

# An Adaptive Method to Enhance SPM Images on Spatial Domain using MATLAB

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**Abstract:** *Scanning Probe Microscope (SPM) is one of the important tools used to characterize the samples in Materials Science Research by studying the surface morphology and analyzing topography. Surfaces are probed with a probing method by scanning the surfaces with a xyz scanning stage. The probed parameter is mapped as intensity of pixels and displayed as Images and stored as digital images for further process. Digital Image Processing is used to analyse these digital images. For a better understanding the images must be of good quality. Before processing the images enhancement is important for a better visibility and process. In this paper the image enhancement is taken as a topic of interest and discussed. Further a few images were taken and analysed with the various enhancing techniques described in the experimental part. A comparison of images shows the need and importance of the enhancement process.*

**Keywords:** AFM, Contrast, GUIDE, Histogram, Image Enhancement, Matlab, SPM, STM

## 1. Introduction

With the invention of Scanning Tunneling Microscopy (STM) by Binnig and Rohrer [1], a new branch of Science and Engineering, the Nanoscience and Technology has emerged. Much advancement in the field have occurred in the field with new microscopes like Atomic Force Microscope (AFM) and so on, but in general called as Scanning Probe Microscope (SPM). SPM has become one of the main tool used to study the surface morphology and topography in many research fields and specifically in the Materials Science field. Temperature variable sample environment, field variable environments are a few to describe about the techniques used to characterize the samples. The probed parameter like Tunneling current in STM is mapped as intensity and represented on pixels so as to get an image representing the surface. These digital images are further processed and used to extract information like detecting the edges, boundaries, feature detection and many more. The information can be extracted with better accuracy if the images are good. The as taken images are looked for the goodness and improved the visibility based on certain rules called image enhancement techniques. A few research articles describe and compare the various techniques used and survey the same and presented. Suganya, et al [2] describes about various enhancement techniques and their usage for better structural appearance. Anish and Agya [3] presented a literature review on image enhancement techniques. Kuldeep et al [4] submitted a review on Image enhancement techniques. Seema et al have made a comparative study of Image enhancement techniques. Janani et al [5] made a study on Image Enhancement techniques. A critical review on Various Image Enhancement techniques was presented by Gursharan Singh and Anand [6]. Raman Maini and Himanshu [7] made a comprehensive review of Image Enhancement Techniques. Many text books describe about the theory behind the algorithms and many literatures describes about the application of it. Gonzalez [8] delas with

complete image processing techniques. Russ [9] book on Image processing is a complete handbook on image processing. Mathworks website [10] is also gives many documents related to Image processing toolbox.

## 2. Experimental Details

### 2.1 Image collection

The SPM images used for analysis are taken with Nanomagnetics make Low Temperature Scanning Hall Probe Microscope (LT - SHPM) and Digital Instruments make Nanoscope II AFM. Out of many images collected and analysed for correctness of the algorithm, four images of a single sample at four different temperatures are taken for explaining the results.

### 2.2 MatLab

MatLAB is one for the common software used by Engineers and researchers and has rich tool boxes including Image Processing toolbox, is chosen for this experiment. The GUIDE (Graphical User Interface Development Environment) option of Matlab gives an easy and interactive way for the user to make use of the package.

### 2.3 Image enhancement of SPM images

Scanning Probe Microscopes are used to probe the surface of specimen to see the morphology and to analysis the topography. To have a better understanding of the surfaces and accurate analysis the visibility of the images taken must be clean from noise, imperfection in the imaging settings and so on. Though the options of setting the imaging parameters during scanning is available, an offline enhancement possibility becomes must to visualize the image in a better way. Enhancement is a process used for better visibility of the features of an image by increasing the

visibility of certain portion and decreasing the visibility of other portion. This can be performed either in spatial domain or in the frequency domain. This paper describes the methods available in the spatial domain with a few examples. As the enhancement deals only with the individual pixel values and doesn't modify anything with the neighbouring pixels it is also called point processing. This is different from the image processing which alters the intensity values of the neighbouring pixel values. Contrast expansion, Contrast Manipulation, Histogram equalization, Local Equalisation, Laplace Sharpening, Unsharp Masking, Derivatives, Edges and Gradients, Textures and Image Maths are the various proven processes used for enhancing an image and depending upon the application any of the above may be implemented.

