MICROSTRUCTURE AND EUTECTIC MORPHOLOGY OF AL–12.5% Si ALLOY REFINED WITH ANTIMONY

Funda KAHRAMAN , Mustafa Kemal KULEKCİ

Mersin University, Faculty of Tarsus Technical Education, 33480 Tarsus / TURKEY

ABSTRACT

Modification of Al-Si cast alloys can be achieved in two different ways, namely by additions of certain elements or with rapid cooling rate. Modifications of the Al-Si alloys are carried out extensively in industry to improve the mechanical properties, particularly ductility. In this study, the effects of antimony additions and growth rate on the microstructure and eutectic morphology on the directionally solidified Al-12.5% Si eutectic alloy has been investigated. The results showed that antimony can be identified as a grain refiner. Over modification occurs in Al-12.5 %Si alloy when modifier is present in the amount of 1 %Sb results in AlSb compound.

Key Woırds: Al-Si alloys, dendrite , flake ,microstructure, modification

ANTİMUAN İLE İNCELTİLMİŞ AL- 12.5 % Si ALAŞIMININ MİKROYAPI VE ÖTEKTİK MORFOLOJİSİ

ÖZET

Al-Si döküm alaşımlarının modifikasyonu, bazı elementlerin ilavesi veya yüksek soğutma hızı ile gerçekleştirilmektedir. Al-Si alaşımlarının modifikasyonu, mekanik özellikleri geliştirmek ve özellikle sünekliği arttırmak için endüstride geniş çapta uygulanmaktadır. Bu çalışmada, yönlendirilerek katılaştırılmış Al-%12.5 Si ötektik alaşımının, mikroyapı ve ötektik morfolojisine, antimuan ilavesinin ve büyüme hızının etkisi araştırılmıştır. Sonuçlar, antimuanın bir tane inceltici olarak kullanılabileceğini göstermiştir. Al-%12.5 Si ötektik alaşımına, %1 oranında antimuan ilave edildiğinde aşırı modifikasyon meydana geldiği ve AlSb bileşiğinin oluştuğu tespit edilmiştir.

Anahtar Kelimeler: Al-Si alaşımları, dendirit, fleyk, mikroyapı, modifikasyon

I. INTRODUCTION

The tribological and mechanical properties of Al-Si alloys have led to extensive use of these alloys in the marine , electrical , automobile and aircraft industries where it is used for cylinder blocks and heads, plain bearings, internal combustion engine pistons and cylinder liners. Al-Si alloys are important for the aluminium casting alloys, mainly because of high fluidty, low shrinkage in casting, high corrosion resistance, good weldability, easy brazing and low coefficient of thermal expansion. The Al-Si alloys are often used in the manufacture of thin walled and complex-shaped parts for which high strength is not requirement [1]. The mechanical properties of Al-Si cast alloys depend not only a chemical composition but, more importantly, on microstructural features such as morphologies of dendritic α-Al, eutectic Si flakes and other intermetallics that present in the microstructure [2,6].Modified Al-Si alloys give better mechanical properties than unmodified alloys [7]. Modification of Al-Si alloys from a flake – like to a fine fibrous silicon structure can be achieved in two different ways, by additions of certain elements (chemical modification) or with a rapid cooling rate (quench modification) [8]. Chemical modification can be made by several elements such as Sr, Na and Sb etc. Sr and Na changes silicon from coarse flake-like to a fine fibrous structure, Sb causes a refinement in the flake-like silicon structure [9-12]. The modification of Al-Si alloys with antimony is a widely used process in industry. In this process the antimony is a permanent constituent of the alloy. Refining effect of the antimony is completed independently from holding time, remelting, degassing with hexachloroethane fluxes which can not be used with sodium or strontium. Degassing with hexachloroethane prevents the porosity formation in the casting. These shortcomings are substantially eliminated when antimony is used. Antimony based alloys are distinguished by their very low susceptibility to gassing and excellent casting properties [1]. Addition of other alkali, alkaline earth, rare earth elements have also been reported to cause modification of Al-Si alloys [8]. In present study, the effects of antimony additions and growth rate on the microstructure and the eutectic morphology on the directionally solidified alloy has been investigated.

II. EXPERIMENTAL PROCEDURE

Al-12.5 % Si alloy was produced from high pure Al (99.999 %) and Si (99.99 %). Pure antimony (99.98 %) was used as modifying agent. It was added to molten Al-12.5 % Si alloy at different amount such as 0.1 %, 0.2 %, 0.5 %, and 1%. The samples which were used in experimental studies were taken from modified and unmodified casting alloys. The solidification conditions for modified and unmodified materials were same; growth rate (R)=2E-3 – 5E-2 cm /s and temperature gradient (G)= 10-50 °C/cm. For microstructure examines the samples were ground, polished and etched according to standard metallographic techniques. The microstructures of the modified and unmodified alloys were studied using optical microscope (OM) and scanning electron microscope (SEM). Microstructural evolution studies were carried out on cast samples, by investigation the morphological change of the Si phase and α-Al phase with modification effect of Sb. The effect of growth rate on microstructure and eutectic morphology was also investigated. Linear intercept method was used to identify the distance between interflakes, and the distance between secondary dendrite arms. The photographs of the microstructure were taken from the centre of the samples, to prevent the variations in microstructure, caused by high cooling rate.

