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# FRACTAL PROPERTIES OF Pd/InP SCHOTTKY CONTACTS

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# Introduction

- Indium-phosphide (InP) is a key material for both optoelectronics and microwave devices. Ohmic and Schottky contacts are substantial parts of these compound semiconductor devices.
- High power density, high operational speed and reliability are the most important factors determining the materials science issues of the components used in these thin metal based layers.
- Palladium appears to be an important component in contact metallization.
- In the device technology the deposition of multilayer metallization is followed by a heat treatment usually at non-equilibrium conditions. During this process an interaction between the compound semiconductor and the metallization resulting in outevaporation of the volatile component and in the case of ternary compound the  As, P and Sb.
- The surface of the heat treated metallization often shows a fractal character.
- The aim of this study was detailed investigation of the fractal behaviour of the Au, Pd and AuPd metallization on the bulk InP crystals after the heat treatment. These patterns are the results of the interaction of a thin (50 nm) layers with a bulk compound semiconductor materials.

# Experimental

- Thermal interaction of indium phosphide (InP) bulk compound semiconductor with thin gold metal films were investigated in the course of the present work.
- The interaction of InP/Au system resulting in a pattern showing fractal dimensions.
- The temperature dependence of the fractal parameters was investigated in broad temperature range from 200 to 600 °C. No significant temperature dependence of the fractal number was observed.
- The same calculations will be presented for Au/InP and AuPd/InP systems. Our calculations show that the Pd-based contacts have a different behaviour that the AuGe metallization where a strong temperature dependence of the fractal number was observed earlier.
- Another topology measure, the structural entropy is also calculated for the samples. The structural entropy is usually applied for determining the type of the localization of charge distributions, but it can also be used for generalized charges, such as the lightness of the pixels of an electron microscopy picture.

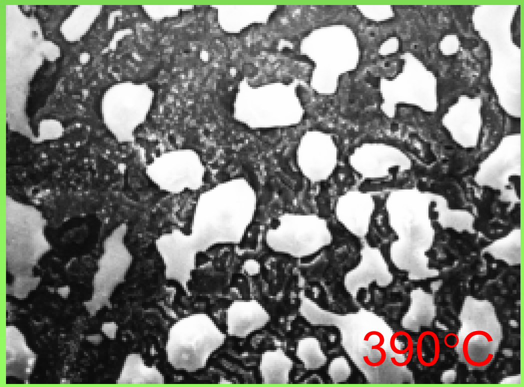
# The heat treatment of the samples

The gold and gold-palladium layers were deposited on n-(100) InP substrates. The wafers were cleaned and degreased in a 1:1 solution of HCl and $H_2O_2$, and immediately before the metallization etched in a 1% Br in methanol solution.

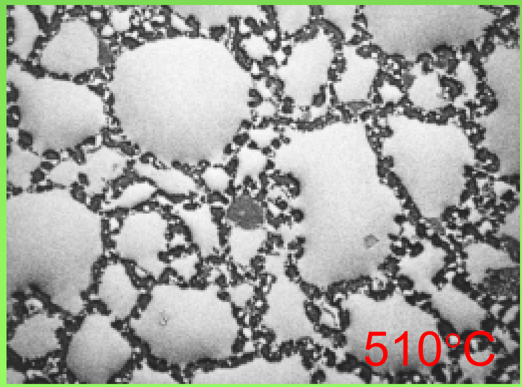
The heat treatment was carried out in the working chamber of a scanning electron microscope(SEM). A linear heat treatment rate of 150 $^{o}$C was applied. During the heating an in situ observation of the outevaporation of the volatile component was observed and SEM pictures was taken at different temperatures.

Substance systems: Au/InP; Pd/InP; AuPd/InP

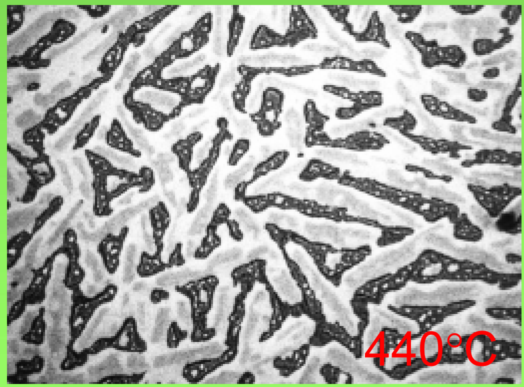
Thickness of Au layer: $v_{Au}$=50nm,




Au/InP




Pd/InP




AuPd/InP

# Fractal dimension

Between the late 1950s and early 1970s Benoit Mandelbrot evolved a new type of mathematics, capable of describing and analysing the structured irregularity of the natural world, and coined a name for the new geometric forms: **fractals**. Fractals are forms with detailed structure on every scale of magnification.

A line is one-dimensional, a plane two-dimensional, a bulk three-dimensional. But in the world of fractals, dimension aquires a broader meaning, and need not be a whole number.

$$\mathbf{N = S^D}$$

$$\mathbf{D = \log N/\log S.}$$

N (the number of miniature pixel in the final figure) is equal to S (the scaling factor) raised to the power D (dimension). In the previous cases it is easy to find the dimension by simply reading the exponent. This simple concept can be generalized to measure non-integral dimensions of many fractals.

**Van-Koch snowflake** (Koch's curve)
**Sierpinsky Triangle**
Menger sponge

# Structural entropy

Entropy, a measure of the degree of disorder in a system, has recently been used in different morphologic studies to quantify regularity.

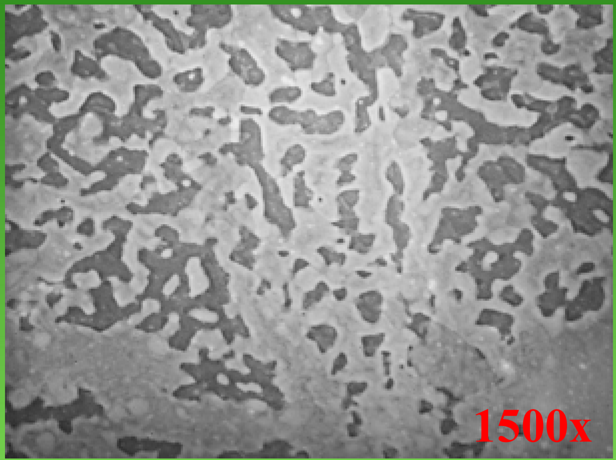
The concept of entropy includes at least 2 points of view--thermodynamic and informatics perspectives.