## 2.4 Histogram of SPM Images

Histogram shows the number of pixels with all the possible brightness level. It gives the idea of the distribution of intensity levels among pixels. If all the intensity levels are covered the quality of the image is considered as good. A GUI based program is written using GUIDE of Matlab to see the histogram of the image to be analysed. This program has an option of loading and viewing the histogram so as to see the quality of the image.

## 2.5 Histogram equalization of SPM Images

Equalisation is redistribution of brightness values of pixels either by stretching or using any transfer function so that the distribution of all intensity levels shall be covered with the pixels. This has the better visibility of the image and helps understanding the images better. This is executed using Histeq function of Image Processing toolbox.

## 2.6 Contrast Manipulation

If a specific region has to be brightened by darkening the other region, helps in looking into the region of interest in the images. This is implemented using the following formula. The display is transformed with the original intensity of the pixel with a power known as gamma.

$$\text{Display}/255 = (\text{Original}/255)^\gamma - 1$$

The power gamma determines the non linear expansion of the brightness. If  $\gamma$  is one, the expansion information on SPM images can be read is linear and same as the original image. For  $\gamma$  less than one, the brighter parts are highlighted and height information of SPM images are read clearly. On the other hand if  $\gamma$  is greater than one then the darker part is enhanced so that the depth portion of the images can be studied easily. Imadjust is the Image Processing Toolbox used for this operation.

## 2.7 Complement of SPM Images

If the images are darker and if the lighter parts are of interest, complementing the image gives the clarity to study the image. Imcomplement of the IPT toolbox is used for implementing this.

## 2.8 Mathematical Operations on SPM Images

Any image contains certain amount of noise which needs to be minimized if not eliminated to enhance the actual feature of interest. Mathematical operations like addition and multiplication increases the signal quality and the noise level gets minimized. Image addition adds up the individual pixel to pixel value so as to enhance the individual pixel value and the multiplication of the image is formed with the product of the individual pixels. The subtraction is used for removing the backgrounds so as to see the features alone separately.

## 3. Results and Discussions

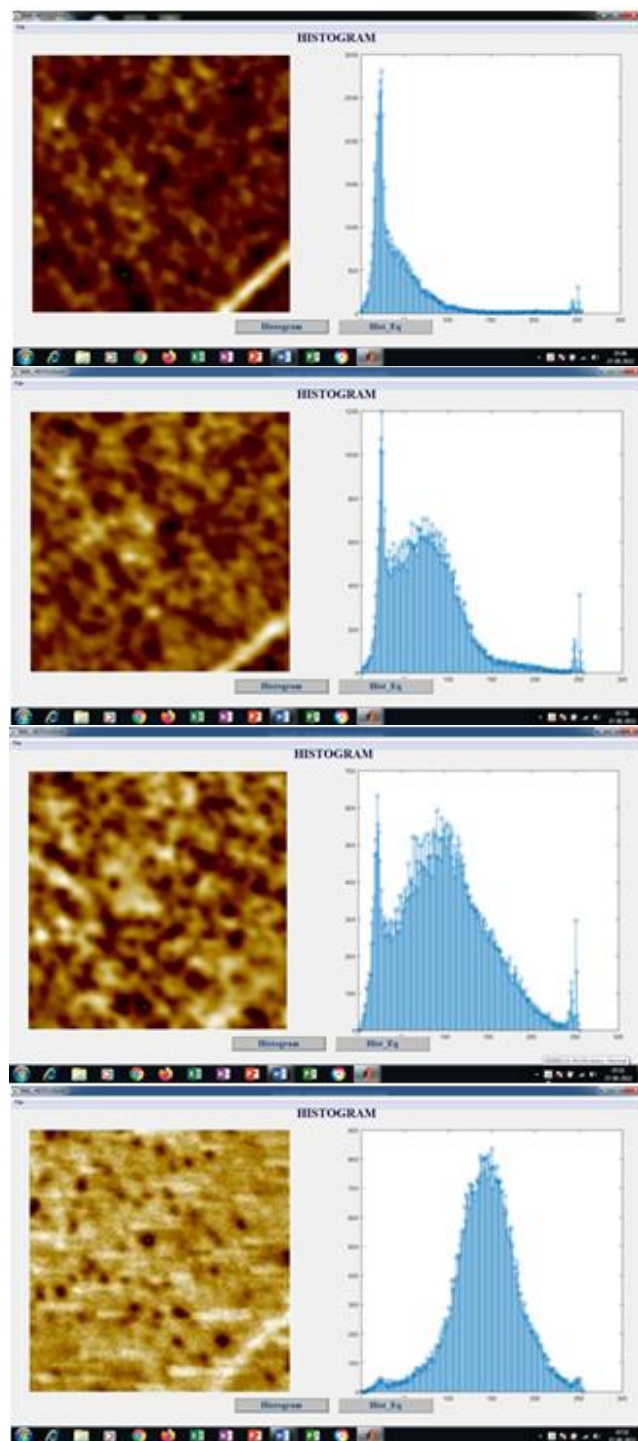


Figure 1: Images as taken at 60°C, 80°C, 100°C and 125°C (top to bottom)