III. RESULTS and DISCUSSION

The microstructure of the unmodified Al-12.5 % Si alloy was a typical mixture of coarse silicon flakes, primary silicon crystals and α-Al dendrites as seen in Figure 1. Non-uniform dispersion of α-Al phase was observed in the microstructure of unmodified alloy. Addition of 0.1 % Sb resulted in increase, in the amount of dendritic α-Al phase as seen in Fiqure 2. The addition of the 0.1 % Sb also makes α-Al phase more columnar and slender.

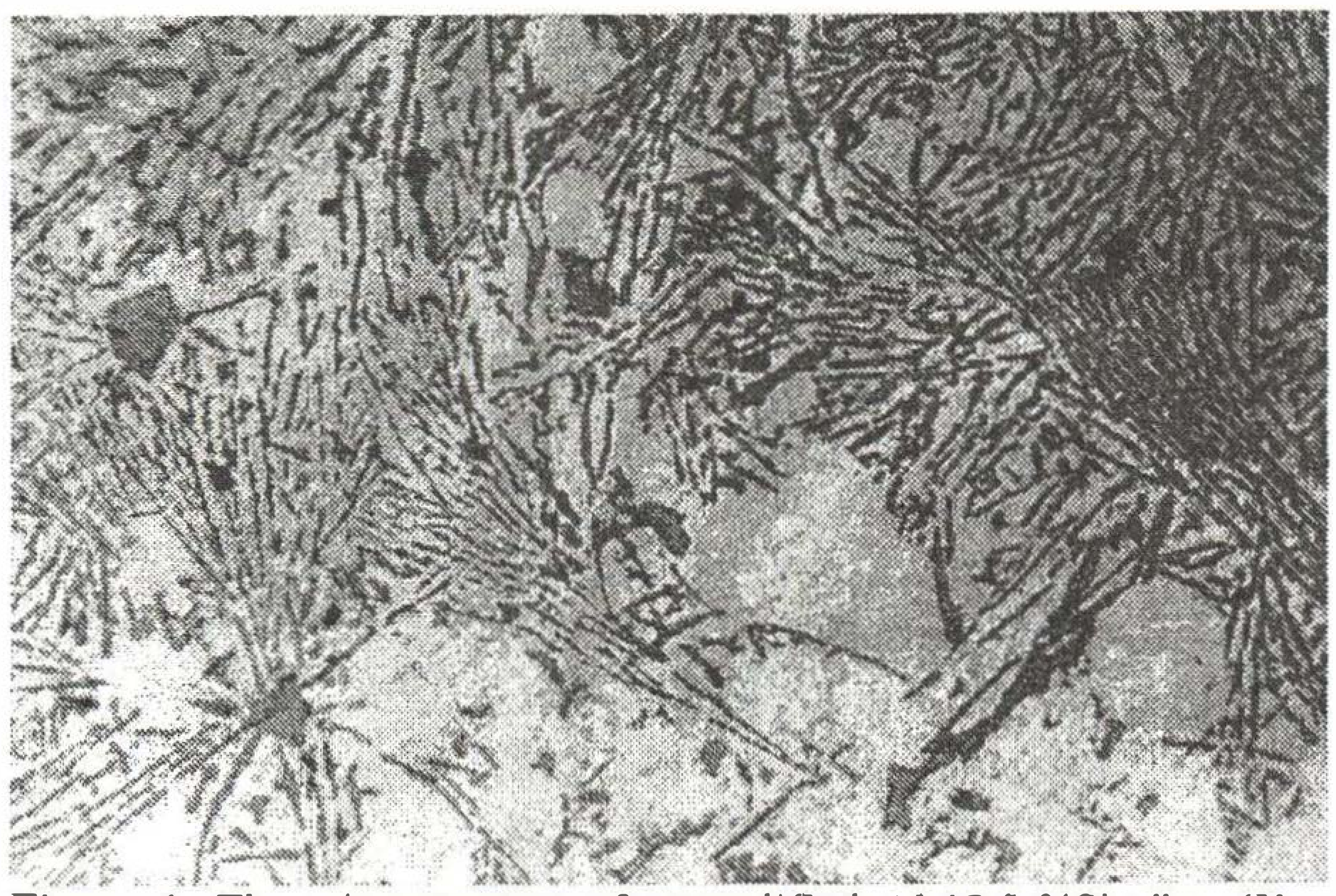


Figure 1. The microstructure of unmodified Al-12.5 %Si alloy (X 100)

The distance between secondary dendrite arms is decreasing with the increase Sb amount in the alloy as seen in Figure 3. Addition of Sb reduces the distance between interflakes. The highest reduction rate in the distance was obtained from 0.1 %Sb addition as seen in Figure 4.The experiments showed that increase in the amount of Sb over 0.1 % does not change the distance much more.

