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High Resolution TEM and Energy Filtering TEM Study of Internal Structure and Composition Distribution in Materials

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High resolution transmission electron microscopy (HRTEM) is a very powerful technique to resolve the structure of the materials at atomic level. However, One of the limitations of the HRTEM technique is that it provides little information about the composition in materials. Except for some special case such as the one shown in the Fig. 1, a high resolution image of Al_3Zr precipitate in Al matrix. This image was recorded at the Scherzer underfocus which is about -50 nm for JEOL 4000EX. The Zr atoms are shown as dark contrast and the Al atoms bright dots in the Scherzer focus so that we can see the composition distribution at the atomic level near the interface.

When the high energy electrons pass through the specimen, the electrons are not only scattered elastically but also accompanying the inelastic scattering. Using an imaging filter which is coupled with TEM allows us to select inelastic scattering electrons associated with a particular energy loss which corresponds to a particular element in the materials to form the image. The energy slit locates in the dispersion plane. This technique is very similar to the regular dark field technique, however, it is a dark field technique in the energy space. This technique provides us the information about the distribution of the composition in the materials. Two examples are given below. We have used this technique to study the phase transformation in the Cu-Be alloy and the interlayer characteristics between diamond film and the silicon substrate. Fig. 2 (a) is a bright field image of the γ phase precipitate in the Cu alloy. This γ phase precipitate is about 6 nm in width and exhibits only little contrast due to being not strongly diffracted. However, it shows brighter contrast in the energy filtering image of Fig. 2 (b) which is recorded using Be K edge loss (111 ev) with the width of energy slit 10 ev. This image implies the γ phase precipitate is Be rich.

Diamond film was grown using microwave plasma CVD technique which consists of three steps: carburization, bias and growth. At the bias stage there is an interlayer of 6 nm thick between diamond and silicon substrate . Most of the regions of the interlayer are of amorphous characteristics which presents a barrier to identify the elemental compositions. Fig. 3 (a) and (b) are the Si and C jump ratio maps of the energy selecting images, respectively. The jump ratio maps were obtained by dividing the post-edge loss image by

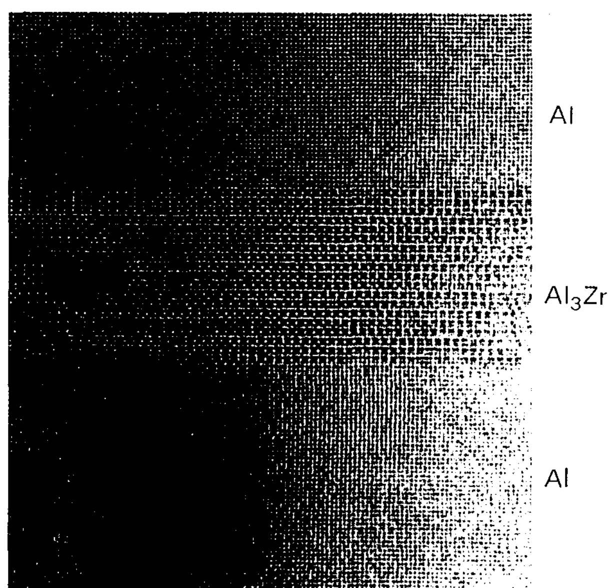

Fig. 1. High resolution image of Al_3Zr precipitate in Al matrix.