The images used in this paper were taken with the same sample to probe distance but with different sample temperatures. From the top, the temperatures of the samples are 60°C, 80°C, 100°C and 125°C. Though the scanning parameters are same, the quality of the images are different. The quality of the image can be known by plotting the Histogram.

In Fig 1, the top image (60°C) doesn't have the brightness distribution uniform and most of the pixels have the lower brightness level and hence looks dark. This is seen with the histogram plot. The second image (80°C) has the distribution better than the first and looks better in the histogram plot. The third image (100°C) is better in its brightness distribution but the fourth one (125°C) is best among all the four because of its brightness distribution with all the pixels. Images of this kind are having better visibility and hence considered suitable for further analysis. Hence to make the images having better visibility the enhancement has to be carried out. Fig 2 shows the results of Histogram equalization of the as taken images. After performing Histogram equalization, the images have the brightness distribution almost same for all. Now it is easier to understand and distinguish the morphological variations occurring because of the temperature variation on the sample.

Fig 3 shows the output of Mathematical operation of Images. When addition of Image with its own image is chosen the value of the individual pixel value gets added up and the intensity level doubles which makes the image brighter and the features looks better. The noise on the image gets minimized because of the added intensity level. Mostly the height information is highlighted and makes easy to note the morphological changes in the image because of the temperature change of sample.

Similarly, Fig 4. Shows the result of mathematical multiplication of image with itself. This enhances the contrast variation which becomes obvious in knowing the features presence and change in the feature with respect to the morphological changes with respect to the change in the environment.

Fig 5 Shows the complement operation of the images. The complement operation inverts and shows the feable darkest parts hidden in the brightest part. By inverting even, the smallest variation hidden can be seen clearly.

Fig 6. Describes about the result of non linear contrast manipulation with the power ( $\gamma < 1$ ). In this case the lighter parts gets expanded and the darker parts gets compressed, this results in studying the lighter part of the images.

Fig 7. Shows the non linear contrast expansion with the power value ( $\gamma > 1$ ). This does exactly opposite of the above. That is the darker parts are expanded and lighter parts are getting compressed. This results in studying the depth or darker side information. Thus using the various image enhancement techniques the images as taken were processed and compared side by side with the resultant image for comparison and analysis.

