SYNOPSIS

The rapid development of various scanning probe methods like SFM or AFM involving microcantilever based sensor technology has slowly enabled mechanical motion to regain its place in the field of science and engineering by miniaturization of mechanical systems down to sub-micron dimensions. Such scaling down of dimensions of microstructures exhibit very high sensitivity to mechanical deformations due to various induced loads. The most widely used Optical beam deflection method (OBDM) for measuring such deflections in microcantilever based sensors is limited by diffraction effects due to dimensional constraints of the structures involved.

A new optical diffraction based profiling technique has been proposed to measure deflection profiles in microcantilever (MC) based sensor probes by the analysis of the diffraction pattern obtained by transilluminating the microstructure by a planar or spherical propagating wavefront. The proposed method employs a double MC structure where one of the cantilevers acts as the active sensor beam while the other acts as a reference beam. The active beam can respond to any molecular recognition induced surface stress changes resulting in bending relative to the fixed passive beam. On account of transillumination, the microstructure profile across the thickness dimension will act as a double slit aperture mask or a two element grating obstacle. The diffracted wavefront thus has the signature of 2D profile of the double microcantilever structure across the incident transilluminated plane of the 3D structure. According to theoretical formulations and simulations, measurement of intensity minima shifts (in the obtained diffraction pattern) of the order of *~0.01mm*, can achieve deformation measurement resolutions of the order of *1nm* in typical microstructure based cantilever probes. Also, it clearly suggests that the proposed optical diffraction based method would have a definite advantage (compared to existing optical and electrical methods) on deflection measurement sensitivity for highly scaled down structures as it would lead to spatial broadening (or in other words, a diffraction induced magnification) in the image space.

The present work also explores the possibility of using polymer materials like Poly- HDDA (PHDDA) for microcantilever sensor technology for having the potential to achieve high mechanical deformation sensitivity in even moderately scaled down structures by virtue of its very low Young's modulus. PHDDA based double microcantilever sensor structures of length 600 µm, width 60 µm and thickness 40 µm each with a gap of 100 µm between the two along the thickness dimension, were fabricated by an in house developed Microstereolithographic system The high thermal stability and very low elastic modulus of Poly-HDDA enables its application as a low noise, very high sensitive sensor material for detection of mechanical deforming agents in microcantilever based sensor technology.

To demonstrate the proposed optical diffraction-based profiling technique, a bent microcantilever structure was designed and fabricated by the MSL system where, essentially one of the microcantilevers was fabricated with a bent profile by varying the gap between the two structures at each cured 2D patterned layer. The diffraction pattern obtained on transilluminating the fabricated structure by a spherical wavefront was analyzed and the possibility of obtaining the deflections at each cross section was ascertained. However, an in depth analysis of the error in fabrication process has not been done at the present stage of the work and hence the obtained diffraction signatures have not also been subjected to a reevaluation with respect to the fabricated design data. The resolution of the fabricated bent profile is limited by the resolution of the linear translational stage used in fabrication and is of the order of $\sim 0.1 \mu m$. More though, the experimental results clearly suggests the feasibility of the proposed diffraction based deflection profiling technique in cantilever-based applications where, the 2D image analysis, according to proposition, will give the entire deflection profile of a microcantilever based sensor to an induced load due to molecular recognition events.

The proposed optical diffraction-based profiling technique relies on the detection and measurement of shifts of intensity minima on the image plane formed by the diffraction of a coherent wavefront at the double microcantilever structure. The intensity distribution on the image plane is recorded by a CCD in terms of grayscale distribution within the limits of the imaging system. The range of grayscales recorded by the CCD corresponds to the tonal range or the overall dynamic contrast range of the sensor. However, speckle introduced in coherent imaging degrades the recordable contrast and hence would in turn also reduce the measurable contrast. Larger the effective dynamic contrast range, larger will also be the achieved resolution in minima intensity shift measurement. Analysis of the minimum detectable shift in intensity minima for the employed optical interrogation setup with respect to the minimum detectable contrast and SNR of the optical measurement system was carried out, in order to justify the applicability of the proposed minima intensity shift measurement technique.

In order to obtain high dynamic contrast range images, mixed-integration imaging technique was employed. Detailed analysis of minimum detectable contrast and its effect on the overall dynamic contrast range of the imaging system was done. Two parameters, namely; MDSI (Minimum Detectable Shift in Intensity minima) and MDD (Minimum Detectable Deflection) have been defined and the corresponding theoretical estimates reveal that the employed imaging system can measure minimum deflections of the order of ~2.2nm for our achieved fabricated dimensions at the present stage of the work. For lower dimensioned structures (which had prompted the proposition of the new technique in the first place) the MDD was estimated to be of the order of ~90pm. The employed imaging system making use of the diffraction pattern can achieve minimum deflection measurement resolutions better than the resolution of deflections expected to get from surface stress induced deflections of microcantilever based sensors. Employing a better imaging camera, with manual focus ring and better macro capability lens, MDD can further be reduced to an order of few picometers.