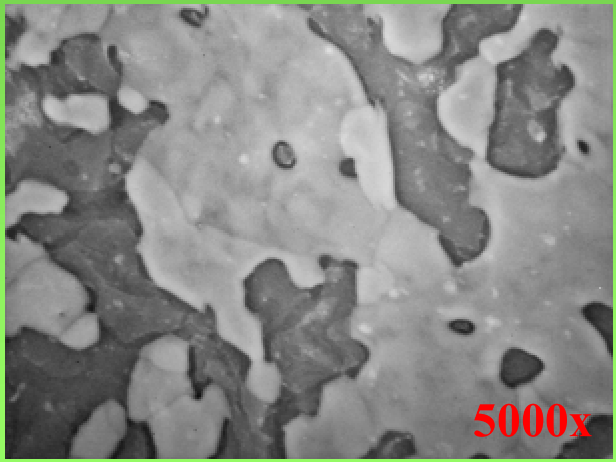
Entropy can be defined by various methods: a measure of nonreversible energy or of system heterogeneity or as information content of a message. It is a statistical measure and system feature composed of macrosystems and microsystems.

The structural entropy of macrosystems relies on definition of individual events and built-in microsystems. It depends on interaction of events and probability distribution (e.g., Gibbs-Boltzmann).

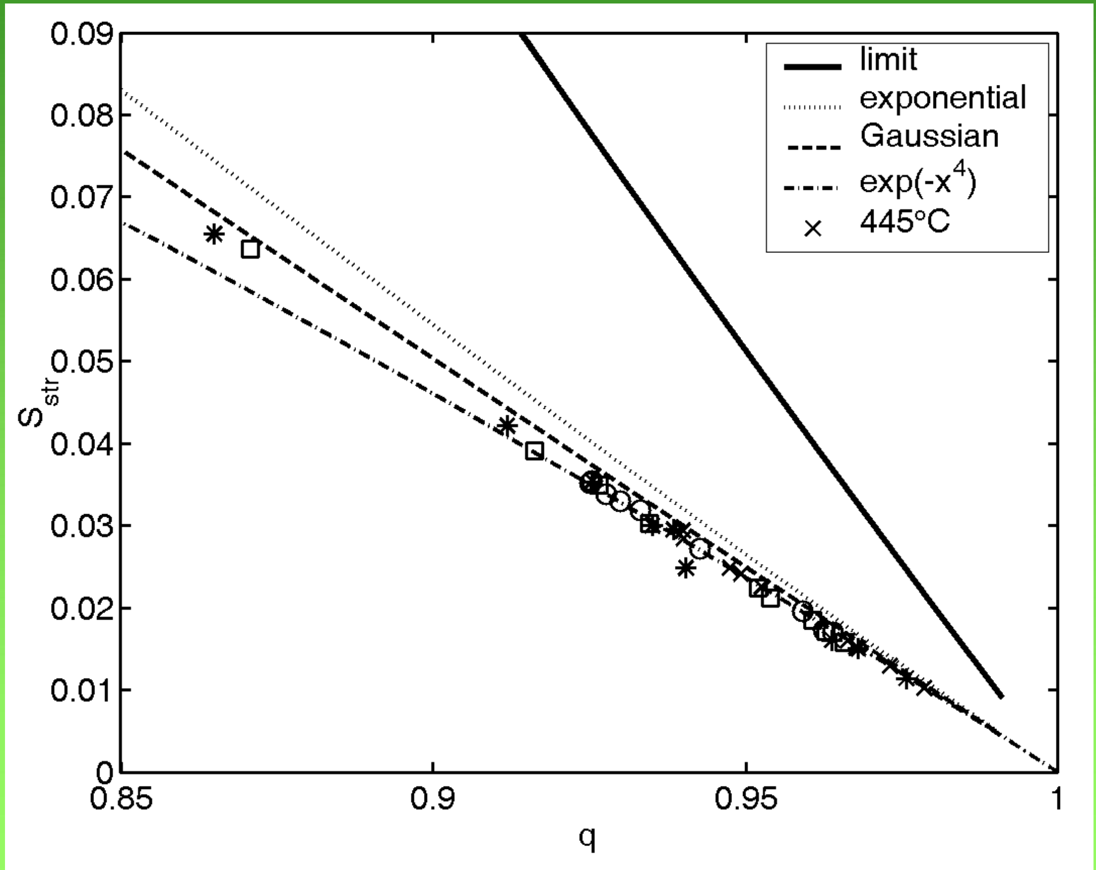
The more generalized q-entropy involves account interaction of neighboring events. The thermodynamic concept of structural entropy can be expanded according to the theorem of Prigogine, introducing entropy flow.