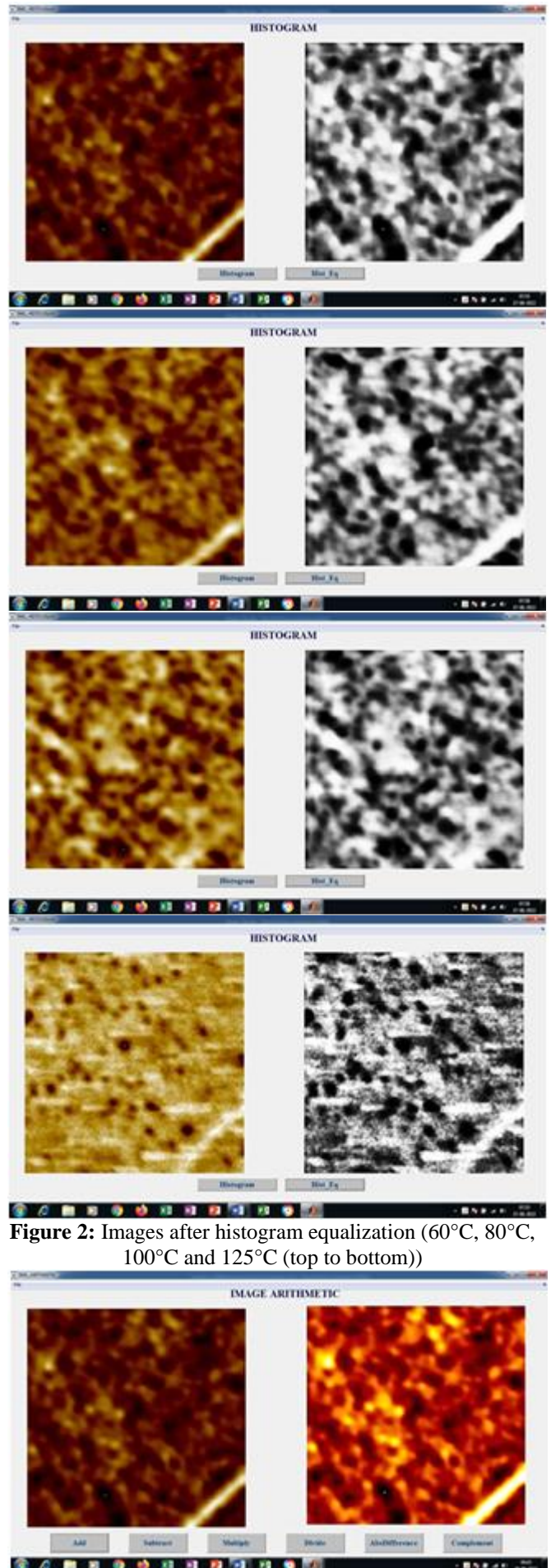


Figure 2: Images after histogram equalization (60°C, 80°C, 100°C and 125°C (top to bottom))





