Morphology of Surfaces of PbTe Films Grown by Pulsed Laser Deposition

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Laser is a powerful tool in many applications. It is especially useful in material processing. Often the light beam is intense enough to vaporize the hardest and most heat resistant materials. This paper discusses laser methods for fabricating high-quality lead chalcogenides. Lead chalcogenides, such as PbTe, PbS and PbSe, have attracted considerable attention because of their potential applications in thermoelectric and infrared devices. A proposed method is to use a defocused laser to apply energy at a single nucleation site, and then propagate materials growth by scanning the laser along the substrate. The explanation of epitaxy mechanisms in PLD is a most important and difficult problem.

The most popular parameter characterizing the morphology of surfaces is the RMS roughness, which represents the root mean square height of a surface around its mean value. A more complete description is provided by the power spectral density (PSD) of the surface topography.

In this paper, average roughness, R_a, is used to describe feature heights and power spectral density is used to describe the contribution of surface features of different lateral sizes to the roughness. R_a is defined as the average absolute deviation of each point in the profile from the mean, and the power spectral density is the magnitude of the Fourier transform (FFT) of the surface profile. In order to quantify the surface quality of three samples, we performed roughness calculation, for a large set of the data for same scan areas as well as different scan areas from different position of the films, involving the RMS roughness – σ and R_a. The power spectral density by FFT algorithm was applied in analyzing the AFM image data. The taper window function for the FFT algorithm was used to reduce edge effects and to minimize spectral leakage before calculation of the PSD. PSD dependant on the spatial frequency f yields, $PSD(f) = K * f^{-\gamma}$, where K has spatial length to the power of PSD. The γ is calculated as the inverse slope in the log-log plot of the high spatial frequency and the PSD. In our study, the length scale (L) considered is 3.0 mm. The maximum frequency is limited by the sampling theorem of Nyquist frequency.

The fractal dimension (D_f) of the films was evaluated to characterize the surface morphology. The fractal dimension of the surface can be obtained from the parameter C of the k-correlation, $D_f = \frac{(7-C)}{2}$. The dimension value determines the relative amounts of the surface irregularities at different distance scales. D_f = 3 is called the extreme fractal; D_f = 2.5 the Brownian fractal and f = 2 the marginal fractal.

The roughness values for samples with different scan areas are shown in Table 1. As one can see, all PSD curves essentially present the same characteristic shape, consisting in a at response in the lower part of the spatial frequency spectrum and a power law roll-o with frequency in the upper part of the spectrum.

Considering the topographic scattering in applications, it is obvious that this would not be influenced by improving the substrate finish and scatter reduction could be achieved only by changing the $S(f) = \frac{A}{[1+(B \cdot f)^2]^{\frac{C}{2}}}$, deposition conditions.

where A, B and C are model parameters. A is the value of the spectrum in the low-frequency limit, the "shoulder parameter" is a "correlation length" which sets the point of the transition between the low and high-frequency behavior, and C is the exponent of the power-law fall-of f at high requencies. At low spatial frequencies ($f_1 = B$) the PSD is constant and equals A; at high f values, the surface is fractal, its PSD function scaling as $1/f_C$. The ABC model succeeds in describing quite satisfactory the morphologies for both the substrate and all thin filmsamples over the entire spatial frequency range. The A, B and C parameters of the respective fits are given in Table 1:

Table 1: The roughness values for samples

films/sustrates	A	B	C
PbTe/Si	0,6	245	2,2
PbTe/Si_3N_4	0,2	140	2,2

Several observations could be drawn from the above results:

- In the mid and high frequency regions, the glass substrate behaves as an ideal fractal surface ($C \geq 2$).

The value of A parameter is related to the low frequency component of surface roughness, while the value of B parameter (the correlation length), is linked to grain size.

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