Implementation of Multimode Step-Index Fiber to Study the Refractive Index of Binary Liquids at the Wavelengths of 630nm, 660nm, 820nm & 850nm

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ABSTRACT

The development of sensors using optical fibers for the measurement of various environmental parameters is a fast growing area across the world in the past few decades. In the last 2decades a tremendously drastic expansion has been seen in the technology of optical fiber chemical sensors. The operation and working principle of optical fiber sensors for study of chemicals are mainly depends upon two major physical processes. They are absorption and adsorption techniques. In the present paper we have proposed a chemical sensor for the measurement of refractive index of binary liquids using a multimode step-index fiber at the wavelengths of 620nm, 660nm, 820nm and 850nm. For this purpose an extrinsic U-shaped glass rod based step index optical fiber sensor is developed operating at wavelengths of 620nm, 660nm, 820nm and 850nm. Output power is recorded by launching light from source into the sensor system using various binary chemical mixtures with different concentrations around the U-shaped glass rod one after the other. The liquid surrounding the U-shaped glass rod acts as a cladding at the sensing zone whose refractive index is always less than the refractive index of the core. Output power observed in the detection is decreased when the concentration of the liquid surrounding the U-shaped glass rod is increased. Thus the relation is formed between output power and concentration of the liquid surrounding the U-shaped glass probe. This study helps calibrating the sensor whose dynamic range lies between1.375n_D to 1.387n_D exhibiting highest sensitivity up to 5th decimal place.

Key words: *Binary chemical mixtures, Refractive Index, Sensing zone, Sensitivity, U-shaped glass rod, Wavelengths of 620nm, 660nm, 820nm and 850nm.*

I. INTRODUCTION

During early 1970's when the optical fiber for communication purpose was developing, it was observed that the transmission characteristics of optical fibers were sensitive to certain external perturbations such as bends, joints, stresses, temperature, etc., and certain internal perturbations such as refractive index, micro structural variations, bubbles, voids, presence of water and hydroxyl content etc. On the observation of sensitivity of optical fiber for these perturbations a new thought began to develop various kinds of devices for the measurement of several environmental parameters with much accuracy and sensitivity. The literature study reveals that the optical fiber sensors have become much popular due their spontaneous response, high sensitivity, cost effectiveness and flexibility in using at different environments [1–10]. The experimental arrangement and the theoretical basis behind the mechanism of the sensor have been explained covering all the aspects in the research papers [11–14]. The main components that are involved in the process of light transmission are the light itself and the optical fiber. Based on the properties of light, four kinds of the sensors can be developed 1.Intensity modulated fiber optic sensors, 2.Phase modulated fiber optic sensors, 3. Wavelength modulated fiber optic sensors, 4. Frequency modulated fiber optic sensors. Depending upon the light modulation fiber optic sensors can be broadly classified into two types. When the light modulation takes place inside the fiber they are called the intrinsic modulated fiber optic sensors. When the light modulation takes place outside the fiber they are called the extrinsic modulated fiber optic sensors. In the present study an extrinsic intensity modulated multimode step-index fiber optic sensor developed to study the refractive index of binary liquids consisting of Propanol and Hexane. The work aims to investigate the effect of the concentration of the binary liquids on the transmission power of the extrinsic multimode fiber optic sensor. Manufacturing easiness of the U-shaped glass probe high S/N values and high temperature availability and non-electro-light liquid made the U-shaped glass probe method employable in the present experimentation.

II. EXPERIMENTAL DETAILS

The basic components of experiment consisting of 1.Light source, 2.Optical power meter, 3.Transmission medium (optical fibers) consisting of sensing zone (U-shaped glass rod). In the experimental arrangement two plastic step-index multimode optical fibers of 200/230μm diameter core and cladding respectively, 50cm length each in which one as input fiber and other as output fiber are used. Four kinds of light sources operating at wavelengths of 620nm, 660nm, 820nm and 850nm are used. At the output end of the sensor system a power meter suitable to read the output power coming from various input sources was used. The Experimental arrangement is shown in Fig. [1].