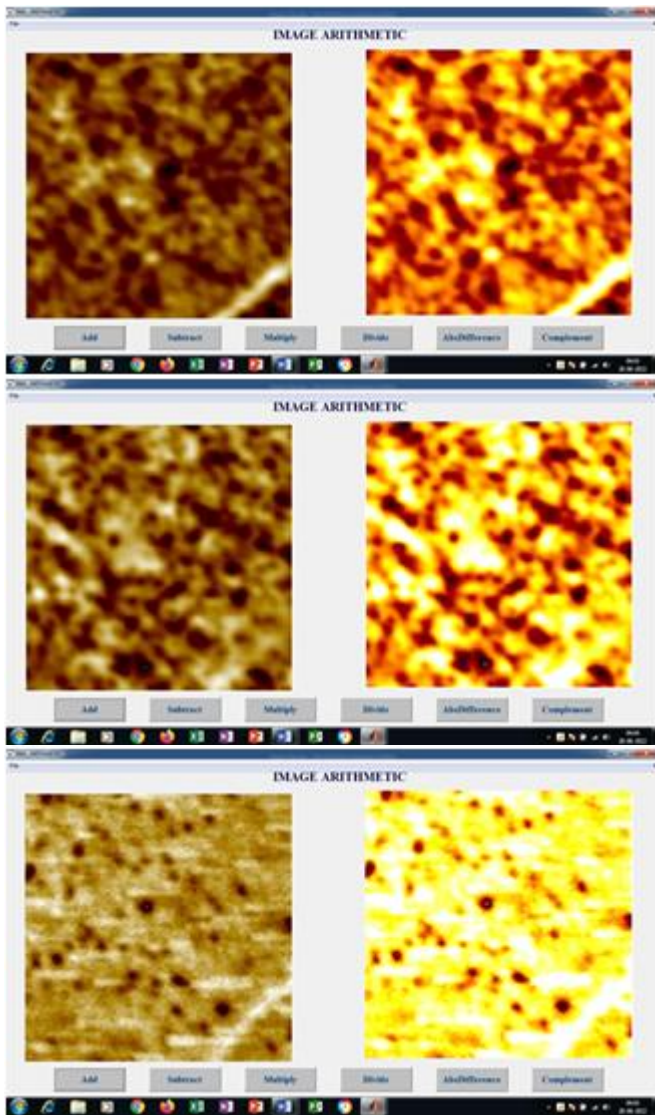


Figure 3: Images with addition operation

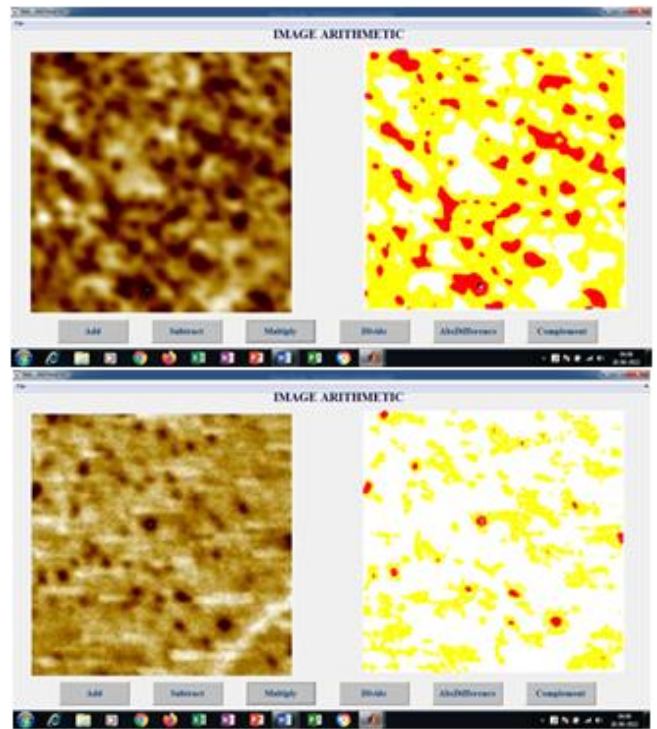
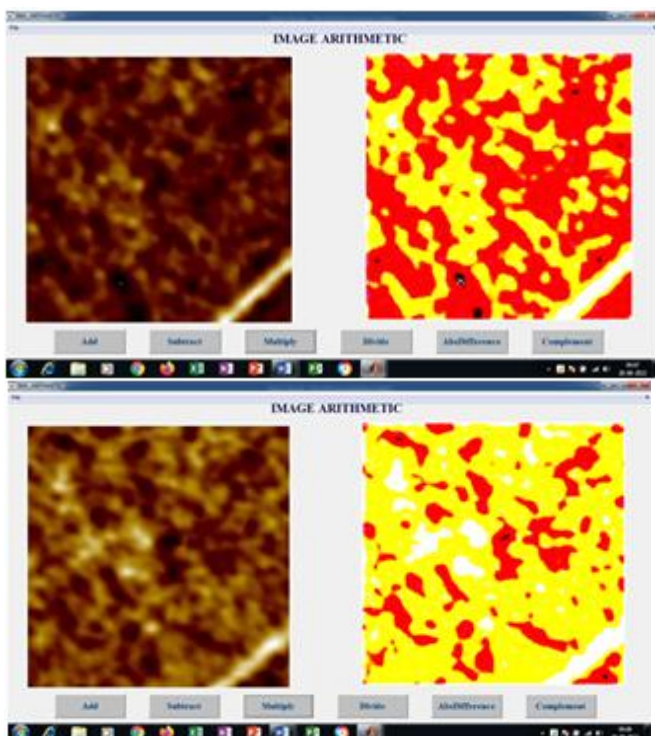
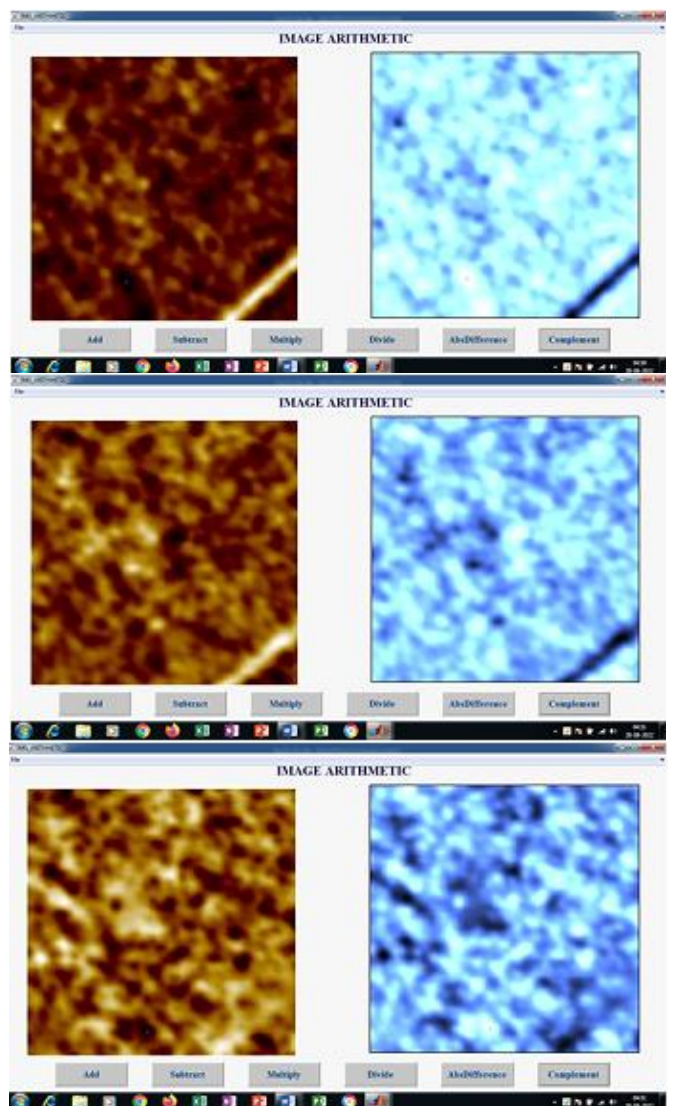