# Au/InP 445°C



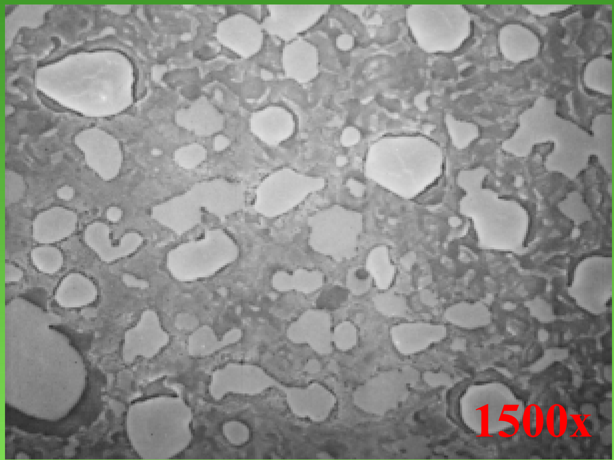



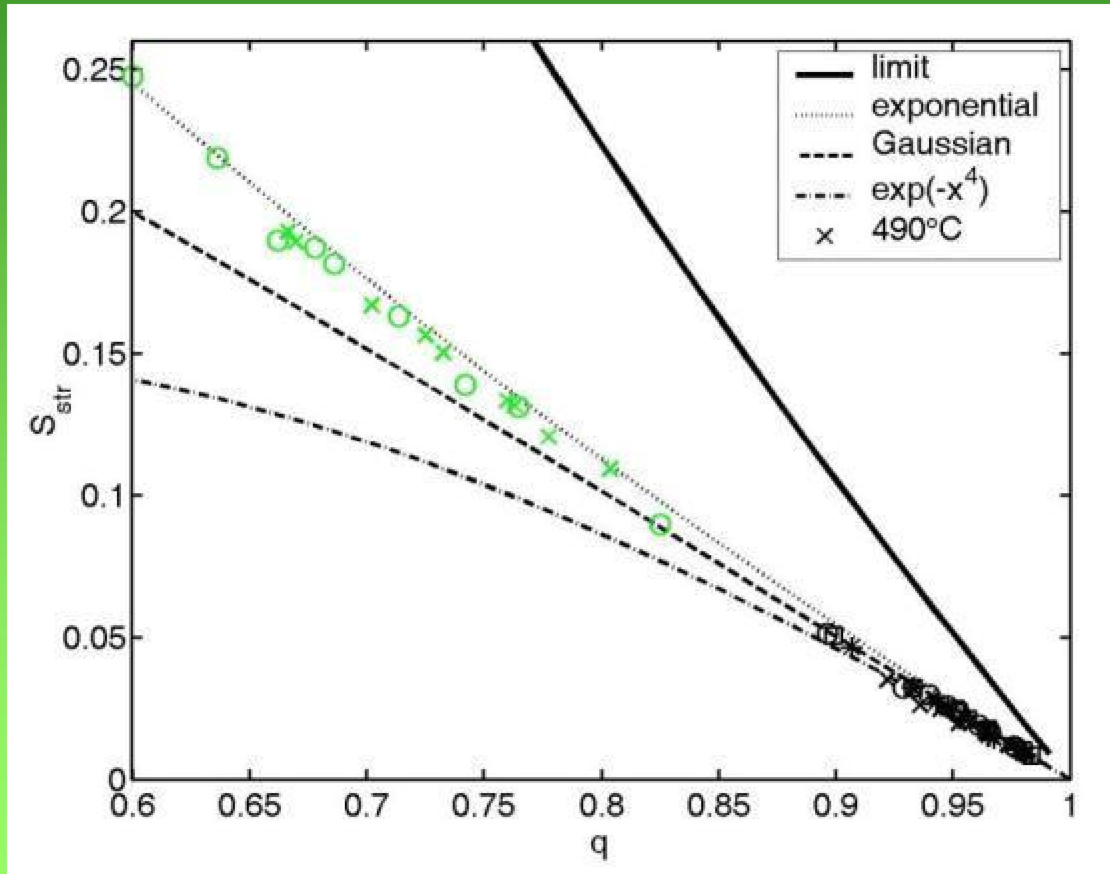

Substance system: Au/InP



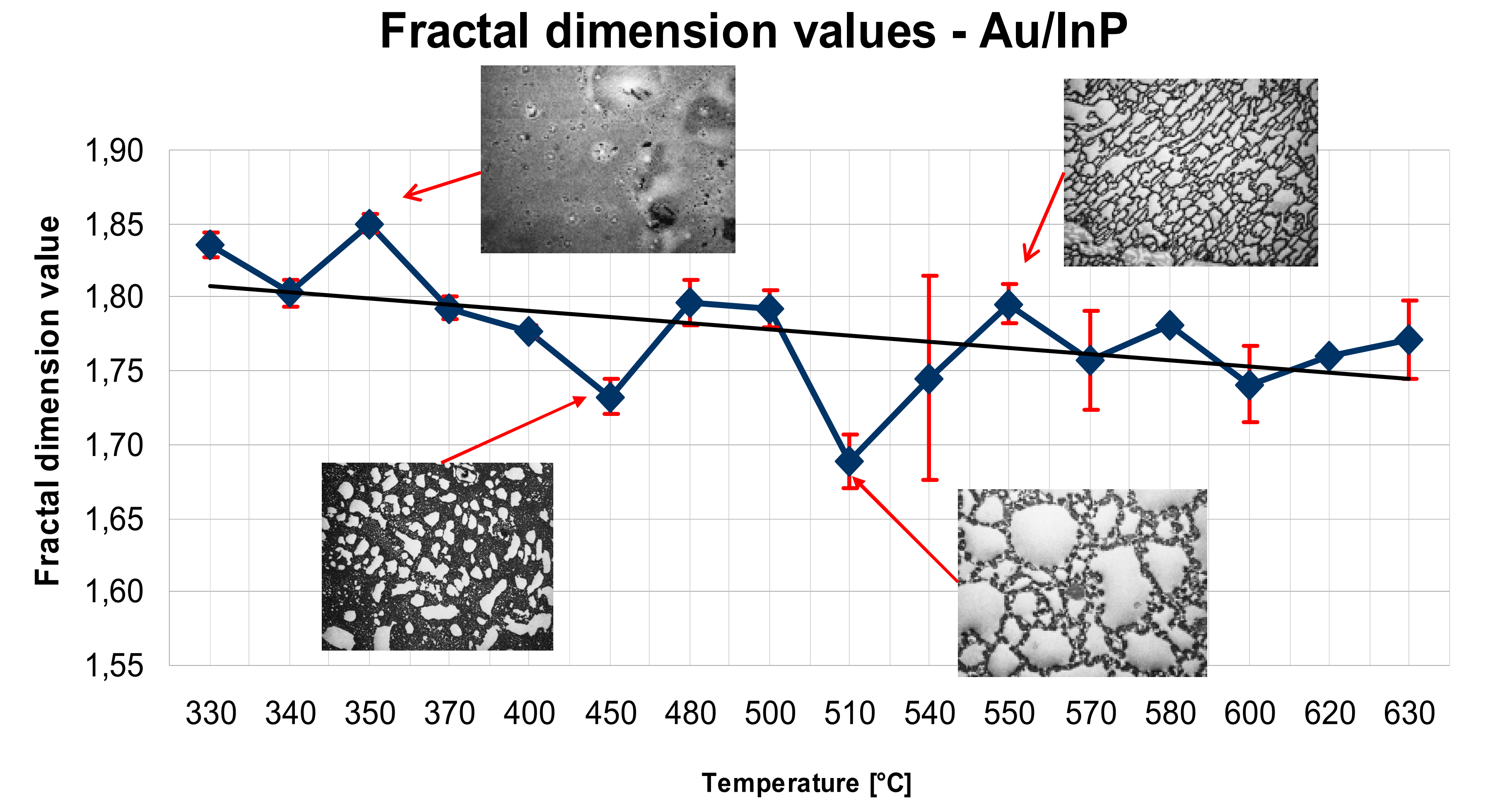
# Au/InP 490°C

Substance system: Au/InP

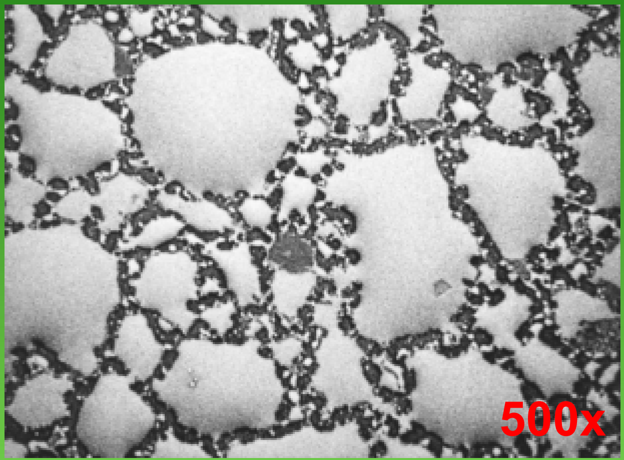


