

## A rapid and facile measurement for corrosion rates using dynamic light scattering technique

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### INTRODUCTION

A variety of iron alloys have been developed for various purposes, but time-consuming corrosion measurements have presented a bottleneck for the development of new alloys. The standard method for measuring the rate of corrosion is the immersion test during which metal specimens in a sodium chloride solution are weighed periodically. The measurement is straightforward but requires reaction times of several months to determine the corrosion rate because corrosion is a slow process. In the present study, we have developed a new method for measuring corrosion rates within several hours under natural corrosion conditions. The main idea of this method is to use metal nanoparticles instead of bulk metal specimens. Because nanoparticle sizes are comparable to the thickness of iron oxide layers formed within one day (~300 nm for pure iron), the time dependent change in nanoparticle size due to corrosion is much more significant than in bulk metal specimens. Small changes in nanoparticle size were measured with nanometer sensitivity using a dynamic light scattering (DLS) method. Although the DLS technique has been extensively applied to determining the size of polymers, proteins, and colloid particles, it has not been adopted for corrosion measurements to the best of our knowledge. The combination of metal nanoparticles and the DLS method was found to be very efficient for determining the corrosion rates of metal alloys.

### RESULT

In contrast to time-consuming conventional immersion tests, accurate results were obtained within several hours using DLS methods applied to iron nanoparticles. Fig. 2 plots the average size of iron nanoparticles as a function of time. The influence of initial nanoparticle size on the corrosion rate was investigated by testing three iron nanoparticles: Cr0-55, Cr0-110, and Cr0-210. These nanoparticles consisted of pure iron but had different average sizes. The average radii of Cr0-55, Cr0-110, and Cr0-210 were measured to be 55, 110, and 210 nm, respectively. As metal oxides formed around the nanoparticles during corrosion, nanoparticle size increased linearly with time and then saturated due to the complete oxidation of iron in the nanoparticles. The size distribution of Cr0-55 is plotted as a function of time on the right of Fig. 2. Note that the size distribution appears almost constant on the logarithmic time scale but the distribution on the linear scale increases with time. Since the average radius of the Cr0-55 nanoparticles was 55 nm and they were assumed to be completely oxidized within 4 h, the corrosion rate of Cr0-55 was 55 nm per 4 h, which corresponded to 0.12 mmy<sup>-1</sup>. Similarly, the corrosion rates of Cr0-110 and Cr0-210 were calculated to

be 0.115 mmy<sup>-1</sup> and 0.123 mmy<sup>-1</sup>, respectively. The similar results of Cr0-55, Cr0-110, and Cr0-210 indicated that the corrosion rates of the particles were almost independent of the initial average size. This corrosion rate was almost identical to the value obtained by conventional immersion tests.

### CONCLUSION

In summary, we have demonstrated the first use of DLS for measuring the corrosion rates of iron and alloy nanoparticles under natural conditions. Because the DLS technique is sensitive to size changes in nanoparticles, with nanometre sensitivity, it provides a way to determine corrosion rates that is more rapid and facile than the time-consuming conventional immersion method. In addition, DLS measurements robustly and reproducibly determine corrosion rates because the measurements are based on the average size of a large number of nanoparticles. Furthermore, high-throughput screening of corrosion-resistant alloys could be easily achieved by using a multi-sample loading system for the measurement.

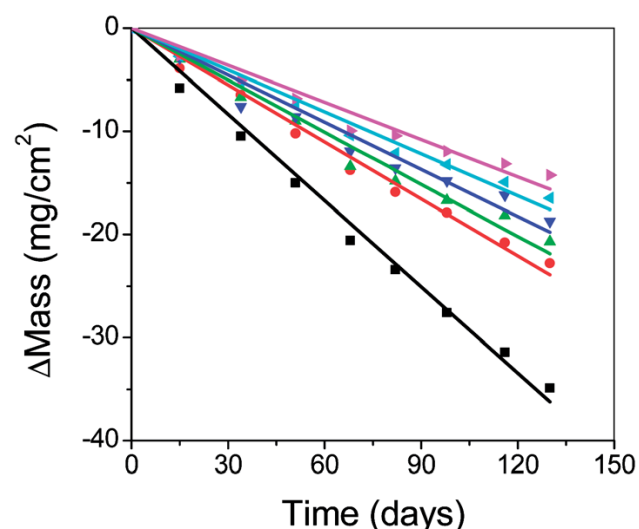


Fig. 1 Time-dependent mass of chromium alloy specimens measured by ASTM G31: Cr0 (black), Cr1 (red), Cr2 (green), Cr3 (blue), Cr4 (sky-blue), Cr5 (magenta).

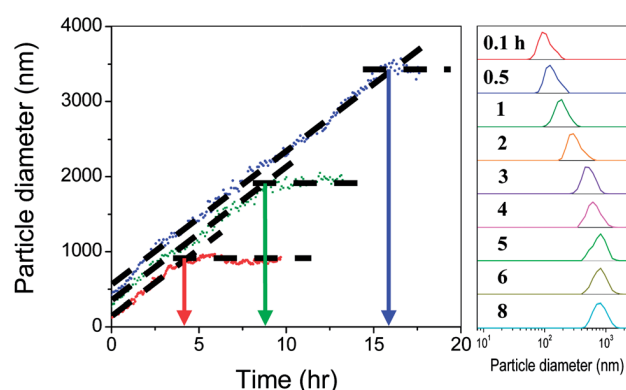


Fig. 2 Time-dependent average size of the iron nanoparticles: Cr0-55 (red), Cr0-110 (green), Cr0-210 (blue). The right graph shows the size distribution of Cr0-55 as a function of corrosion time.

### REFERENCE

- [1] J. Joo, H. Seo, C. Chun, K. Han, H. Jung, S. Kim and S. Jeon, *Analyst*, **137**, 584 (2012)