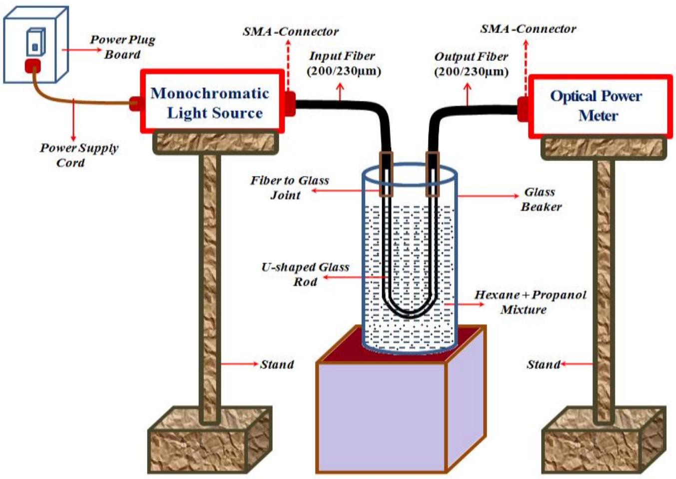

Fig.1: Experimental Arrangement of Multimode Step-Index Extrinsic Fiber Optic Sensor

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U-shaped solid glass rod has been used as an extrinsic sensing probe to measure the various concentrations of binary mixtures mixed at different proportions. Geometrical parameters of the U-shaped glass rod is shown in Fig.[2].

Thickness of rod:	0.5mm
Total height of the glass rod(H):	40mm
Height of the glass rod immersed in chemical mixture(h):	25mm
Width between two prongs(Z):	5mm
Radius of the Curvature(X):	2.5mm
Depth of the Curvature(Y):	2.5mm

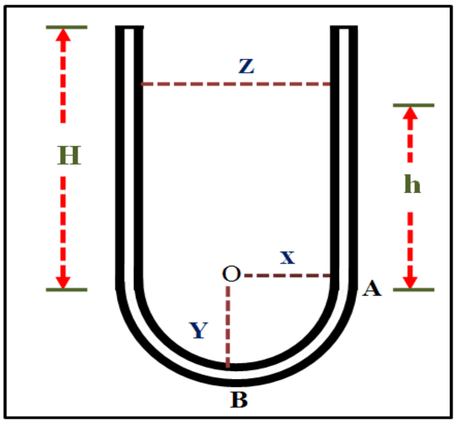

Fig.2: Geometrical parameters of the U-shaped glass rod

In the present experiment the U-shaped glass rod acts as a core in the region of sensing and the liquid surrounding the U-shaped glass rod acts as a liquid cladding in the region of sensing whose concentration is acts nothing but the measurand and the core (U-shaped glass rod) is exposed directly to measurand (binary mixture). To increase the penetration of the evanescent field at the region of sensing, a U-bend glass rod configuration is used which intern maximize the sensitivity of the sensor. The interaction of the evanescent field with absorbing binary mixture modulates the intensity of the light transmitting through the fiber, causing a corresponding change in the output power. It has been already reported in the literature that the decrease in the bend radius of the U-shaped element will enhance the sensitivity of the sensor. Binary mixtures are prepared from Propanol and Hexane by selecting proper ratios making the total volume equal to 10ml.

Standard chemical parameter of Propanol and Hexane

Property	**Propanol (C_3H_8O)**	**Hexane (C_6H14)**
Molar Mass (g/mole)	60.096	86.178
Refractive index(n)	1.387	1.375
Density (g/ml)	0.803	0.6606
Color	Colourless Liquid	Colourless Liquid
Boiling Point	97℃	68.5℃
Melting Point	-126℃	-96℃
Dielectric Constant($\varepsilon = n^2$)	1.92377	1.89062

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III. RESULTS AND DISCUSSION

The experiment is initially started by using light source operating at a wavelength of 630nm by exposing the U-shaped glass rod to the binary mixture of different ratios one after the other, the output power noted at each time and was recorded. The relation between concentration of the binary mixtures with different ratio and the refractive index recorded by using Digital Refractometer (RX 7000i) as shown in Fig.[3].