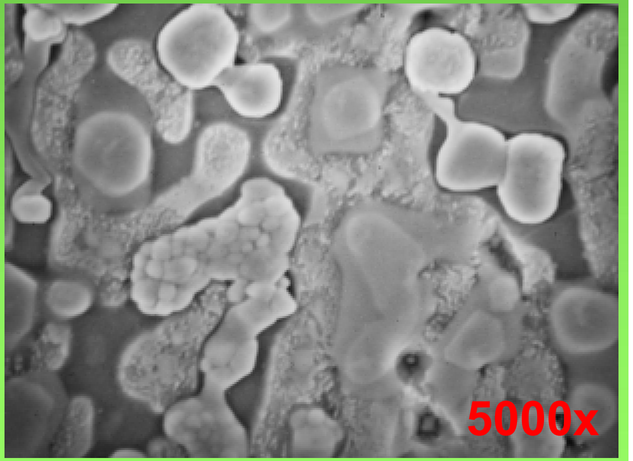



# Fractal dimension values Au/InP

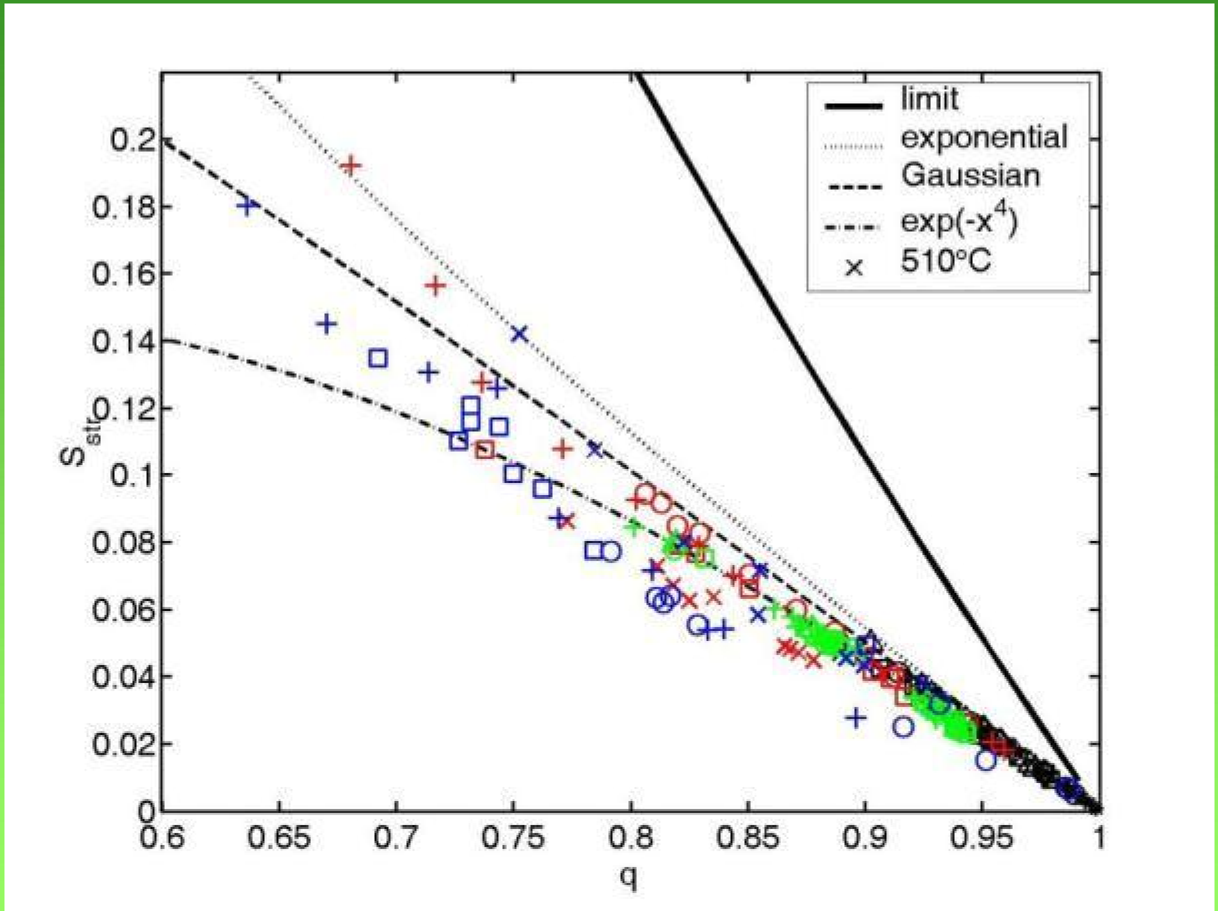


# Pd/InP 510°C

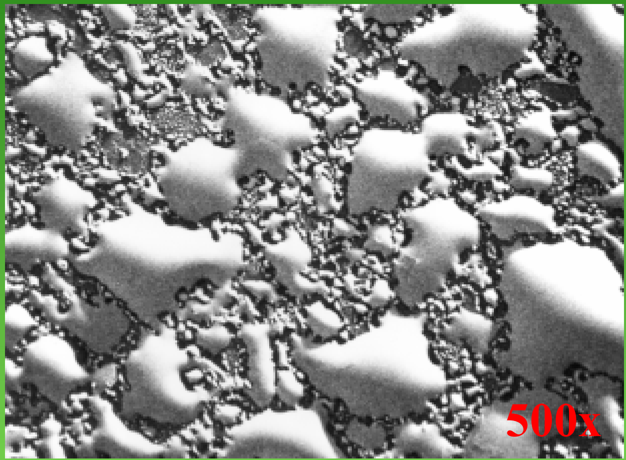


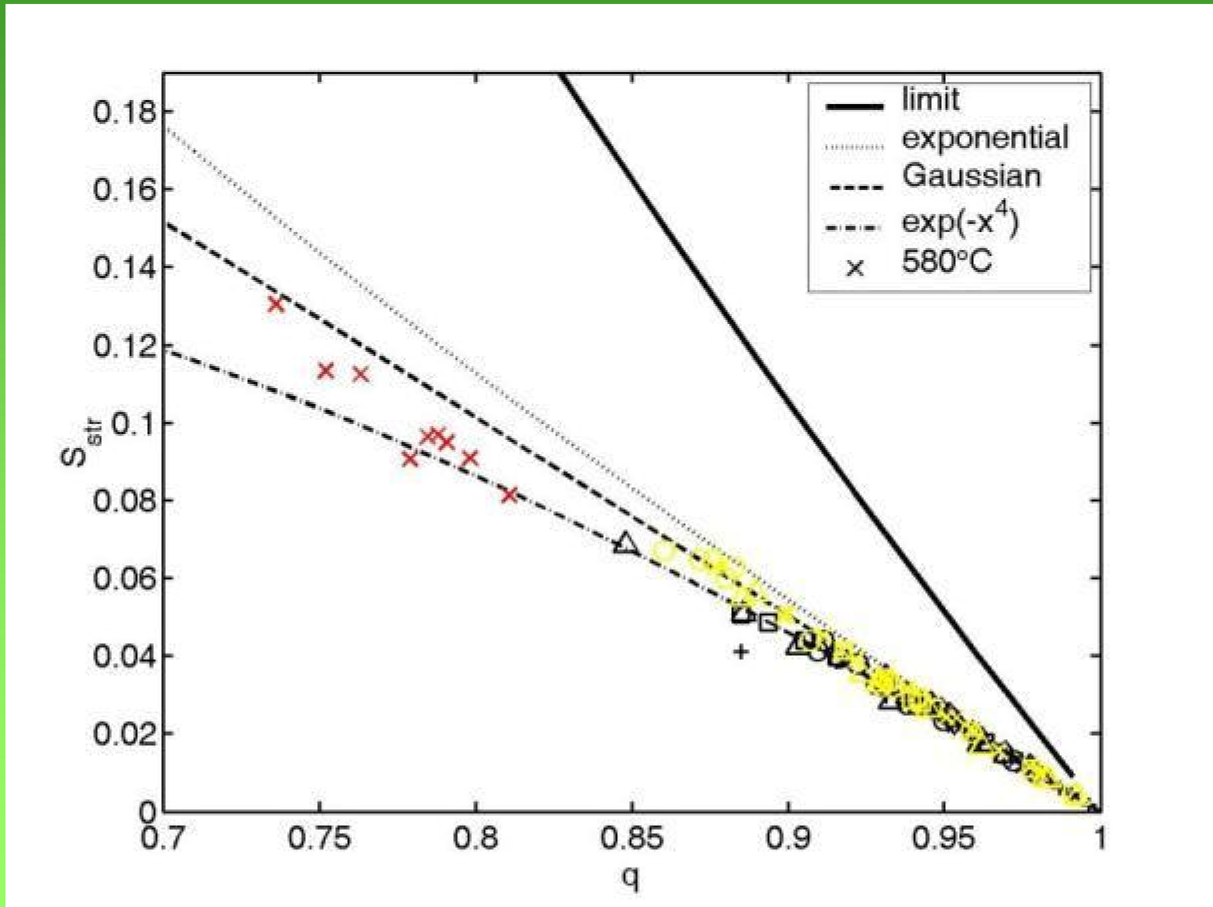

Substance system: Pd/InP



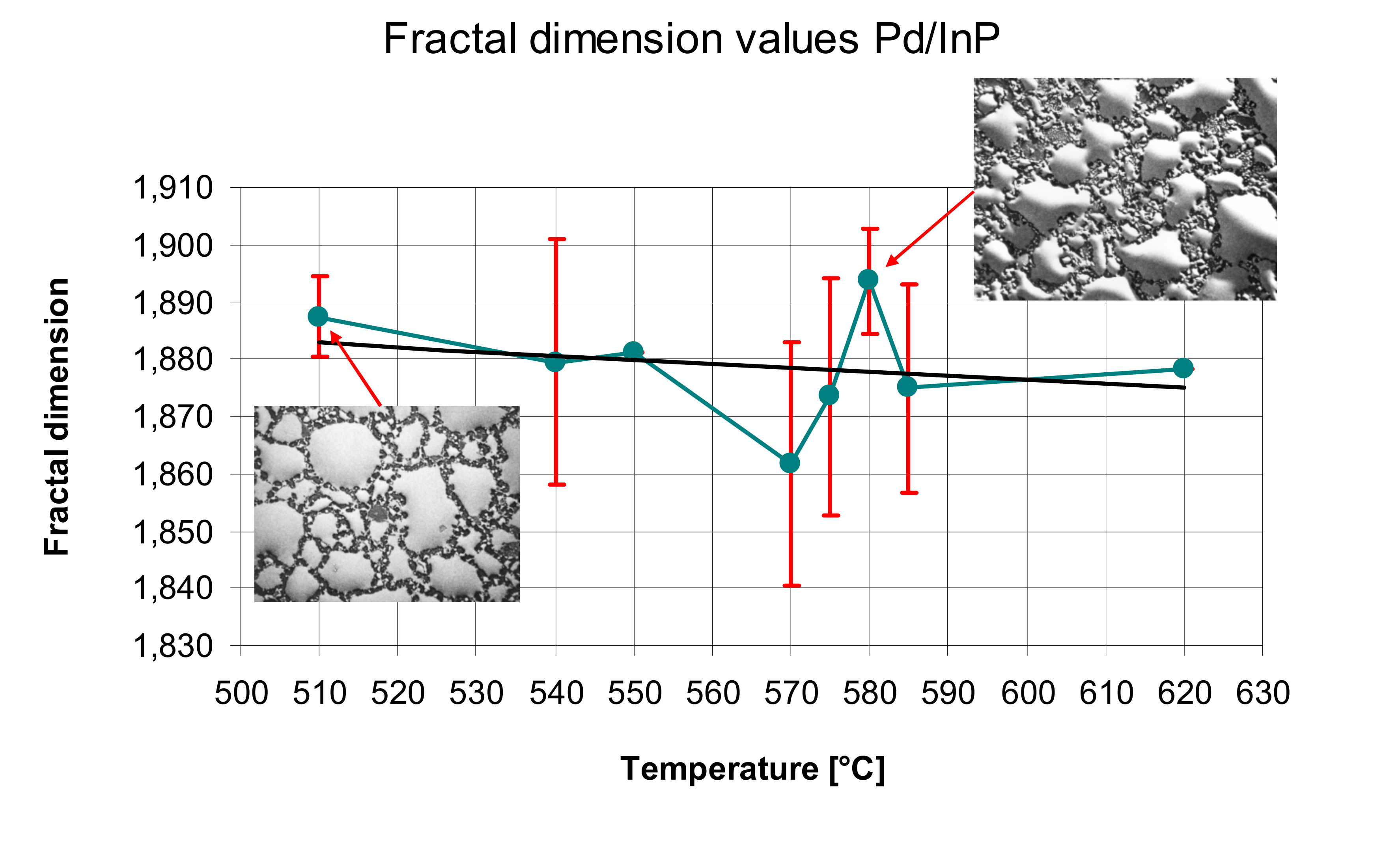
