In this work we report on the structure characteristics of Cu2S nano-crystals and the fractal features in crystal growth. The Cu2S crystals were produced by using a carbon-coated TEM copper grid added with a few drops of dispersed Graphene loaded with sulfur nano-particles in ethanol. When the solution is dried, a variety of well-constructed tine crystals were observed near the copper bars in microscope, which were mostly dendrites as shown in Figure 1a, similar to the observation by Q Han[1]. The diffraction patterns obtained from different dendrites all showed a 6-fold symmetry, as shown in Fig.1b, which can be indexed with hexagonal Cu2S[2]. No other phases or amorphous copper sulfide, as reported in [1], were observed. Actually the crystallized dendrites exhibit a porous feature since they are composed of numerous nano-crystals in size of few nanometers, as indicated in dark-field scanning TEM images, an example presented in Figure2a. An interesting question is the diffraction pattern from a large area of a dendrite having a number of branches, see in Fig.1a, show a simple [001] pattern that means all nano-crystals are so well oriented that not only along the C-axis, but also the atomic arrangement of those c-planes are aligned in 3o of rotation with respect to each other, see the Fig.1b. That implies hundreds or even thousands of copper sulfide nano-particles bonded together porously could behave as a single crystal, rather than a randomly arranged one.

Of the well-oriented nano-crystals the produced copper-sulfide crystals present interesting self-similarity morphologies, the dendrites like a leaf, a fern, or even a mountain top, some of them We calculated the fractal dimensions using the box-counting method [3] on the nano-crystals and the Matlab codes designed by San Pedro [4]. The fractal dimension of a typical Cu2S-dentride, as shown in Figure 3a is 1.8623, while the ideal value is 2.

[References]
[1] Qiaofeng Han, Shanshan Sun, Jiansheng Li and Xin Wang, Nanotechnology 22 (2011) 155607.

Acknowledgement: [Acknowledgement]
This project is supported by National Basic Research Program of China (2010CB934700) and National Natural Science Foundation of China (Grant No. 21210004).
Fig. 1: (a) Dendrites observed on Cu-bars of thin carbon film coated copper grids; (b) the corresponding electron diffraction pattern from the selected area circled in (a) indicating a [001] oriented Cu2S and the C-plane of different branches are well-aligned within 3° in rotation respectively.

Fig. 2: An enlarged image from a portion of a dendrite obtained in dark field scanning TEM mode (Z-contrast imaging) exhibits a porous structure composed of nano- Cu2S-crystals (bright dots) in size of 5±1 nm and different size of holes (black dots).

Fig. 3: Cu2 Nano-crystal growth produces a variety of fragmented self-similar shapes similar to leafs, ferns, or other plants, a typical example shown in (a). After the fractal dimension analysis, the grayscale image (a) became a binary image (b) with a threshold of 190, estimated from the slope of the test-fit line as show in (c).