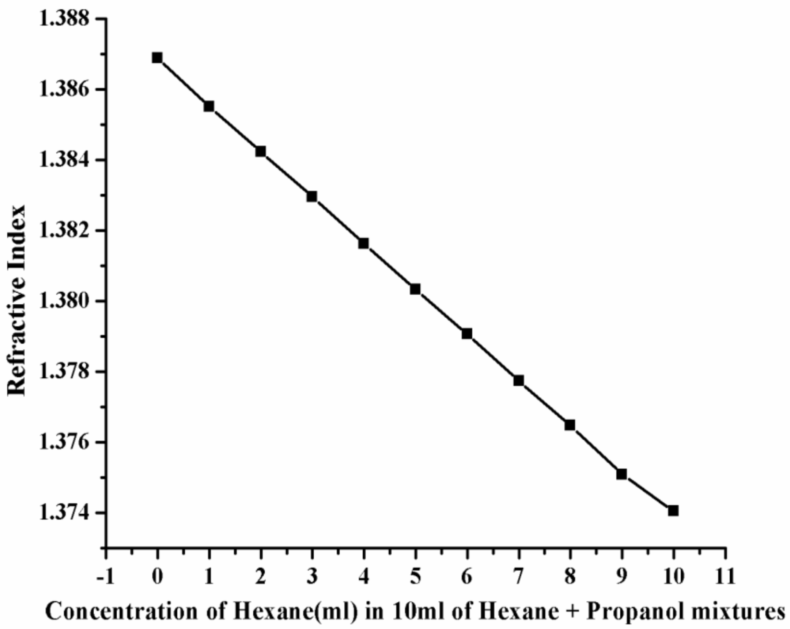

Fig.3: Relation between Concentration of Hexane(ml) in 10ml of Hexane + Propanol mixtures Vs Refractive Index

The experiment is repeated by using various light sources operating at wavelengths of 660nm, 820nm and 850nm. The variation of output power with concentration and refractive index are recoded and represented graphically in Fig.[4–5].

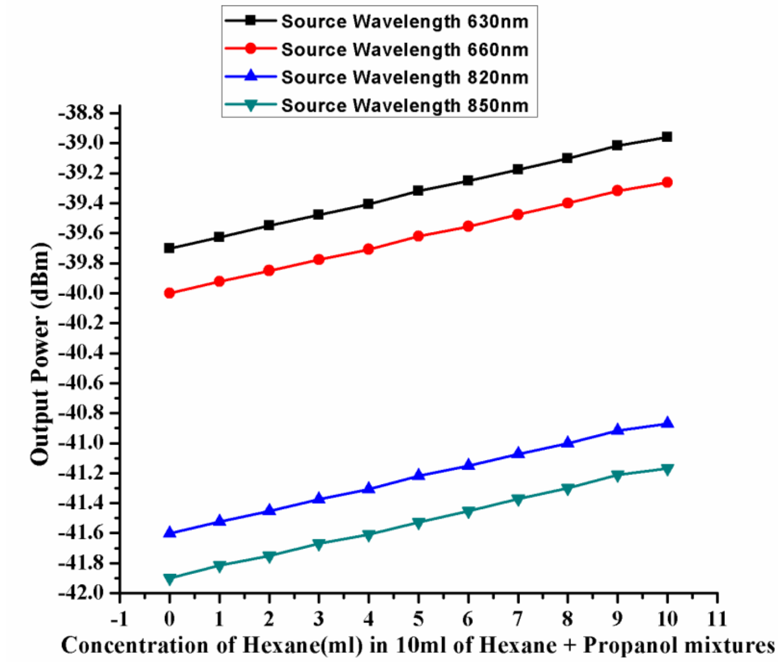

Fig.4: Relation between Concentration of Hexane(ml) in 10ml of Hexane + Propanol mixtures Vs Output Power(dBm) for wavelengths of 620nm, 660nm, 820nm & 850nm