# Pd/InP 580°C




Substance system: Pd/InP

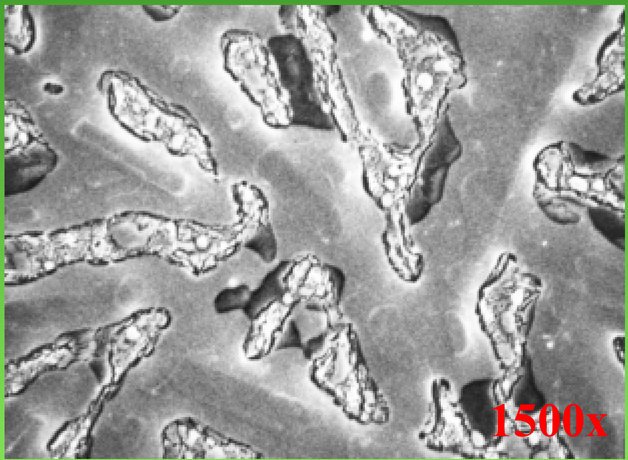


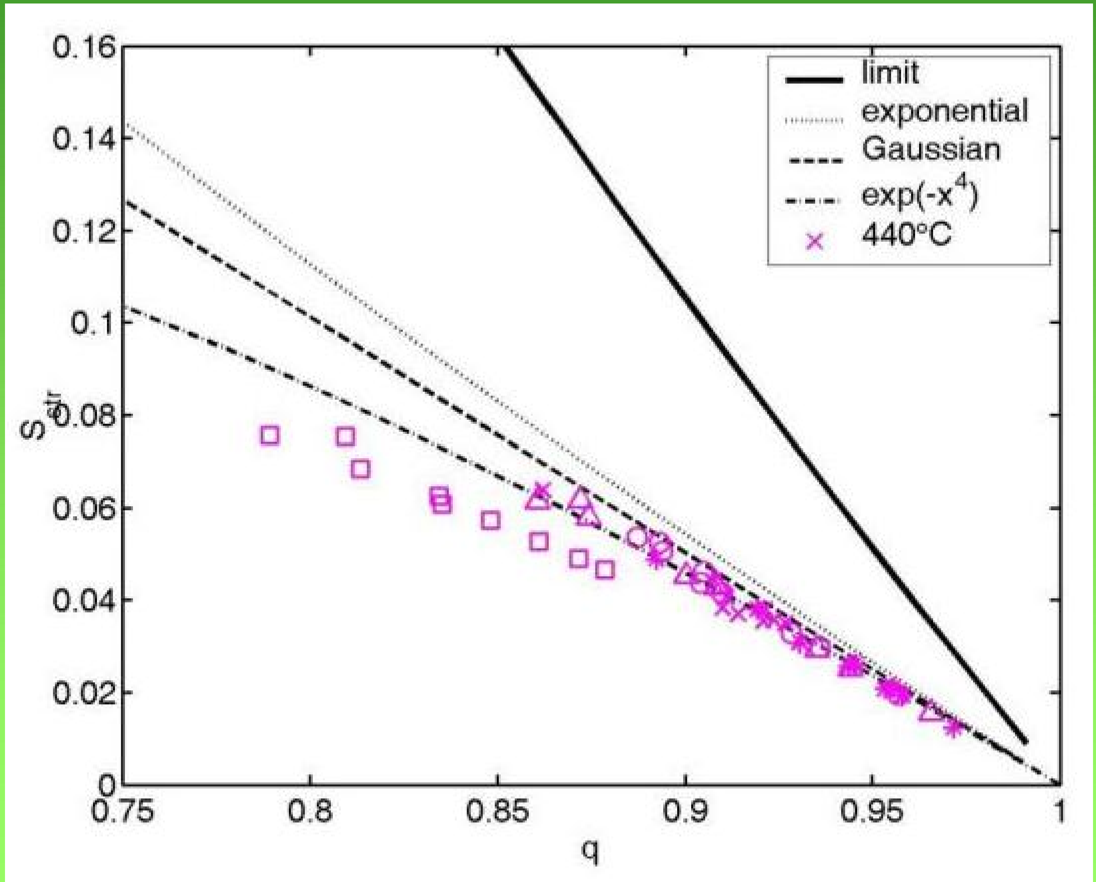
# Fractal dimension values Pd/InP



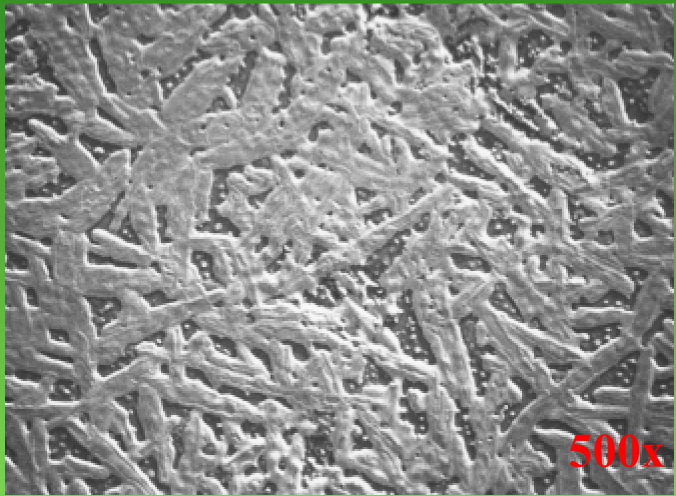
# AuPd/InP 440°C

Substance system: AuPd/InP

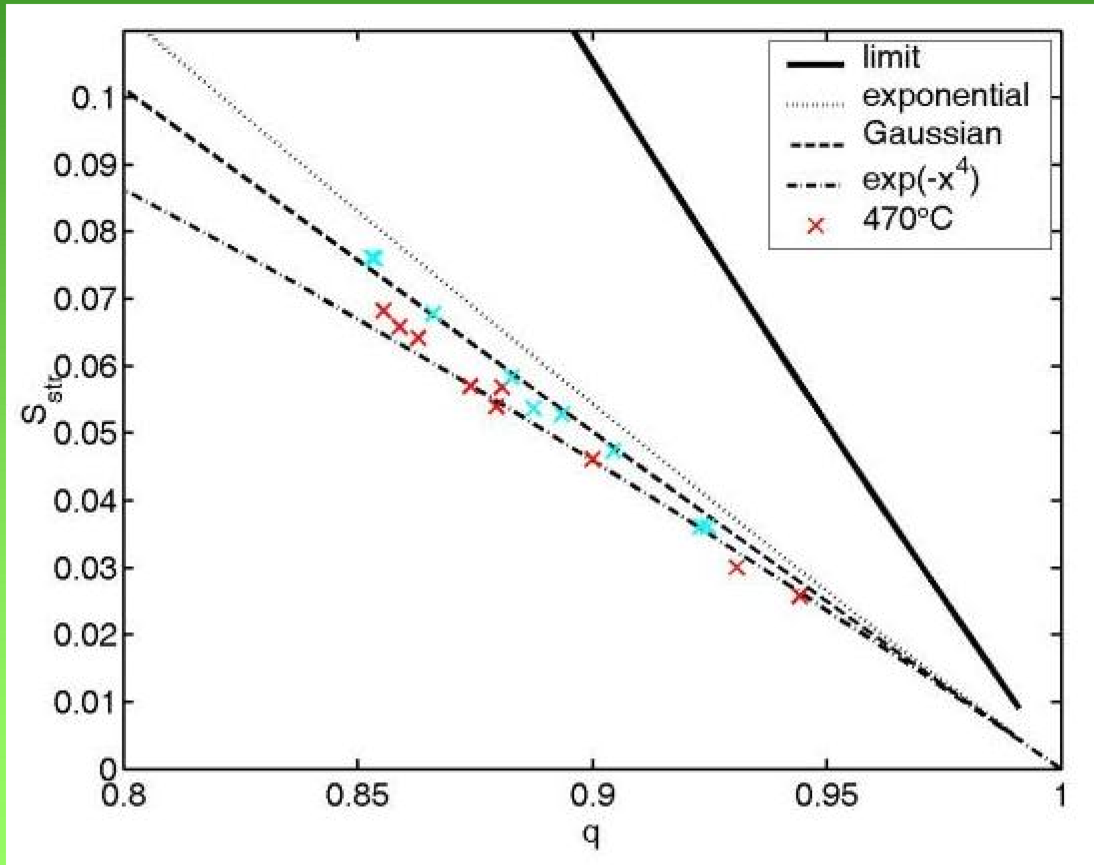