Figure 4: Images with Multiplication operation





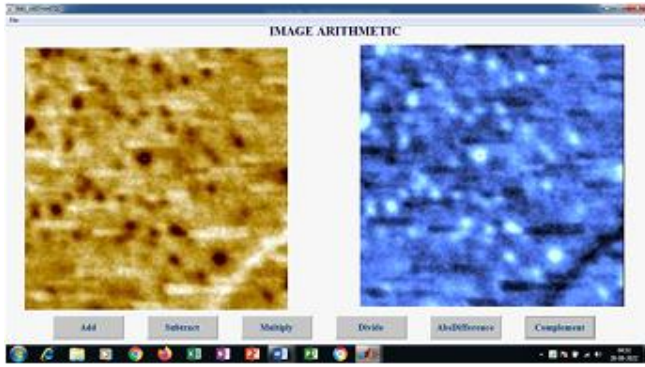


Figure 5: Images with Complement Operation

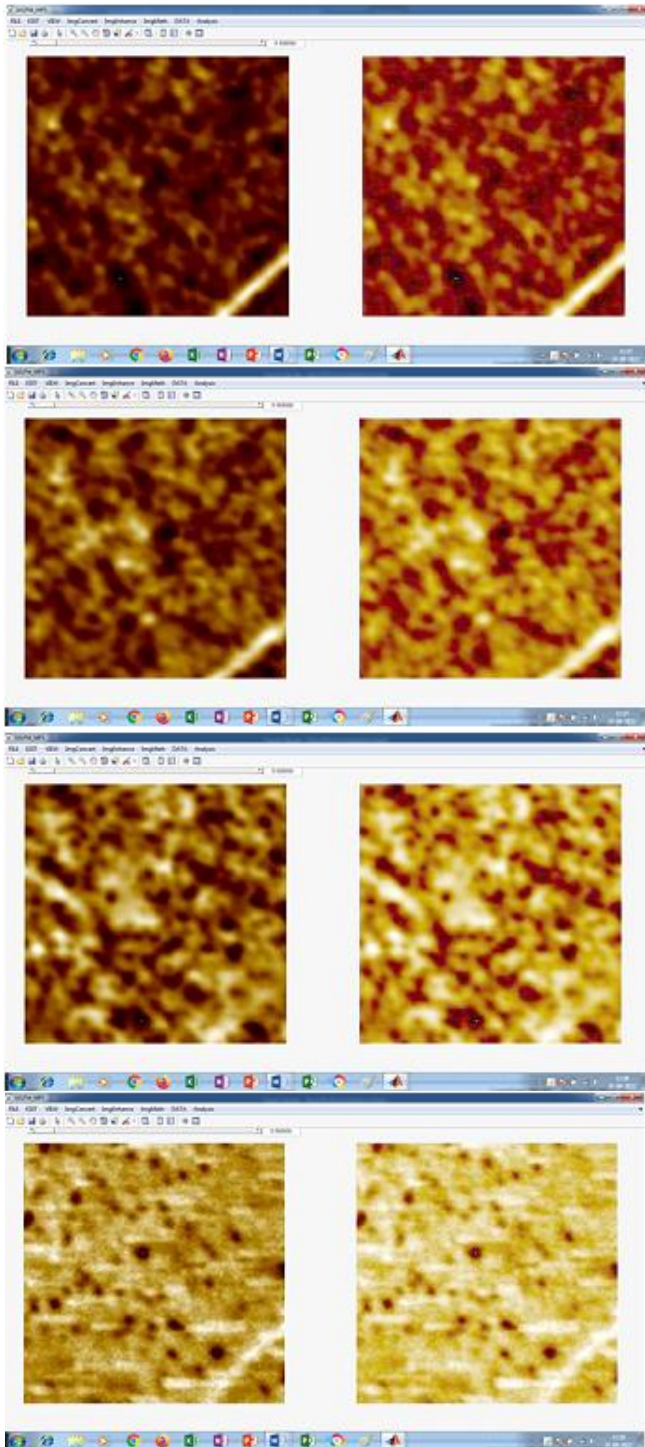


Figure 6: Images with contrast manipulation ( $\gamma < 1$ )