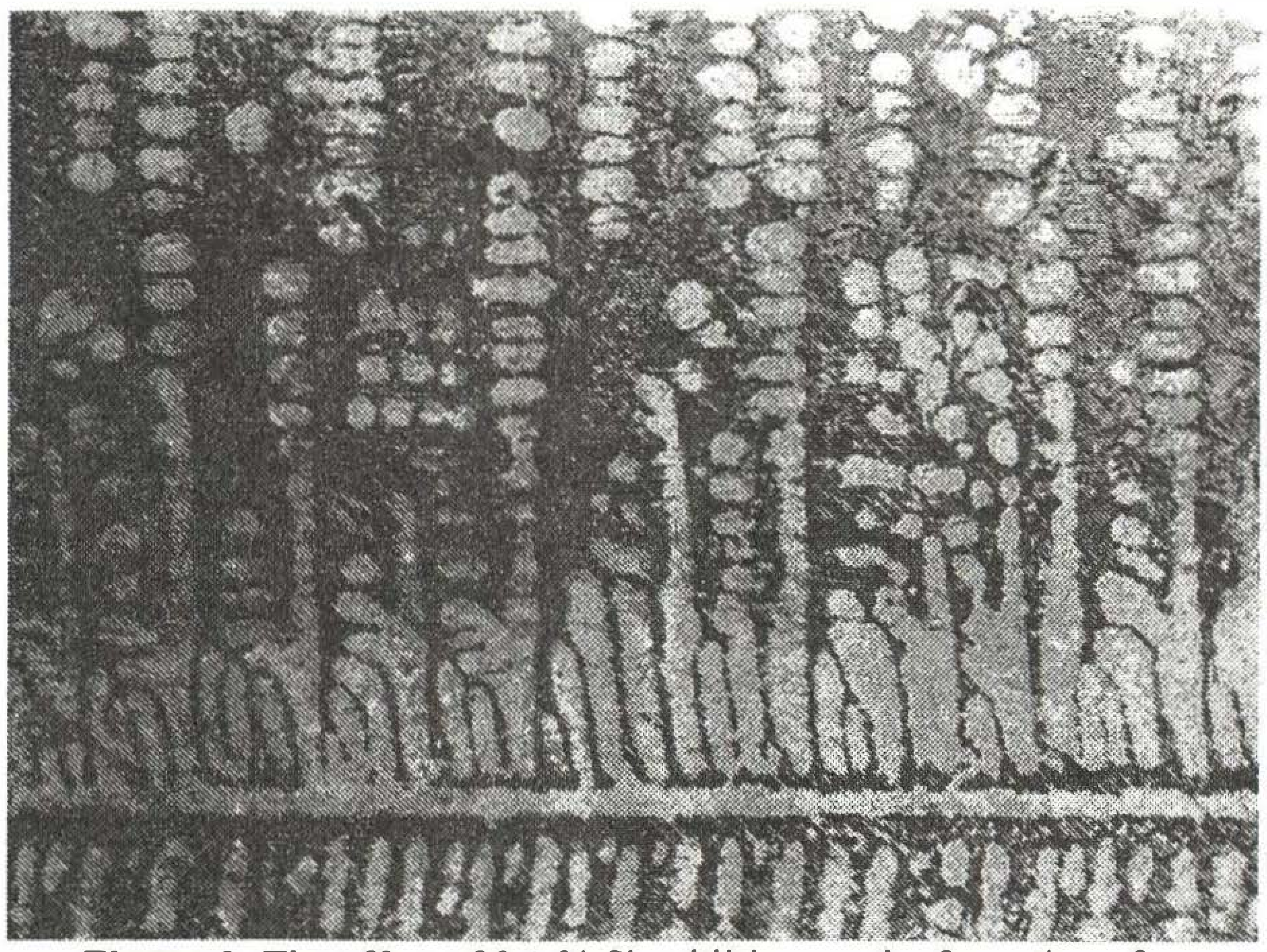


Figure 2. The effect of 0.1 % Sb addition on the formation of dendritic α-Al phase (X 100)

