Nanomechanical Characterization and Metrology for Low-k / ULK Materials

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ABSTRACT

Low-k and ULK films are used in microelectronic products. These films have become an important material to develop next-generation integrated circuits that allow higher current densities by reducing the interconnect resistive capacitive delay. These films are designed for low dielectric constants by the choice of material and by increasing the volume of embedded pores. At the same time the low-k materials must exhibit enough structural support to be compatible with the demands of modern semiconductor processing. The damascene type processing may include chemical-mechanical polishing (CMP), lithography, etching etc. The dielectric and mechanical properties should not be affected.

For porous dielectric films the porosity is directly related to the dielectric constant [1]. Nanomechanical tests are therefore a suitable method of characterizing both – the structural stability and the expected dielectric performance. Force–displacement curves of an indentation experiment represent a fingerprint of the material and allow to directly characterizing the corresponding change in the process. Therefore an increasing demand for determining mechanical properties as a part of the process control is expected. More sophisticated methods of mechanical testing and the combination of methods allow to fully characterizing the structural change inside a low-k film.

Examples of different applications for nanomechanical testing in this area will be shown that allow characterizing the thin film adhesion to the substrate. The interfacial failure of a three layer film stack is shown as well as the effect of an unwanted collapse of porosity close to the surface that can be easily identified in the force-displacement curve of an indentation experiment. Overall monitoring hardness and modulus vs. depth allows studying substrate effects as well as stiffer materials regions. The profile of this property vs. depth curve will change with varying film thickness or structure variations. The meaning of “not producing a good film” becomes measurable.

REFERENCES

1. K.Vanstreels and A.M.Urbanowicz; J.Vac.Sci. Technol. B, Vol. 28, No. 1, Jan/Feb 2010