Experimental Determination of Inelastic Mean Free Paths for Calculation of TEM Specimen Thickness

E. Verleysen[1,2,3], H. Bender[1], D. Schryvers[3] and W. Vandervorst[1,2]

1. Imec, Kapeldreef 75, 3001 Leuven, Belgium
2. K.U. Leuven, IKS, Celestijnenlaan 200D, 3001 Leuven, Belgium
3. Universiteit Antwerpen, EMAT, Groenenborgerlaan 171, 2020 Antwerpen, Belgium

ABSTRACT

The continuous scaling in semiconductor technology has made accurate characterization of transistor components more challenging. In this context, accurate determination of TEM specimen thickness is gaining importance. The aim of this work is to develop an experimental methodology to determine the electron mean free path for inelastic scattering, which in turn can be used to determine the thickness of TEM specimens by Electron Energy Loss Spectroscopy (EELS). The methodology is based on the study of cone shaped specimens which are prepared with focused ion beam (FIB) by milling ring shaped patterns with gradually decreasing diameter. The investigated specimens contain nickel silicides with different compositions on top of a Si substrate. Figure 1 shows a TEM and an HAADF-STEM image of such a cone shaped specimen with a $NiSi_2$ layer on a Si substrate. Since the intersection of the cones is circular, the width of the cones equals the maximum specimen thickness. The ratio of the specimen thickness to the electron mean free path for inelastic scattering can be determined by EELS, since this ratio is related to the total intensity of the spectrum scaled by the intensity of the zero loss peak [1]. EELS profiles are measured along the full width of the cone shaped specimens and the ratio of specimen thickness to the mean free path is determined at each point of the profile. Since for the cone shaped specimens the specimen thickness along the profile is known, the mean free path can be determined. The dependence on the experimental conditions and material composition is studied. The experimental mean free paths are compared to calculated values obtained with the formulae available in literature [1]. It is shown that the calculated values significantly underestimate the true specimen thickness for high accelerating voltages. The experimentally determined mean free paths are used to determine the thickness of TEM specimen of device structures containing nickel silicides.

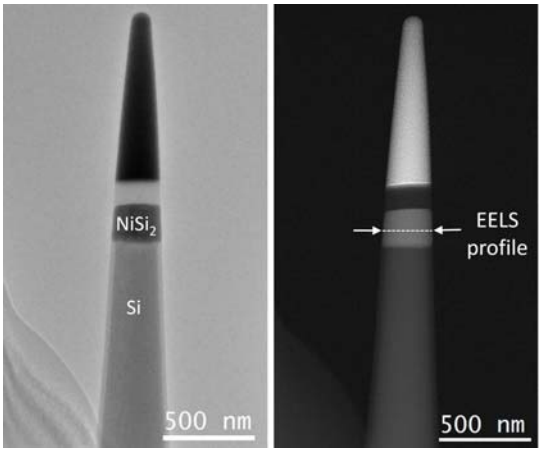

FIGURE 1. TEM and HAADF-STEM image of a cone shaped specimen which contains a $NiSi_2$ layer

1. R.F. Egerton, *Electron Energy Loss Spectroscopy in the Electron Microscope*, New York: Plenium Press, 1986