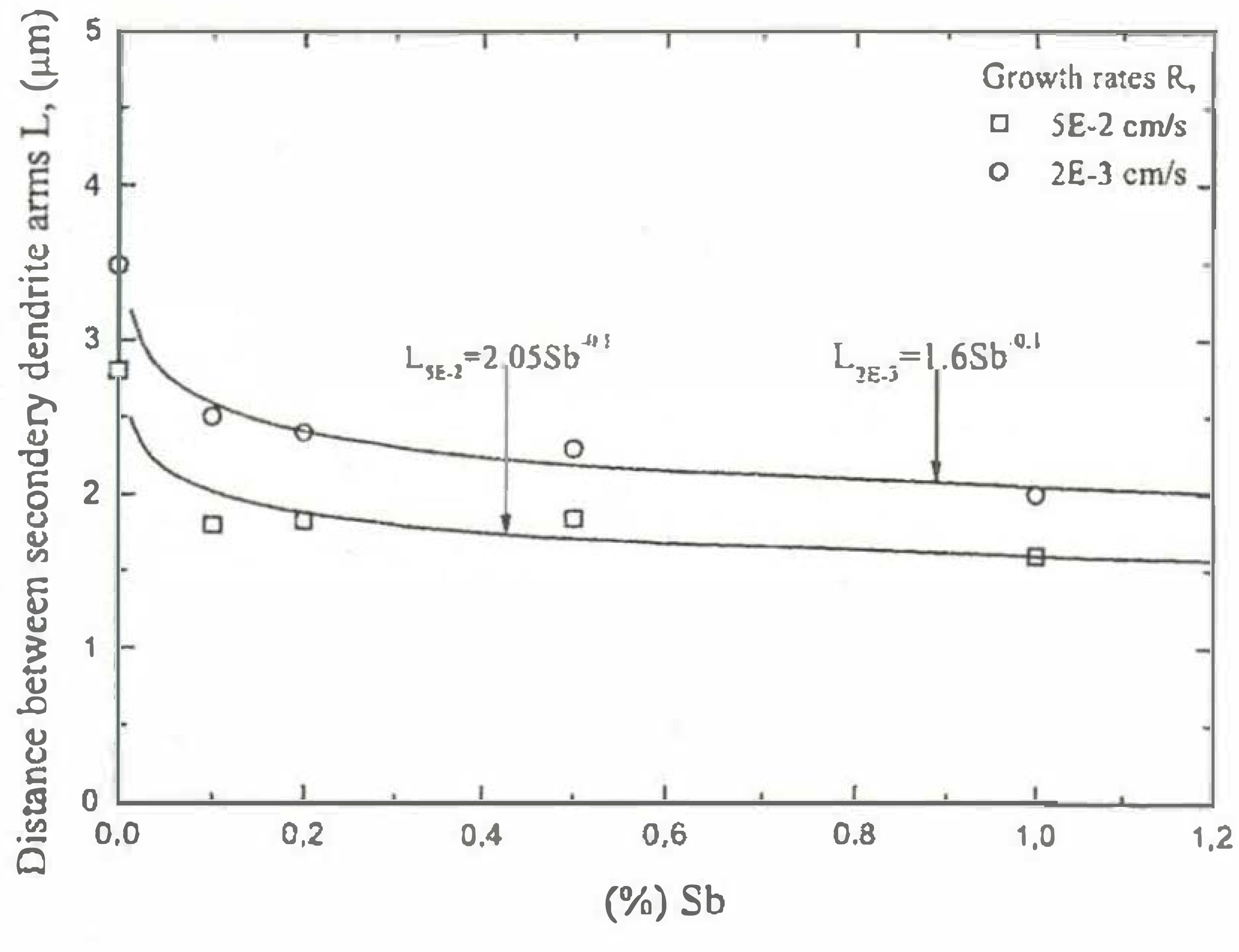


Figure 3. Change in the distance of secondary dendrite arms due to increase in Sb amount in the alloy

Almost same distances were obtained for 0.2 %, 0.5%, 1% Sb addition. When the microstructure of the studied material assessed it is seen that the best modification can be obtained for 0.1 %Sb level. Increase in the Sb over the 0.1 % does not change the eutectic microstructure of the alloy significantly, as seen in the images given in Figure 4. SEM images were taken from the material to asses the effect of Sb addition on the shape of silicon flakes. Sb addition refined the flake like structure containing short, closely, spaced silicon flakes as seen in Figure 5. Sb addition did not result in a flake-fibrous transition in the morphology of the silicon phase. The experimental studies showed that the eutectic morphology can be modified with growth rate. Increase in the growth rate reduced the distance between interflakes and the size of the flakes as seen in Figure 6. The experimental studies showed that there is a relation between λ and R^n. Where λ is the distance between silicon flakes, R growth rate and n grow rate exponent. The effect of growth rate on the distance between interflakes is given in Figure 7.

