However, the speed of camera doesn't always fully meet the requirement to follow the detail of a running car.

Dynamic processes are everywhere.

In the world of catalysis, chemical reactions take place on the catalyst surface where the reaction is facilitated without consumption of the catalyst materials. Numerous dynamic processes occur on the catalyst surface during a catalytic reaction, due to the variation of, for example, temperature, reactant composition, etc. These processes cause the structure change of the catalyst, which in turn affects the catalytic reaction on the catalyst surface. It is of interest and also important to follow the catalyst structure changes, so that we can further flexibly control the catalytic reactions by corelating the catalytic properties with the varying surface structures. However, some dynamics are fast. The probing "camera" we commonly use are in contrast slow.

In this thesis work we are looking at the carbon monoxide oxidation reaction ($CO \rightarrow CO_2$) on an ideal Pd surface. The local gas composition change right above the catalyst surface will cause a restructuring of the surface. This process normally has a time scale of milliseconds to seconds. Unfortunately, the techniques we are using is not fast enough to follow the structure change, giving the tested result with high noise.

--Then what to do?

Imagine we took a batch of pictures of a beautiful architecture. Due to a far distance, bad weather, and low camera resolution, all the pictures are so blurry. Often I will just simply open photoshop and import all the pictures as layers, and use stack mode->mean, which stacks all the same pictures and average them, thus we get a new picture with a much higher quality. Such a simple and great method isn't it?

--Can this idea also be used in our surface structure change study?

First, where to get this batch of same pictures? We here use a time resolved techniques to probe the surface structure with time evolution. Then we use a cyclic gas pulse to drive the surface structure change periodically, with totally same measuring condition applied on each period. So ideally an identical surface structure can be found in the next period, which is reflected by the probing technics to give a same picture from the last period. By driving the surface to oscillate many cycles, we can obtain identical pictures from each cycle. Here we call these same pictures as "events". Then we just simply add events together and average them! Find events, and average! By the way, a small technical issue needs to be noticed is that we need to well align each picture before adding them together, otherwise mismatch of pictures makes the resulted picture even worse.

On the other hand, it is understandable that the pictures from all the period may not be identical with each other in reality, because of the change of the speed of the probing equipment and unavoidable variation of environment with a long time duration of measurement. So we would also look at the individual event from all the period. Thus we can have a look at how scattered of all the events are, and give a compensation of our event-averaging method.