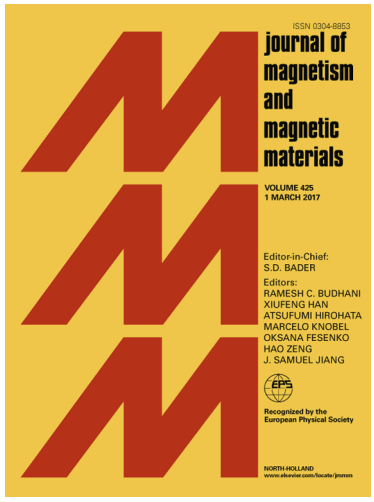

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Domain Wall Characterization Inside Grain and Around Grain Boundary under Tensile Stress

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Abstract: Stress measurement is important field of Non-destructive testing and evaluation (NDT&E). This can ensure the stability and structural rigidity of the workpiece. The challenging task of stress measurement is the properties characterization of the microscopic magnetic, especially the microstructure at different location of grains. The qualitative analysis of magnetic properties changes under low stresses inside grain and around grain boundary are difficult to obtain a reliable solution. This paper investigates characters of the domain wall inside grains and around grains boundaries under low tensile stresses. The domain wall of the silicon steel sheet is captured by the magneto-optical Kerr effect (MOKE) microscopy. The stress changes the magneto-elastic energy and the angle between magnetization and stress. The relationship among domain wall, magneto-elastic energy, the magnetization inside grains and around grains boundaries under different tensile stresses is provided and analyzed in details. Magnetization work calculates the energy required for magnetization to quantify the difference of the magnetic domains distribution caused by increment of magneto-elastic energy under different tensile stresses in different locations. The difference of magnetization work in these locations is highly affected by the tensile stress. This proposed work has the potential to evaluate the effect of grain and grain boundary on stress measurement.

Keywords: Tensile stress; Grain boundary; Grain; Magneto-optical Kerr effect microscopy (MOKE); Domain Wall Characterization.

Ⅰ. Introduction

Since stress concentration is the main cause of fatigue failure and damage, a wide range of Non-Destructive Testing and Evaluation (NDT&E) methods have been employed for stress measurement [1-3]. As nondestructive measurements for the inspection of macrostructures of ferromagnetic materials, the ultrasonic pulse velocity method, eddy current, magnetic particle testing are used for the measurement of the stress and defect state in a material [4-7]. The magnetic Barkhausen noise (MBN) is one of NDT technique for residual stresses evaluations based on the dynamic magnetization processes [8-10]. The influence of mechanical stress on the magnetic properties of ferromagnetic materials and the correlation between mechanical stress and hysteresis loop has been widely studied by many researchers [11-12]. Metal magnetic memory (MMM) is a recently developed technique with special ability for stress detection and stress history [13-14]. Studies showed that the modified J-A model describes the variation in MMM field in the process of fatigue [15-16]. Recently, magnetic domain structure and domain wall motion are used to observe the magnetic microstructures under different stress based on the high spatial resolution measurement of stress in ferromagnetic materials [17-22]. The magnetic domain changes of grain oriented electrical steel domain wall (DW) motion velocity feature under stress by using magneto-optical Kerr microscopy was investigated [17-19]. Another study showed domain wall interactions with cementite precipitate along with macro magnetic responses [23]. However, the domain walls dynamics at different locations of grains and their relationships with different (applied) stresses, which could be applied for magnetic NDT&E via MBN and MMM, are not attempted.

The challenging task of stress measurement is the properties characterization of the microscopic magnetic. Grain boundary character and grain boundary connectivity play a key role in controlling grain boundary related bulk properties [24]. Grain boundary is also important microstructural element that can affect the motion of the domain walls in polycrystalline materials. The interaction between the grain boundary microstructure and magnetic domain walls is investigated in previous studies [25-26]. These works found the relationship between the grain-size and the MBN power, and investigated the effect of the grain boundary misorientation on the MBN [27-28]. In addition, it shows the relationship between grain boundary migration and severe plastic deformation in nanomaterials [29]. However, the qualitative analysis of magnetic properties change under low stresses inside the grains and around grains boundaries are difficult to obtain a reliable solution, as well as the effect of grains and grains boundaries on the domain wall distribution under low tensile stress.

This paper investigates characters of the domain wall inside the grain and around grain boundary under low tensile stresses. All the tensile stresses in this paper are in the elastic deformation range. In this paper, magnetic domain images can be captured by using magneto-optical Kerr effect microscopy. The intensity of the magnetic domain images is used to characterize the magnetization intensity. The magneto-elastic energy is present to analyze magnetic property variation [30-32] with a review of domain wall modelling. The relationship among the magnetic domain, magneto-elastic energy, the magnetization inside grains and around grains boundaries under