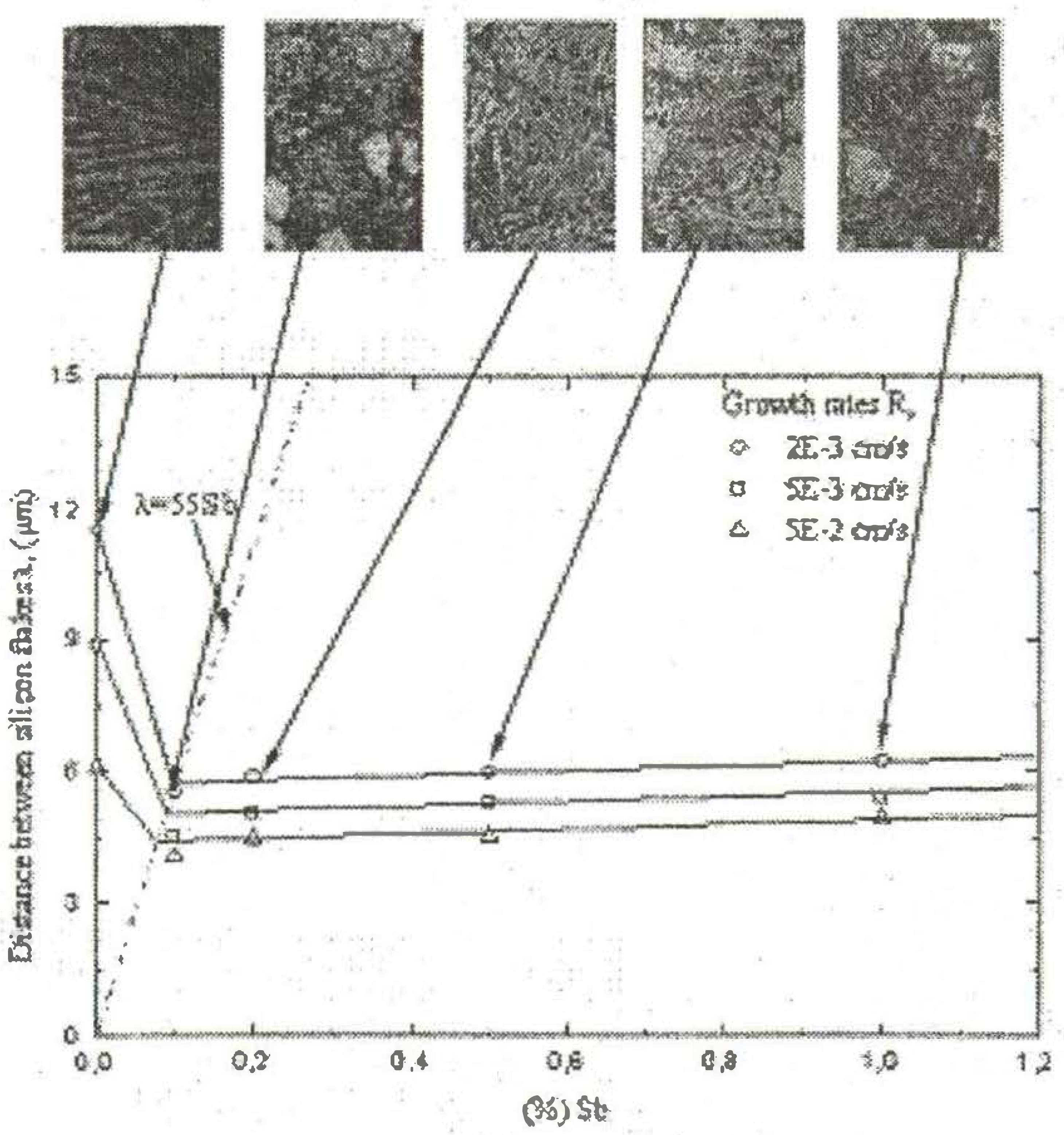
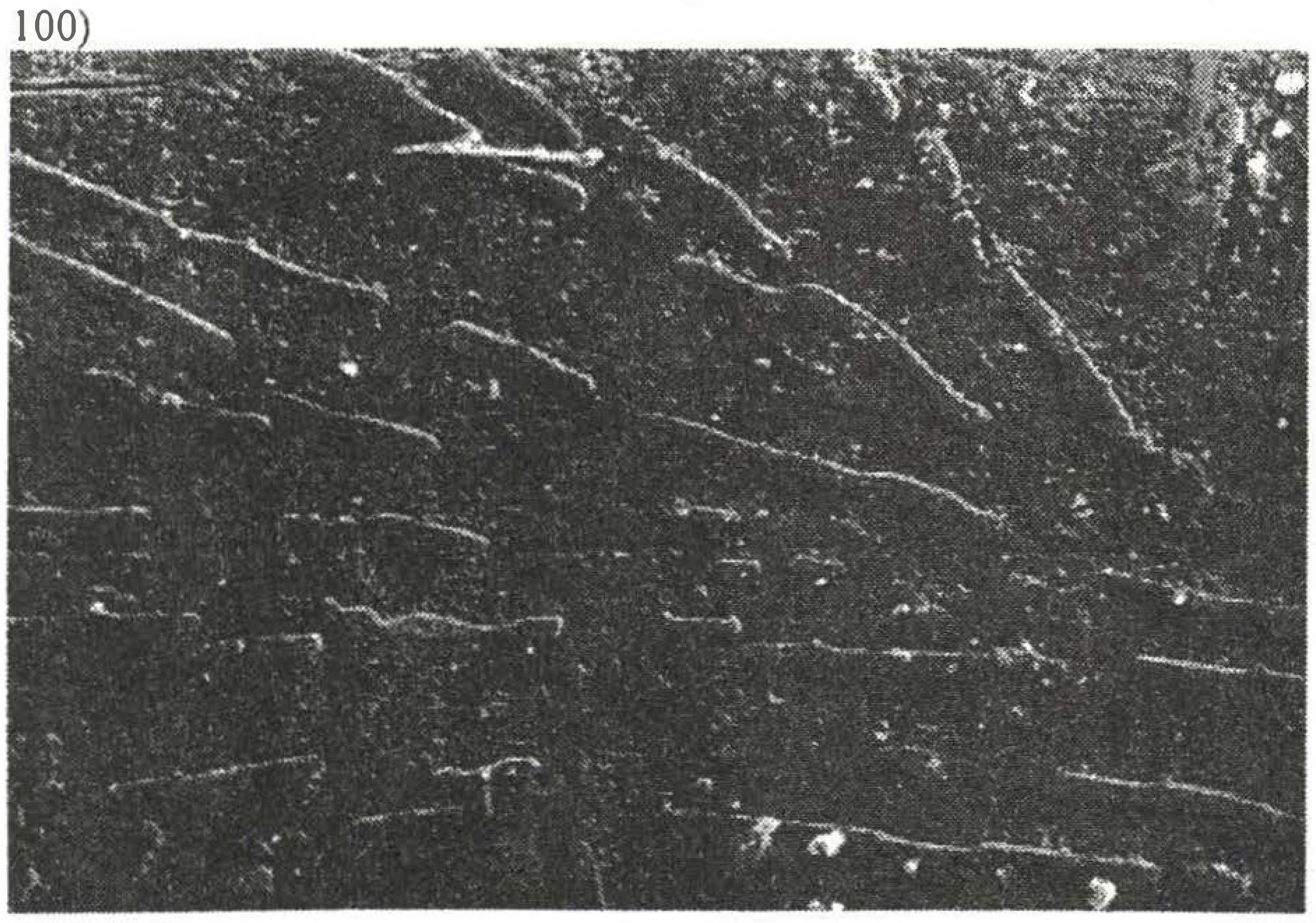