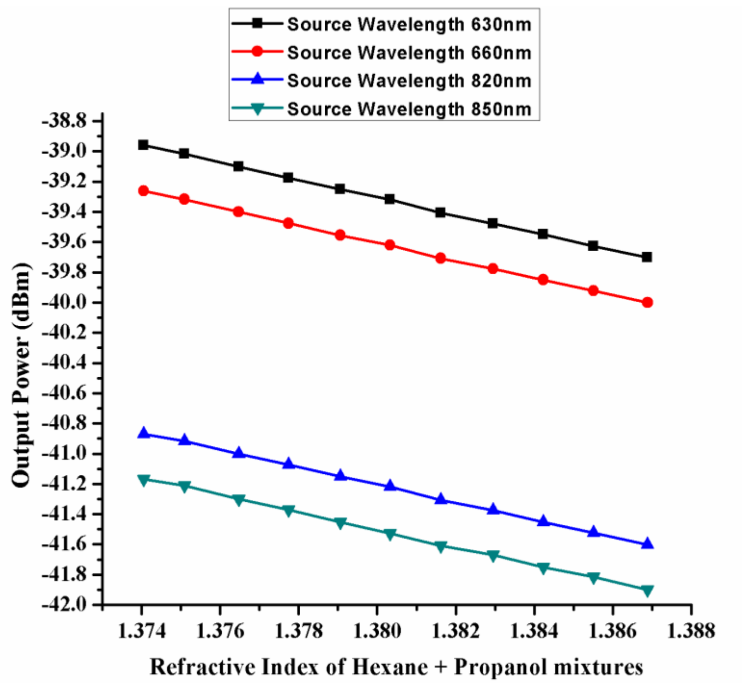

Fig.5: Relation between Refractive Index of Hexane + Propanol mixtures Vs Output Power(dBm) for wavelengths of 620nm, 660nm, 820nm & 850nm

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Power Loss: The power loss due to the interacting of the light with the liquid cladding in the region of sensing can be defined as the difference between the power launched into the fiber and output power.

Power Loss = Power launched into the fiber – Output power

The relationship between loss of power and the refractive index of the liquid cladding is presented graphically in Fig. [6].

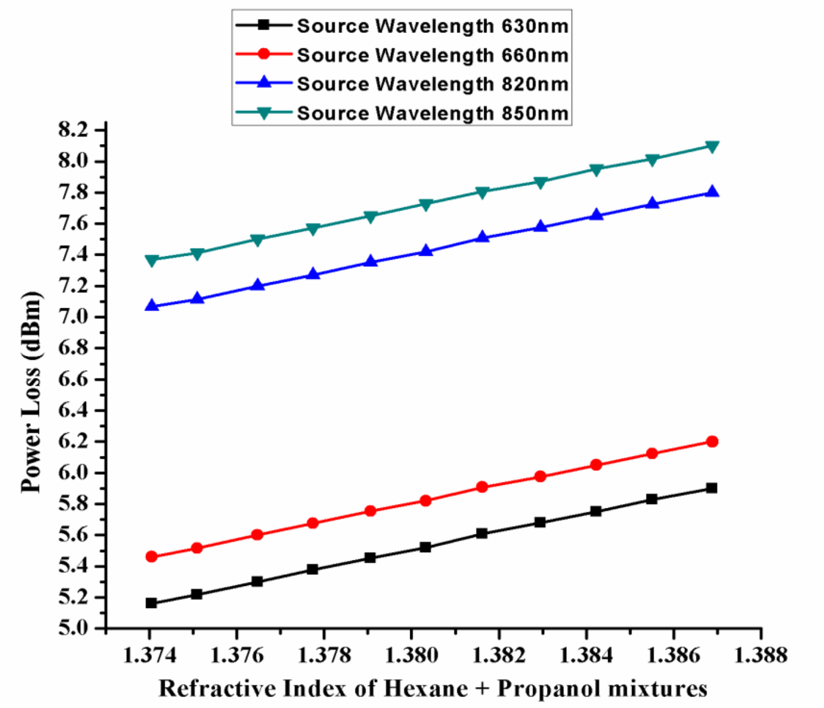

Fig.6: Relation between Refractive Index of Hexane + Propanol mixtures Vs Power Loss(dBm) for wavelengths of 620nm, 660nm, 820nm & 850nm

Similarly the relationship between concentration of liquid and power loss is shown in Fig.[7].