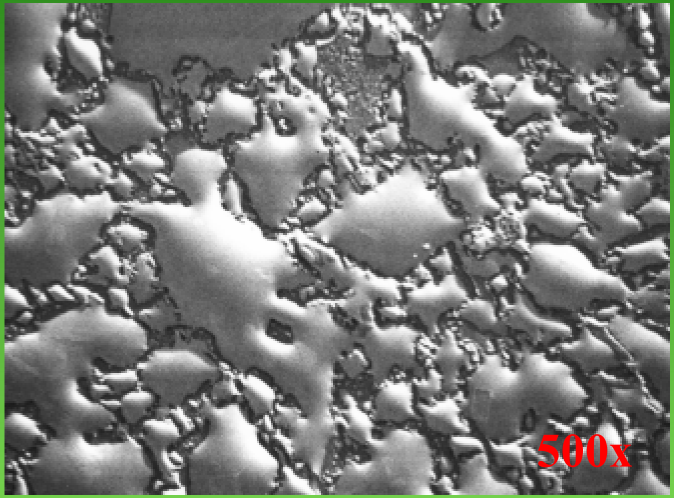
# AuPd/InP 470°C



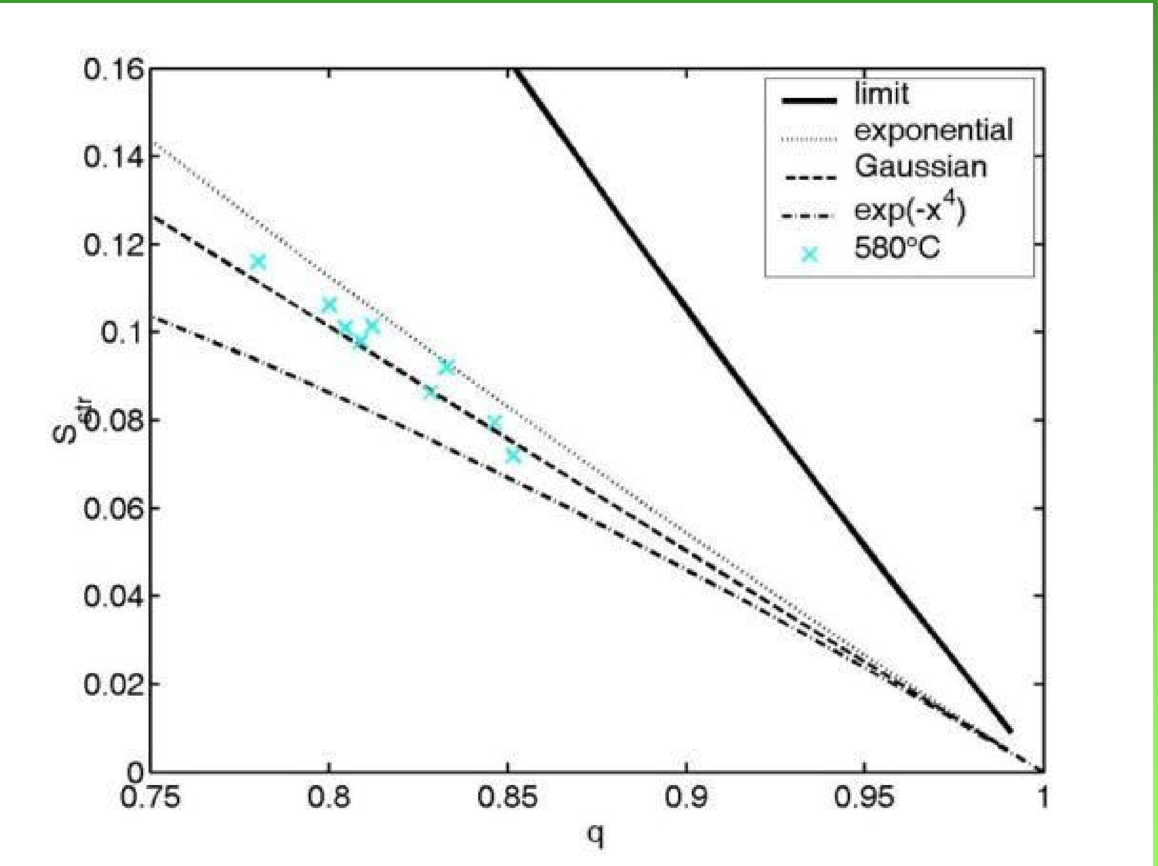

Substance system: AuPd/InP



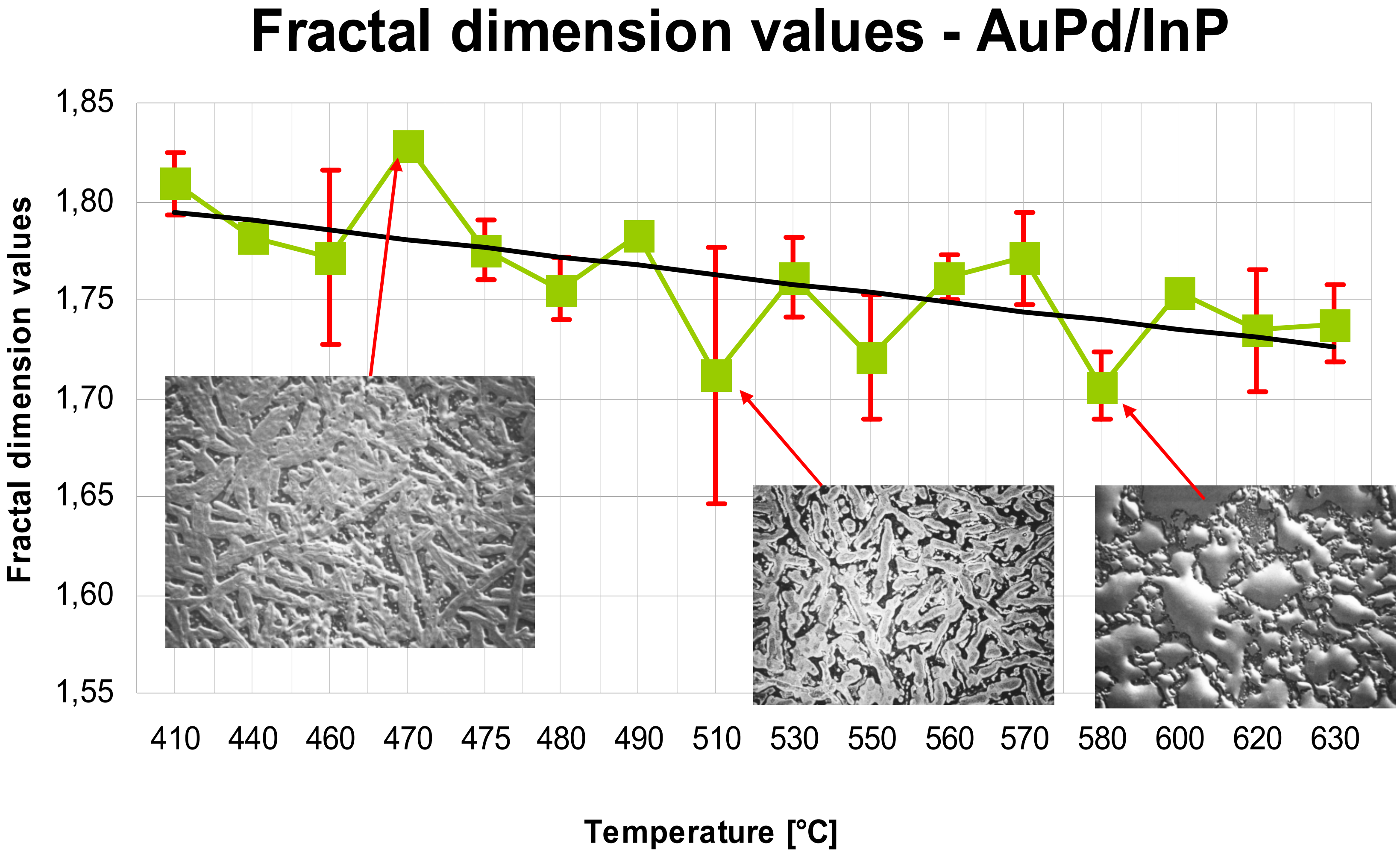
# AuPd/InP 580°Cc



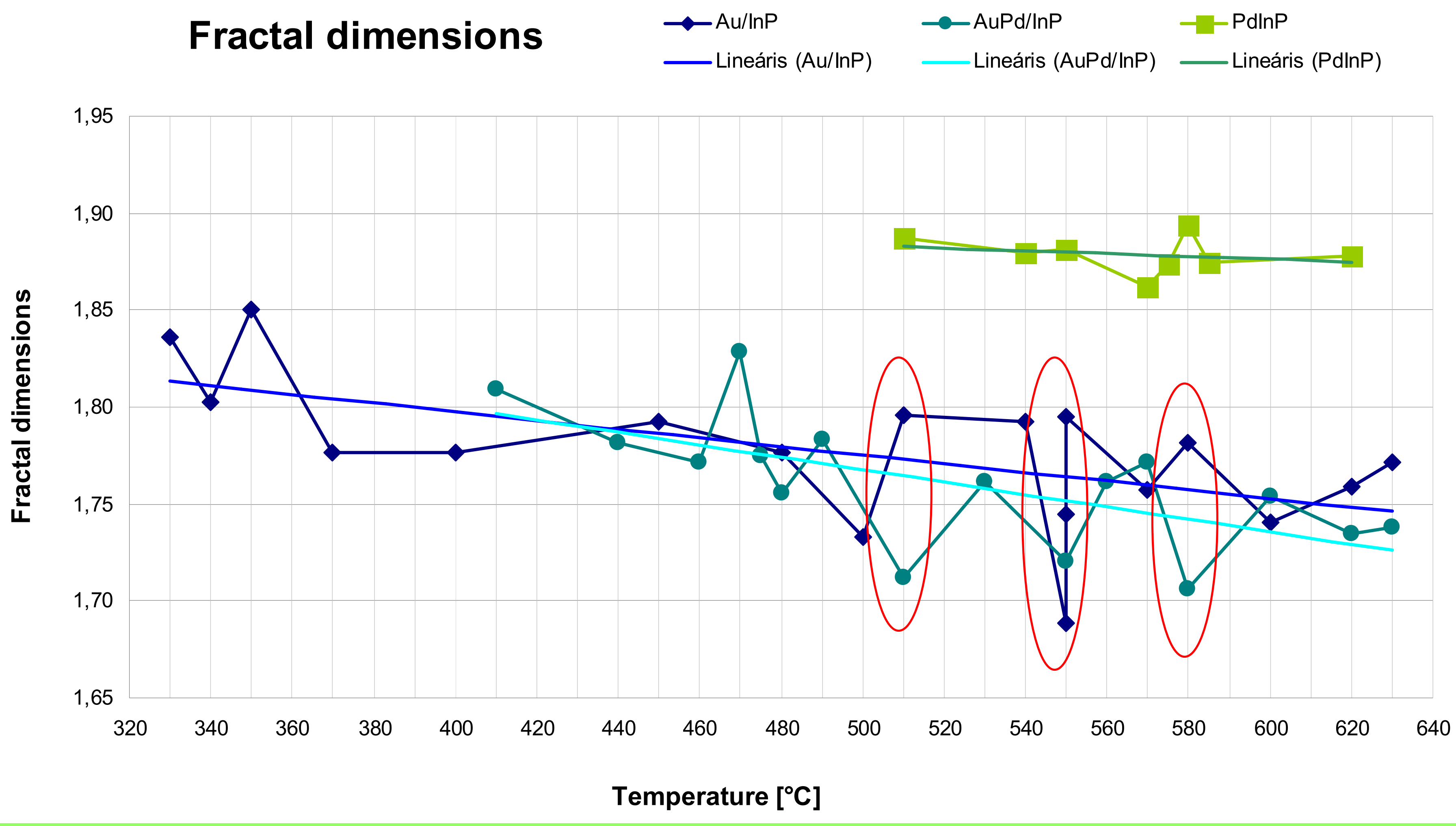

Substance system: AuPd/InP



# Fractal dimension values AuPd/InP



# Results



Fractal dimensions
Au/InP
AuPd/InP
PdInP
Lineáris (Au/InP)
Lineáris (AuPd/InP)
Lineáris (PdInP)
1,95
1,90
1,85
1,80
1,75
1,70
1,65
Fractal dimensions
320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640
Temperature [°C]

# Conclusions

The surface of the heat treated Au, Pd, AuPd shows fractal dimensions.

No significant temperature dependence of the fractal dimensions was observed.

Structural entropy can be used for characterization of the surface of the heat treated samples.