Figure 4. The change in the distance between interflakes and images of eutectic microstructure of the alloys at different Sb amount (X 100)



a

b

Figure 5.The effect of Sb addition on the eutectic morphology (a: 0 % Sb, b: 0.1 % Sb) (X2000)

a

b

Figure 6. Effect of the growth rate on the eutectic morphology.(a:2E-3 cm/s, b:5E-2 cm/s) (X 2500).

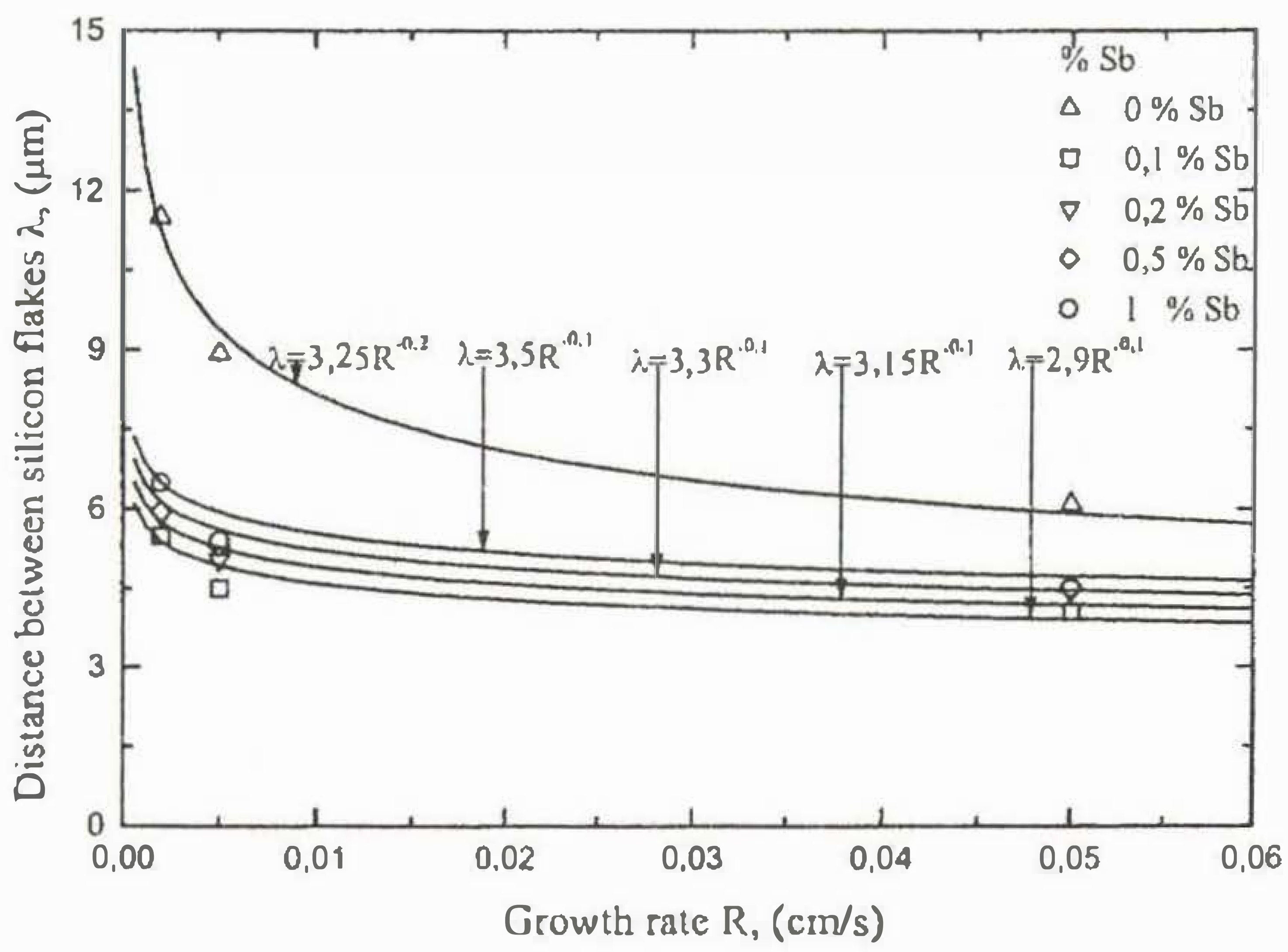


Figure 7.The relation between growth rate and distance between interflakes

Experimental results confirm that AlSb compound is present in Al-12.5 % Si with 1% Sb as seen in SEM image given in Fiqure 8.

