Kelly A & Nicholson R B. Precipitation hardening.
Progr. Mater. Sci. **10**:149-391, 1963.

A review of precipitation hardening in metallic systems including detailed coverage of the kinetics, the morphology of the precipitates, and a complete review of the mechanical properties of single crystals of (age-hardening) alloy systems is presented. This was the first review since extensive work had been carried out using the transmission electron microscope, accurate resistivity measurements, and accurate measurements of the plastic properties of single crystals. This enabled the processes hindering dislocation motion to be identified, and in broad outline, the phenomenon of age-hardening to be satisfactorily explained. [The *SCI*® indicates that this paper has been cited over 445 times since 1963.]

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"This review was carried out when I had returned to Cambridge to a lectureship in metallurgy from the position of associate professor of metallurgy and materials science at Northwestern University. Robin Nicholson was a postdoctoral research worker at Cambridge.

"Since the end of the war, the process of age-hardening had been studied most effectively, in the early stages, by use of the X-ray techniques introduced by Guinier in France and Preston in England (see reference one). These could give some information on the form of the precipitate but could give very little information on the distribution. In addition, there was great interest in the phenomenon of quenching itself because of the interest in studies of radiation damage and because quenching was thought of as a means of introducing only vacancies into a lattice. In 1956, Peter Hirsch and Mike Whelan had enabled individual dislocations to be seen moving in pure metals.

"Nicholson applied this technique to the study of thin films of precipitation hardenable alloys as part of his PhD thesis. He was able to produce the first direct pictures of Guinier-Preston zones. Using the technique we could also see, in some cases, the dislocation interacting with obstacles. However, the observations with the electron microscope were of such a small volume of material that most pictures did not prove or disprove the importance of particular modes of interaction in determining the flow stress; such could only come from quantitative agreement between experimental measure of the yield or flow stress and a theory of the interaction.

"At Northwestern, I had carried out detailed X-ray studies using the methods of Guinier and Preston. In addition, I had carried out studies of the mechanical properties of single crystals. For the first time, therefore, we were able to write a review of which both authors had direct, firsthand knowledge of the use of the X-ray techniques, the electron microscope, and of the measurements of the plastic properties of the crystals. It was a most fruitful article containing many new results previously unpublished, some of which have never been published since.

"We received a lot of help from colleagues. At that time it would be true to say that Cambridge was the leading centre for thin film electron microscopy and we had some of the foremost brains in dislocation mechanics in the world. Had we failed to produce a good review, it could almost be said we were incompetent. We were very lucky to come together and to find that our personalities suited writing such an article. I cannot remember any serious dispute as to what we should say. Nicholson was meticulous and cheerful as an experimentalist with a surprisingly wide knowledge of various alloy systems. I, who had been trained as a physicist, tried to be incisive and to make detailed physical models of each of the interaction processes. Many of these have turned out to be wrong but the attempt led, we believe, to a very stimulating article which has been widely quoted because of breadth of coverage and the fact that we were able to write a completely up-to-date account, even though it took a year to publish, which much frustrated us.

"The review presented a large number of specific aspects of precipitation hardening which required further research to produce an understanding. It was while carrying out this review that I stumbled across the idea of fibre reinforcement and after completing the review my main scientific interest turned in the direction of fibre reinforcement of metals, ceramics, and most important, organic resins. The review was also a fruitful source of ideas for others and perhaps their generous acknowledgement is the reason for its frequent quotation.

"There was a sequel called *Strengthening Methods in Crystals*, a multiple-author work which we edited and which was published as a book by Elsevier."[1]

1. **Kelly A & Nicholson R B**, eds. *Strengthening methods in crystals.* Amsterdam: Elsevier, 1971. 629 p.