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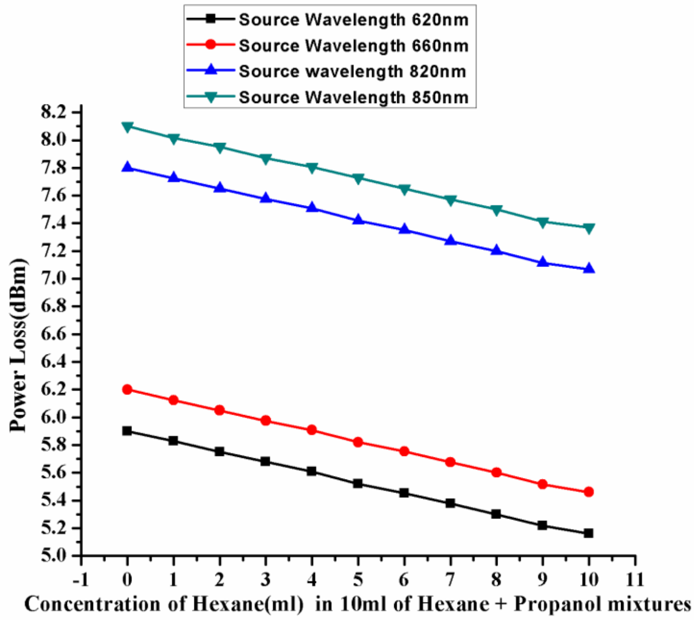

Fig.7: Relation between Concentraion of Hexane(ml) in 10ml of Hexane + Propanol mixtures Vs Output Power(dBm) for wavelengths of 620nm, 660nm, 820nm & 850nm

Finally the molefraction of Hexane in the mixtures of Hexane + Propanol has been calculated and relationship between molefraction of Hexane, output power and power loss has been shown graphically in Fig.[8–9].

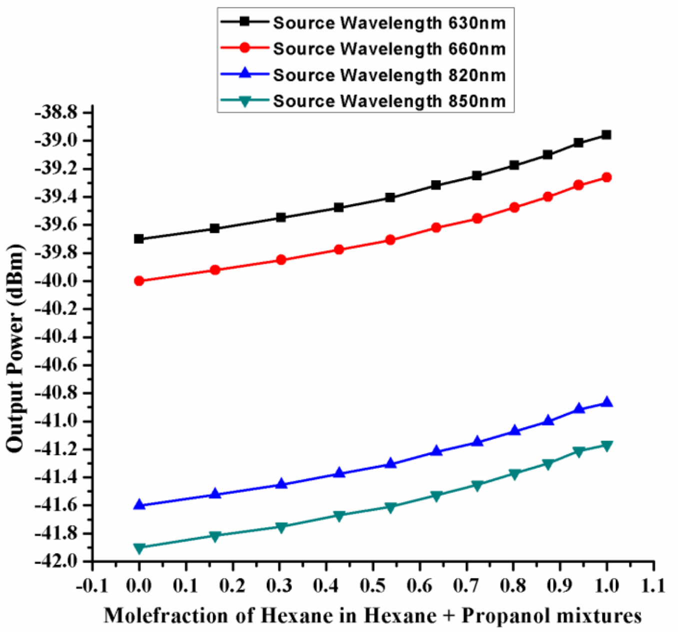

Fig.8: Relation between Molefraction of Hexane in Hexane + Propanol mixtures Vs Output Power(dBm) for wavelengths of 620nm, 660nm, 820nm & 850nm