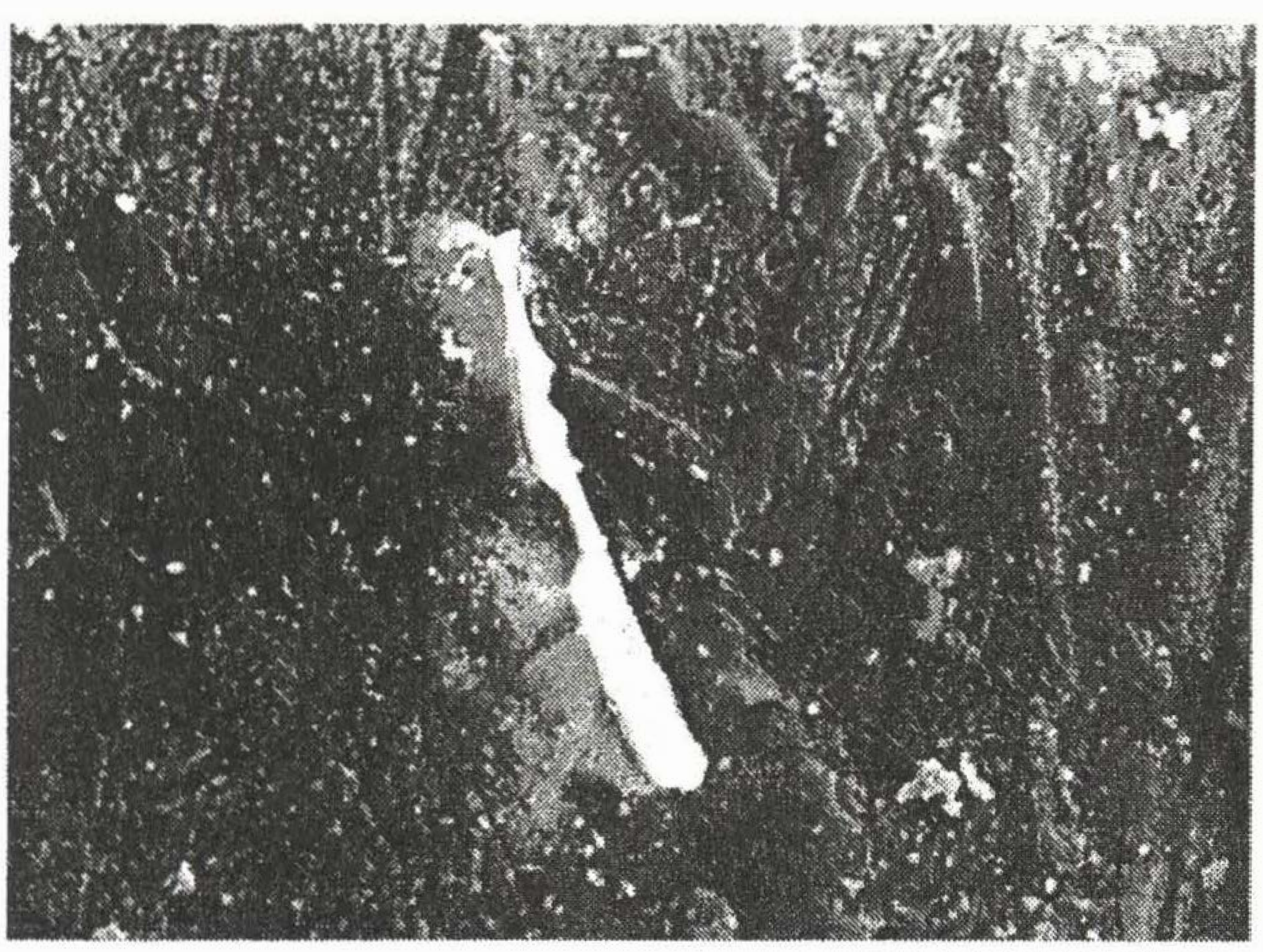


Figure 8. AlSb compound fonnation in Al-12.5% Si with 1%Sb (X3500).

Over modification of Al-12.5 % Si alloy is caused by the formation of the compound AlSb. X-ray spectra a result of studied material is given in Figure 9.