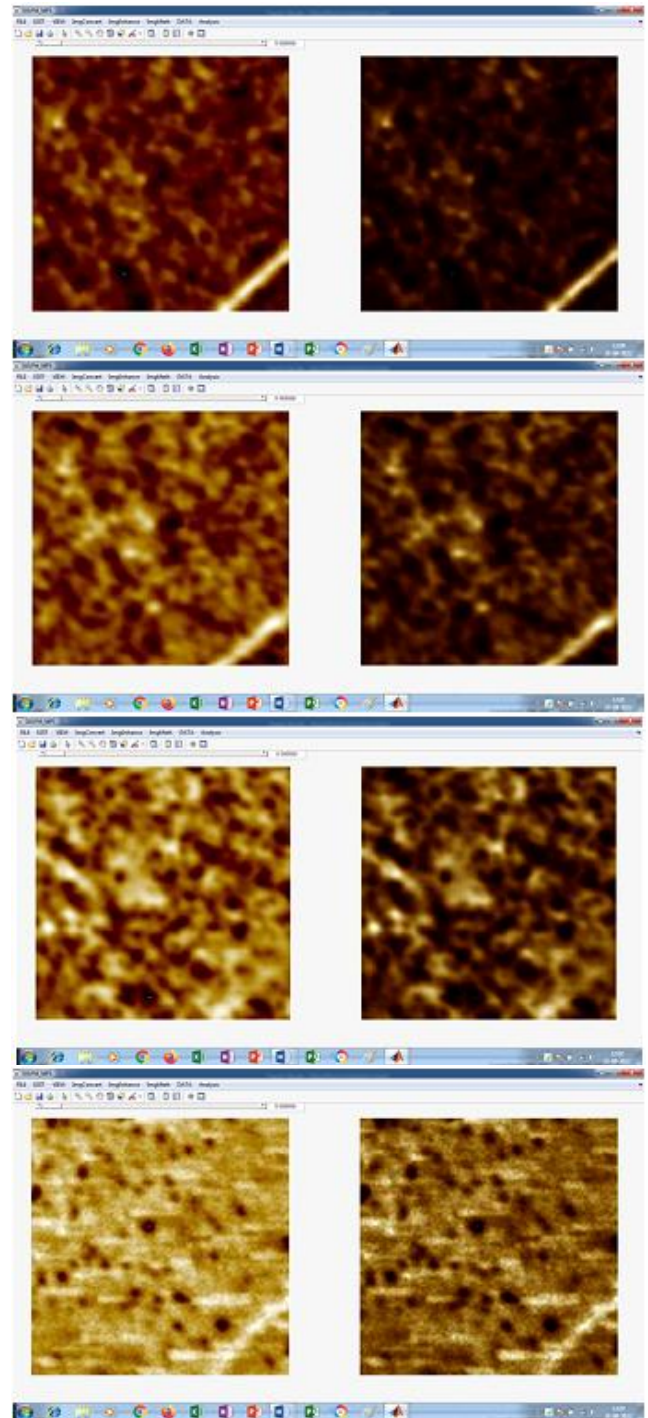


Figure 7: Images with contrast manipulation ( $\gamma > 1$ )

#### 4. Conclusion

SPM images are used for study of surface morphology of samples and analyse their topography which is a more powerful tool in Materials Science. A better visibility of the image is necessary to understand and study the sample. The brightness of the pixels are indications of the surface. Though the samples are probed with same conditions, the image quality differs with respect to the surface structure. Hence manipulation of the intensity becomes necessary for better visibility. A user needs an easy to use software to choose an option among various available manipulation techniques. This paper describes about such a software written as a GUI which can be operated easily by anyone

who may not be even aware of image processing techniques but can make the image suitable for their further analysis process. This GUIDE based software layout shows the original image on the left side and the processed image on the right side for better comparison.

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