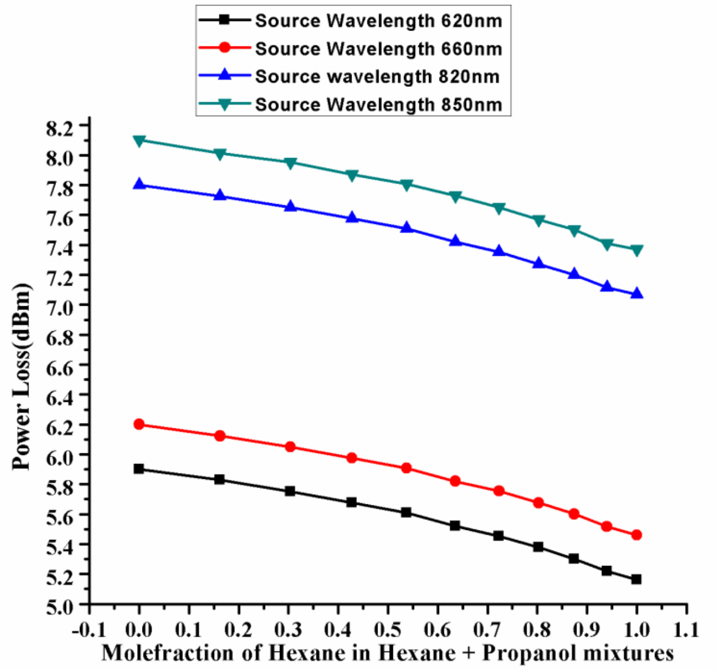

Fig.9: Relation between Molefraction of Hexane in Hexane + Propanol mixtures Vs Power Loss(dBm) for wavelengths of 620nm, 660nm, 820nm & 850nm

IV. CONCLUSION

It is concluded that from the investigation of the study, as the concentration of propanol in the binary mixture increases, the refractive index of the guiding liquid also increases. It is also observed that for all the wavelengths (620nm, 660nm, 820nm & 850nm) with increasing the index of refraction of guiding medium the output power decreases and hence power loss is increases. The graphs showing the variation of output power with the variation of the refractive index of the guiding liquid can be used as calibration curves to measure the refractive index of the unknown transparent liquids in the dynamic range of 1.375 nD to 1.387 nD at room temperature.

REFERENCES

[1] D. A. Krohn, “Fiber Optic Sensor – Fundamentals and Applications”, Instrument Society of America (1988).

[2] R. E. Chappel and R.T. Ballesh, “Fiber Optics used Reliable Drum Water Level Indication”, Engineering Conference – TAPPI Proceedings, pp. 313–317.

[3] Proceedings of Conference on “Optical Fiber Sensors–2, Stuttdart, September 5–7, 1984 VDE Velag GmgH.

[4] Proceedings of Conference on “Optical Fiber Sensors–3, San Diego, 1985, OSA IEEE.

[5] B. Culshaw, A.D. Day and Y. Rhtshka, “Special issure on Optical Fiber Sensors”, IEEE/OSAJ Light Wave Technol., Vol.13, No.7, (1995)

[6] T.G. Giallorenzi and S. Ezekiel, “Speical isuure on Optical Fiber Sensors”, Optics News, Vol.15, No.11, (1989).

[7] A.K. Ghatak, B. Culshaw, V. Nagarajan and B.D. Khurana, "Trends in Fiber Optics and Optical Communications, Viva Books Pvt. Ltd., New Delhi (1995).

[8] R. M. Measures and K. Lin, "Fiber Optic Sensors – Focus on Smart Systems", IEEE Circuits A Devices Magazine, pp. 37–46, (1992).

[9] T. G. Giallorenzi, J.A. Bocaro, A. Dandridge and J.H. Cole "Optical Fiber Sensors Challenge the Competition", IEEE spectrum, pp.44–49 (1986).

[10] Pal B P., 1991, "Fundamentals of Fiber Optics in Telecommunication and Sensor Systems", 1st edn. (Delhi: Wiley Eastern), pp.571–573.

[11] Cherif K, Hleli S, Abdelghani A, Jaffrezic–Renault N and Matejee V, 2002, "Chemical Detection in Liquid Media with a Refractometric Sensor Based on a Multimode Optical Fiber Sensor", pp.195–204.

[12] Kumar A, Subrahmanyam T V B, Sharma A D, Thyagarajan K, Pal B P and Goyal I C, 1984, "Novel Refractometer using a Tapered Optical Fiber", Electron. Lett.20, pp.534–535.

[13] S. Srinivasulu, Dr. S. Venkateswara Rao, "Influence of Geometrical Parameters on the Transmission Characteristics of a U-Shaped Glass Probe: Determination of the Sensitivity of an Extrinsic Fiber Optic Refractometer", Journal of Emerging Technologies and Innovative Research, Vol. No.5, Issue No.9, pp.341-346, September, 2018

[14] S. Srinivasulu, Dr. S. Venkateswara Rao, "Evanescent Wave Absorption Based Fiber Optic Chemical Sensor - Determination of Various Parameters of Binary Liquids", International Journal of Management, Technology and Engineering, Vol. No.8, Issue No. XI, pp.1673-1682, November, 2018

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