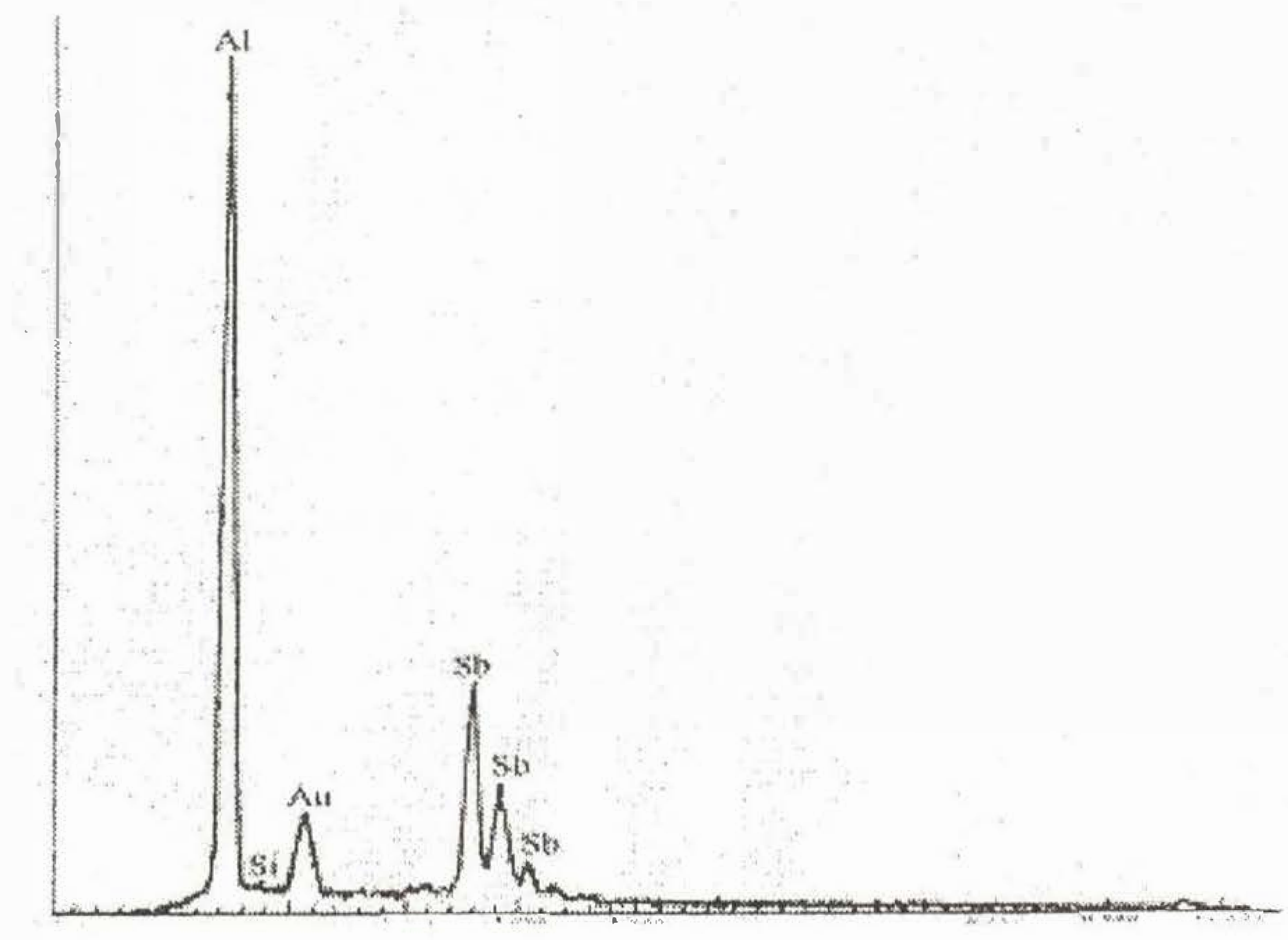


Figure 9.Energy dispensive X-ray spectra recorded from 1 %Sb added Al-12.5% Si alloy.

CONCLUSION

- The microstructure of the unmodified Al-12.5 %Si alloy is a typical microstructure of coarse silicon flakes often radiating from polyhedral primary silicon crystals and α -Al dendrites.
- Al-12.5 %Si alloy can be modified by Sb addition or changing growth rate. Increase in the growth rate effects alloy in similar manner obtained with Sb addition.
- Addition of the Sb refines the eutectic microstructure by reducing distance between interflakes and does not result in a flake –fibrous transition in the morphology of the silicon phase.
- The addition of Sb to Al-12.5 %Si alloy prevents the formation of primary silicon crystals.
- Addition of 0.1 % Sb to Al-12.5 %Si alloy promotes the growth of columnar and slender dendrites and results in a remarkable increase in the amount of dendritic α-Al phase, compared to the unmodified alloy.
- Distance between secondary dendrite arms greatly decreases with addition of 0.1 %Sb. The effect of the Sb addition over 0.1 %Sb is limited on the distance of dendrite arms.
- The best modification was obtained for 0.1%Sb level. Al-12.5%Si alloy with 0.1 %Sb contains short, closely spaced silicon flakes.
- Distance between silicon flakes remarkably decrease with 0.1%Sb additions.taking into consideration the increase in the Sb amount over 0.1%Sb, the decrease in the distance between flakes is limited.
- Over modification occurs in Al-12.5 %Si alloy when modifier is present in the amount of 1% Sb to cause its formation as AlSb compound.
- Increase in the growth rate, reduces the distance between silicon flakes, and the size of the flakes.
- There is a relation between silicon flakes distance and growth rate. Growth rate exponent changes with the amount of Sb addition.

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