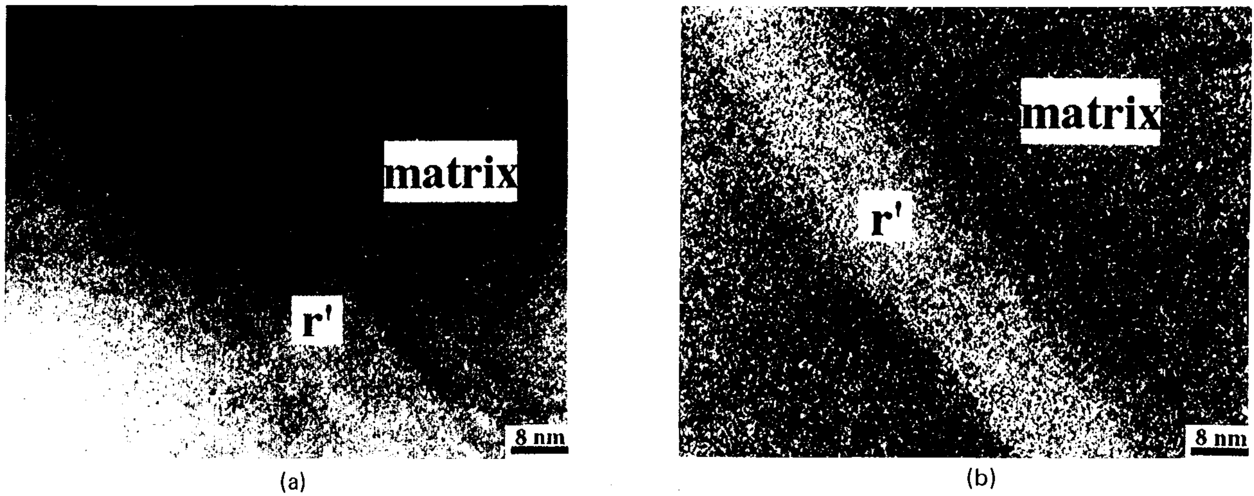

Fig. 2. (a) Bright field image of g precipitate in Cu alloy. (b) The Be K-edge core loss (111 ev) image of (a)

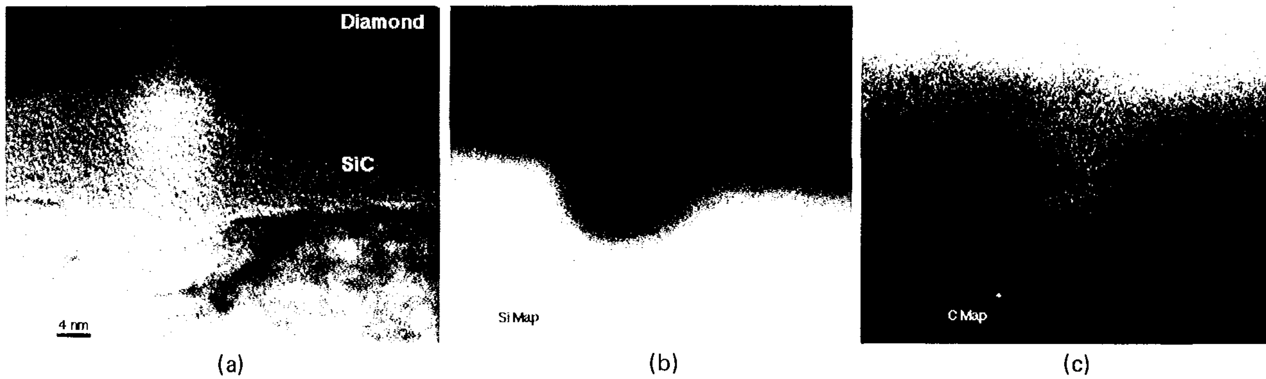

Fig. 3. (a) high resolution image of microwave plasma CVD diamond on silicon. (a) the jump ration map of Si. (b) the jump ration map of C.

the pre-edge image. The post-edge image of Si and C were recorded at the 119 and 303ev, respectively. The pre-edge image were recorded at 79 and 263 ev. The width of the energy slit was set to be 10 ev. There are three contrast levels in both images. It could confirm that the interfacial layer is SiC. We have done the same anaylsis on the specimen in the carburization stage. An amorphous layer consisting of carbon was covered on the Si amorphous layer. It may suggest that the thin interlayer transforms from carbon in the process of carburization to SiC in following bias stage.

With combination of the high resolution TEM and energy filter, we are able to obtain the infiormation of the structure and composition at near atomic level simutaneously. There is, however, still a limitation of detection of the minor elements within the materials due to the low intensity of the inelastic scattering electron and low signal to background ratio of electron source. With the recently developed field emmision TEM, these two techniques will become more powerful from the excellent coherency and the high brightness of the electron source.